Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Environment, Sustainability and Climate Change (HND)

Module: Low Carbon Technology (ACNA5003)

TUTOR: LARA HOPKINSON

Heat pumps for decarbonising building emissions

March 2026

MELINDA HILL (2116602)

Word Count: 3,614

Contents

1 Introduction 1

1.1 Global climate goals 1

1.2 UK policy targets 1

1.3 Decarbonising energy 1

1.4 Progress towards global decarbonisation of energy 2

1.5 Progress towards decarbonisation in the UK 3

1.6 Energy efficiency 4

2 Heat pumps for decarbonising building emissions 6

2.1 Future-proofing buildings 6

2.2 Background statistics on the current uptake of heat pumps across the UK . 7

2.3 Case studies from around the World to highlight the benefits of moving to a heat pump technology. 9

2.3.1 Norway 9

2.3.2 China 11

2.4 Some of the challenges around retrofitting heat pumps 13

2.4.1 Grid capacity and demand management 13

2.4.2 Costs to households 13

2.4.3 Public perception 15

2.4.4 Other challenges 15

2.5 Benefits of moving to heat pumps for building space heating 17

2.5.1 Efficiency and decarbonisation 17

2.5.2 Improved air quality 17

3 Conclusion 18

4 References 19

List of Figures

Figure 1-1 Forecast global annual change in electricity demand and generation from fossil, wind and solar, and other low carbon sources (Ember, 2025) 3

Figure 1-2 Reductions in greenhouse gas emissions by sector in UK(CRIPPA et al., 2025) 4

Figure 2-1 Sales of heat pumps per 1000 households in 2024 (EHPA, no date) 10

Figure 2-2 Heat pump sales in China and in the rest of the world, 2019-2023 (IEA, 2024b) 11

Figure 2-3 TCO under different economic policy scenarios, for range values of SCoPs (Rosenow et al., 2025) 14

1 Introduction

1.1 Global climate goals

The Paris Agreement aims to avert the most severe impacts of climate change by limiting global warming to well below 2°C above pre-industrial levels, while pursuing efforts to restrict warming to 1.5°C. Achieving this goal requires global greenhouse gas (GHG) emissions to reach net zero by around mid-century (United Nations [UN], n.d.a; n.d.b).

1.2 UK policy targets

The “net UK carbon account” is required to be at least 100% lower than the 1990 baseline by 2050, which is the legal definition of net zero established in the Climate Change Act 2008 (Burnett, 2026). In order to achieve this and as part of its Nationally Determined Contribution (NDC) under the Paris Agreement, the UK has committed to reducing emissions by 68% from 1990 levels by 2030 (CCC, 2025a).

1.3 Decarbonising energy

A rapid transformation of the energy system is required, combining the expansion of renewable energy with significant improvements in energy efficiency and changes in energy consumption patterns. Most of the technologies and behavioural changes required to achieve net zero by 2050 are already available today (CCC, 2025a).

Energy production and consumption are responsible for over three quarters of global GHG emissions (Olympios, Justo Alonso and Pantaleo, 2025). Progress towards decarbonising energy depends on adopting a wide range of sustainable, low-carbon

technologies within key sectors, including electricity supply, buildings and heating, industry, and transport. These include clean energy-generating technologies from renewable sources such as solar photovoltaics and wind turbines; energy-saving technologies such as washing machines, heat pump tumble driers, and induction hobs; and other technologies that facilitate the transition to clean energy, such as electric vehicles and heat pumps (Eppe et al., 2025).

Within industry, there are also many opportunities to decarbonise, for example through the upcoming installation of an electric arc furnace at the Tata Steel works in Port Talbot and a solar photovoltaic farm used to contribute to power generation in Morriston hospital in Swansea (Welsh Government, 2022; UK Steel, 2026).

1.4 Progress towards global decarbonisation of energy

Ten years on from the Paris Agreement has seen a surge in the use of renewable energy, priming the world for a low-carbon future, energy security and economic growth. However, the Emissions Gap Report 2025 states that global warming is approaching 1.5°C and will likely exceed it soon, and even if countries live up to their NDCs to reduce GHG emissions, the world will warm by 2.3°C to 2.5°C by the end of the century (UNEP, 2026).

As noted by Krause, “We have the technology and know-how to end the climate crisis.” “What we need now is the political will” (UNEP, 2026).

The highest emitters of GHG emissions are China, the US, India, the EU, the Russian Federation and Indonesia(United Nations, n.d.- a). In 2025, fossil fuel generation in China and India showed a “plateauing or declining” trend, offsetting small increases in the US and the EU, while milder weather conditions helped moderate growth in energy demand. Consequently, emissions from fossil fuels increased by an estimated 0.1% (Ember, 2025; Myllyvirta, 2026). This was substantially lower than in 2024, when global energy-related CO_2 emissions rose by 0.8% (IEA, 2025). Although weather conditions played a significant role, fossil fuel generation in 2025 remained nearly unchanged despite substantial growth in energy demand. This almost marked the first instance since the COVID-19 pandemic in which fossil fuel generation did not

increase. Figure 1-1 shows forecast global annual changes in electricity demand and generation from fossil fuels with the latter being unchanged (Ember, 2025; Myllyvirta, 2026).

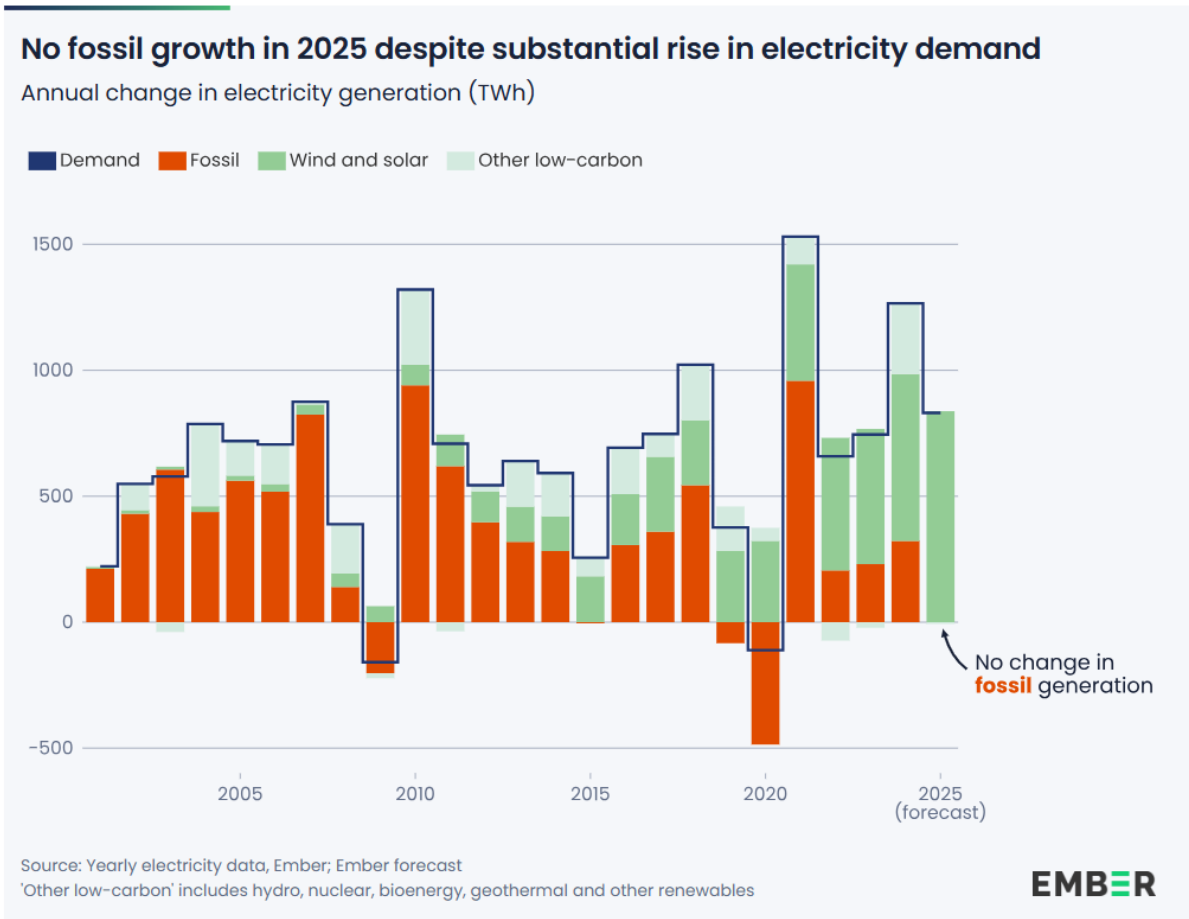

Figure 1-1 Forecast global annual change in electricity demand and generation from fossil, wind and solar, and other low carbon sources (Ember, 2025)

Meanwhile in 2025, solar and wind renewables provided 48% of EU electricity and, for the first time, overtook fossil fuels (Petrovich, 2026).

1.5 Progress towards decarbonisation in the UK

Under the Climate Change Act 2008, the UK has set five-yearly carbon budgets, which place a statutory cap on the GHG emissions it can produce in these timeframes. Within the fourth carbon budget, which covers the period from 2023 to 2027 (or 2031

to 2035 in Wales), a 52% reduction in emissions on 1990 levels is required (a 73% reduction in emissions on 1990 levels is required in Wales) (CCC, 2025a).

The UK's GHG emissions have been steadily decreasing so that levels in 2024 were around 50% below those in 1990. This was largely driven by decarbonisation in the power industry sector and industrial combustion and processes sector as illustrated in Figure 1-2 (CCC, 2025a; CRIPPA et al., 2025).

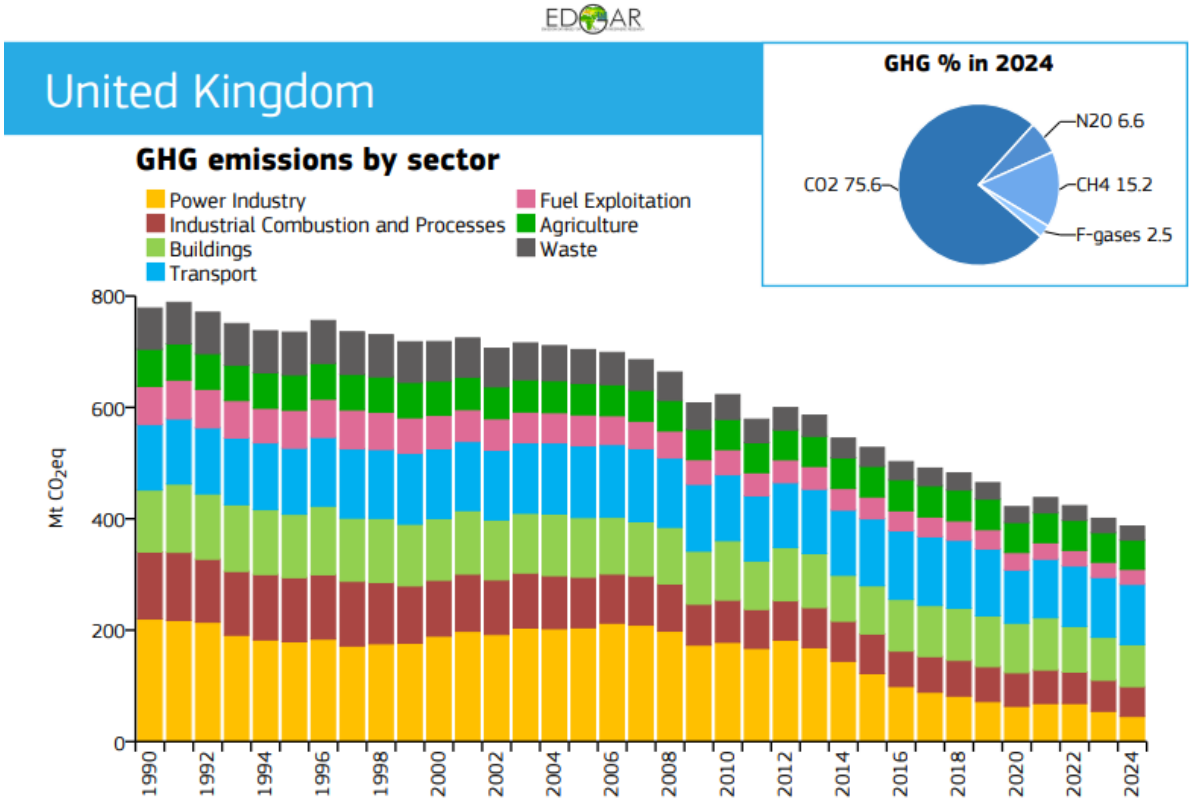

Figure 1-2 Reductions in greenhouse gas emissions by sector in UK(CRIPPA et al.*, 2025)*

1.6 Energy efficiency

Clean energy generation is only one aspect of decarbonisation. Energy efficiency (using less power to perform the same task) is referred to as the "first fuel" in clean energy transitions, highlighting the significance of saving energy. While clean energy replaces fossil fuel supply, energy efficiency reduces demand (IEA, 2023).

The climate crisis is occurring alongside a global energy crisis - comparable in scale to the 1973 oil crisis - which began in 2021 during the post-pandemic recovery and

was exacerbated by the Russian Federation's invasion of Ukraine. In response to rising energy prices, efforts to improve energy efficiency have accelerated, particularly in Europe. These improvements include increased electrification, advances in technical efficiency, and the promotion of behavioural change (IEA, 2023; UK Parliament, 2026)

2 Heat pumps for decarbonising building emissions

2.1 Future-proofing buildings

The UK buildings sector has not seen a marked reduction in GHG emissions, as illustrated in Figure 1-2. In 2021, around 28 million households generated 18% of the country's total GHG emissions and around 30 million buildings generated almost a quarter of all UK emissions (Department for Business, Energy and Industry Strategy [BEIS], 2021; National Audit Office, 2024; CRIPPA et al., 2025) A holistic approach to future-proofing the energy efficiency of buildings is required, covering environmental, economic and socio-economic criteria (Georgiadou et al. 2012).

The National Institute for Health and Care Excellence (2019) estimates that excess winter deaths in the coldest quarter of housing are almost three times higher than in the warmest quarter. Gasparrini et al. (2015) also found that excess mortality during cold spells is higher in the UK than in comparable countries.

In 2023, 15% of English homes were non-decent; the definition of a decent home includes providing “a reasonable degree of thermal comfort.” This is considered to be the highest proportion of substandard homes in Europe, and significantly higher than many other countries including Germany (12%), Bulgaria (11%), Lithuania (11%) and Poland (6%)(Home Builders Federation, 2023; UK Government, 2023). While this UK Government definition of a decent home has limitations, as the methodology is unclear, policies aimed at decarbonising heating must also ensure adequate warmth for all (as discussed in Section 2.4).

2.2 Background statistics on the current uptake of heat pumps across the UK

Heat pump (HP) systems are an important low-carbon technology for providing secure and sustainable heating globally. Electrically powered HPs are commercially available and use well-established technology similar to refrigerators or air conditioners. HPs are at least three times more energy efficient than traditional boilers. Rather than generating heat, they collect heat from nearby sources; for example, the surrounding air, underground or from water or waste heat from a factory (IEA, 2022; Żelazna and Pawłowski, 2025).

By 2050, it is estimated 55% of all buildings worldwide will need HPs to meet climate goals, representing about 1.8 billion units across the building sector(IEA, 2021).

Despite this, fewer than 1% of UK households have installed a HP (Energy Security and Net Zero Committee, 2025). The UK Government (2021) aims to deploy at least 600,000 HPs (2.16% of households) per year by 2028 in order to keep on track to net zero by 2050. Meanwhile, the UK Climate Change Committee (CCC) Balanced Pathway requires the annual rate of HP installations to be 450,000 by 2030, in order that all home heating will come from low-carbon sources by 2050 (Sarsentis, 2023; CCC, 2025b; UK Parliament, 2025a). The UK has committed itself to no longer installing fossil-fuel boilers after 2035, although around a fifth of houses might be exempt (as discussed in Section 2.4.5) (BEIS, 2021; UK Parliament, 2024)

In 2024, 43,939 HPs were deployed in the UK with support from Department for Energy Security and Net Zero (DESNZ) policies, representing around 0.15% of UK households. Although this reflects a increase of around 56% compared with 2023 figures, deployment remains significantly below the levels required to meet national targets (CCC, 2025a; DESNZ, 2026). The CCC has identified the buildings sector as having the largest gap between policy ambition and real-world adoption across all sectors assessed against the Government's 2035 emissions targets, highlighting the need for a combination of financial, technical, and behavioural interventions (UK Parliament, 2025b).

The next sections draw on international case studies to highlight the benefits of HPs, while also addressing key challenges associated with retrofitting them, as well as their potential for building space heating.

2.3 Case studies from around the World to highlight the benefits of moving to a heat pump technology.

2.3.1 Norway

By 2035, Norway plans to reduce its GHG emissions by at least 70–75% compared to 1990 levels under its NDC (The United Nations Framework Convention on Climate Change [UNFCCC], 2026).

Norway is a heating-dominated country - a significant proportion of its energy is used for space heating due to its cold climate. Prior to the 21st century, HPs were not widely used due to their high installation costs and the availability of relatively cheap hydropower-based electricity. The shift away from heating oil began after the 1973 oil crisis. A period of low rainfall led to rising electricity prices in the early 2000s prompting the government to introduce subsidies to encourage the uptake of HPs (Sadeghi, Ijaz and Singh, 2022). As electricity was already widely used for heating, the economic case for adopting HPs was clearer than in countries such as the UK, where heating is largely gas-based.

As a result, Norway now has the highest number of HPs per capita in Europe. Regulations have prohibited the installation of new fossil fuel heating systems since 1 January 2016 (IEA, 2024a). By 2024, nearly two-thirds of households had installed HPs with sales remaining high at 48 units per 1,000 households - around 14 times higher than in the UK - as shown in Figure 2-1 (European Heat Pump Association [EHPA], n.d.).

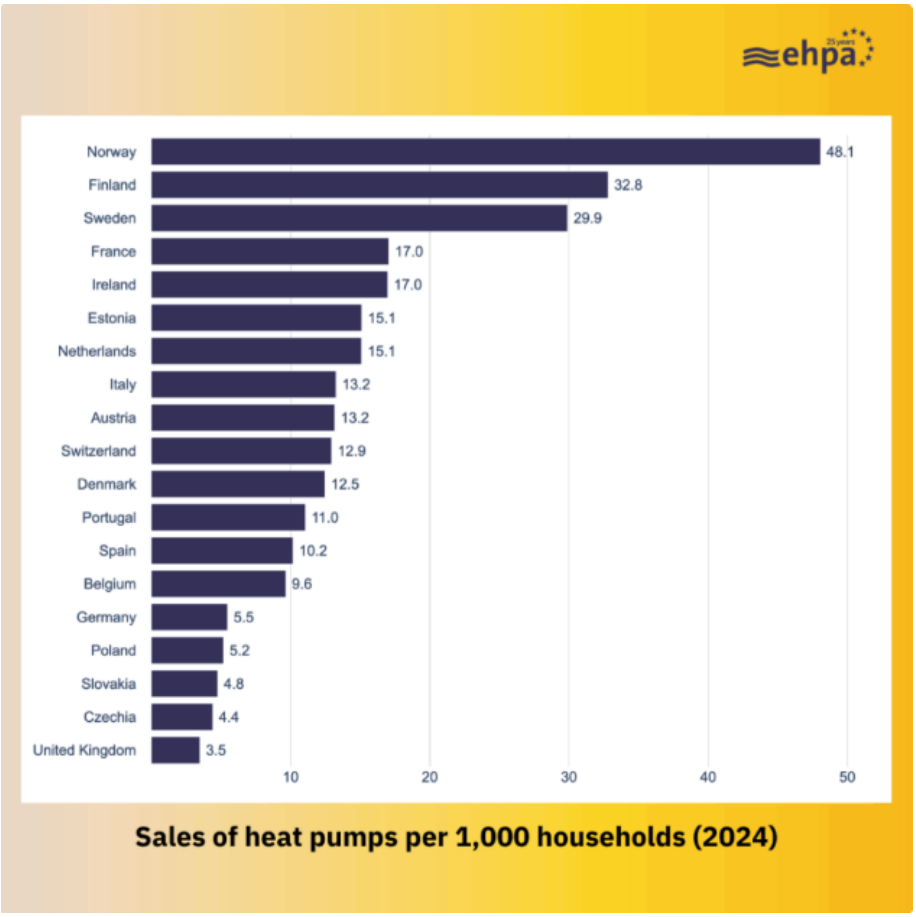

Figure 2-1 Sales of heat pumps per 1000 households in 2024 (EHPA, no date)

Norway maintains high energy-efficiency standards in buildings, many of which rely on passive measures such as insulation and heat gains from occupants, appliances, and solar radiation (IEA, 2017; Organisation for Economic Co-operation and Development [OECD], 2022). These standards enhance the performance of HPs, reduce capital costs, and lower operating expenses (IEA, 2022). As a result, Norway provides a strong example of the effective use of HPs in cold climates (European Commission, 2025).

Due to its historical predominance of hydropower, Norway was already a lower-carbon economy than most. The widespread use of electricity, particularly for heating, meant that building energy use had largely been decarbonised. While replacing electric heating with HPs is unlikely to significantly affect long-term GHG emissions to support Norway's NDC under the Paris Agreement, it can reduce their peak electricity demand and free up electricity for international trade (IEA, 2017).

2.3.2 China

China, the world's second most populous country, accounts for roughly 17% of the global population in 2024 (World Bank Group, 2026b, 2026a). Driven by rapid urbanisation and an expansive industrial base, its industrial and building sectors account for nearly one-third of global heat consumption (IEA, 2024b; Yan *et al.*, 2024), with building heating demand growing faster than anywhere else in the world over the past decade (IEA, 2024b).

China has pledged "Dual Carbon" goals to peak carbon emissions before 2030 and achieve carbon neutrality by 2060 (IEA, 2024b; Wu, Yang and Zhang, 2025). Key policies include coal-to-gas and coal-to-electric heating, modernisation of district heating networks, and promotion of energy-efficient HPs (IEA, 2024b; Wang, Zhou and Zhang, 2024), largely driven by severe air pollution crises such as the 2013 Beijing smog (Wong and Karplus, 2017; The SAIS Review of International Affairs, 2026). While coal still supplies about half of final energy use for heating in buildings and industry, its share has declined by over 5% in the past decade. Concurrently, China has become the world's largest HP market, accounting for more than a quarter of global sales, as shown in Figure 2-2 (IEA, 2024b).

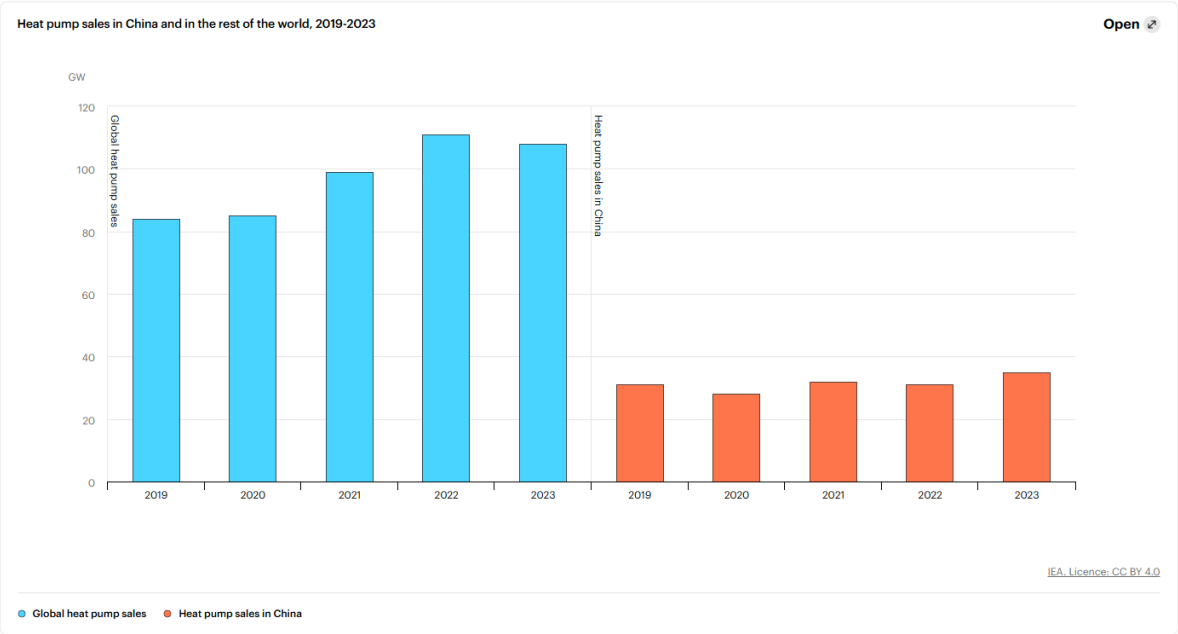

Figure 2-2 Heat pump sales in China and in the rest of the world, 2019-2023 (IEA, 2024b)

The IEA (2024b) report provides a comprehensive overview of the deployment of HPs in buildings, industry and district heating in China and examines opportunities to accelerate adoption. Nearly 20% of China's industrial heat demand is low- and medium-temperature heat, below 200 °C, the optimal range for state-of-the-art HP applications. HPs are also effective for capturing waste heat in district heating networks and industrial processes. In 2022, HPs provided a small share of heat within industry and district networks, but they accounted for approximately 8% of heating equipment sales for buildings in China, and have already achieved widespread adoption in parts of central and southern China, providing a proven pathway to decarbonise heating and cooling. Estimates suggest that about 40% of heat consumption across buildings and industry could theoretically be supplied by state-of-the-art HPs, supporting China's Dual Carbon goals.

There is no plausible path to limiting global warming to 1.5 °C without China. As the world's largest energy consumer and carbon emitter - responsible for roughly one-third of global CO_2 emissions - China's pledges are uniquely significant. Nearly 90% of its GHG emissions stem from the energy sector, making energy policy central to the transition to carbon neutrality. HPs can play an important role in achieving China's Dual Carbon goals. Achieving these goals aligns with China's broader development objectives, including rising prosperity, improved air quality, technological leadership, and a shift toward innovation-driven growth (IEA, 2024b).

2.4 Some of the challenges around retrofitting heat pumps

2.4.1 Grid capacity and demand management

Decarbonising home heating is a major challenge for the government in achieving net zero, as it depends on the engagement of nearly all households (NAO, 2024). Expanding renewable electricity provides a pathway to cut emissions from buildings by shifting to electric heating systems. However, this transition is expected to increase electricity demand, requiring careful management of peak loads and the maintenance of grid stability (Watson et al., 2019).

At the same time, decarbonising electricity generation presents further difficulties. In 2021, the government set a target for all electricity to come from clean sources by 2035, while ensuring security of supply and meeting a projected demand increase of up to 60% (UK Parliament, 2023). Renewable sources such as wind and solar are inherently intermittent due to their dependence on weather conditions. DESNZ has also recognised that a shift to electric heating could alter existing patterns of electricity demand. To ensure the grid can reliably manage fluctuations in both supply and demand throughout the day, particularly during winter, additional low-carbon technologies will likely be needed. These may include gas-fired power stations with carbon capture, hydrogen-based generation, and long-duration energy storage (UK Parliament, 2024).

2.4.2 Costs to households

Many households struggle with heating costs, with over a third of homes in England spending more than 10% of their post-housing income on energy in 2023 (UK Parliament, 2025b).

On average, HPs currently cost around four times more than a gas boiler, and higher electricity prices can also make it more expensive to run. Consequently, the total cost of ownership (TCO) of a HP - despite a typical efficiency, or Seasonal Coefficient of Performance (SCoP), of around 3.3, remains higher than that of a gas boiler for many households (UK Parliament, 2024; Rosenow *et al.*, 2025).

Economic policy scenario analyses by Rosenow et al. (2025), shown in Figure 2-2, demonstrate how different policy choices influence the relative TCO of HPs. In a business-as-usual case (Graph 1), HPs remain considerably more expensive than gas heating. Applying a carbon tax on gas that aligns with electricity permit prices (Graph 2) produces only modest changes. However, shifting levies from electricity bills to general taxation (Graph 3) significantly improves the cost competitiveness of HPs compared to gas heating, while shifting those levies onto gas (Graph 4) creates even stronger financial incentives for HP uptake.

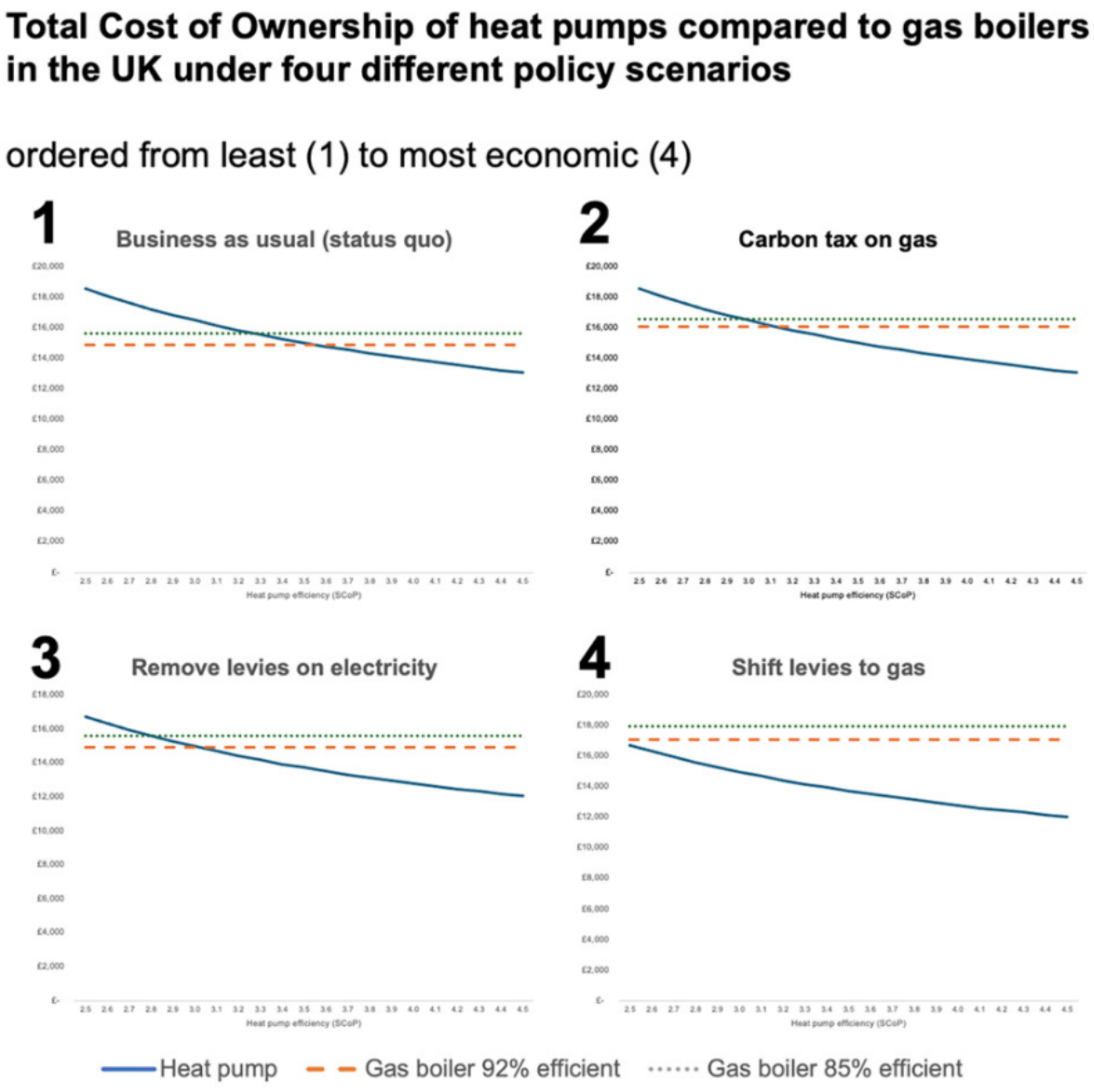

Figure 2-3 TCO under different economic policy scenarios, for range values of SCoPs (Rosenow et al., 2025)

However, equity concerns will require management under both scenarios 3 and 4 (Graphs 3 and 4 in Figure 2-2). In scenario 3, households that depend more heavily on gas for heating than electricity would experience higher costs. In scenario 4, the increased cost of gas heating would likely necessitate compensation measures - particularly for low-income households - alongside targeted support to enable the transition to low-carbon heating systems (Rosenow *et al.*, 2024, 2025).

2.4.3 Public perception

Public perceptions and acceptance of HPs play a key role in achieving international climate change targets. They are shaped by factors such as cost, comfort, disruption, environmental benefits, and level of control (Becker *et al.*, 2023). Awareness is another important factor. Despite the government's expectation that almost all households will need to take part in decarbonising home heating, around 30% of respondents to a government survey in summer 2023 reported that they had either never heard of, or knew very little about, the need to change how homes are heated in order to achieve net zero (National Audit Office, 2024).

Research shows that while there is generally high satisfaction with gas, HPs are often met with uncertainty. Many people have questions about how HPs function and whether they can adequately meet household heating needs. While hydrogen boilers are viewed as a modern alternative to natural gas, heat pumps are not always perceived as a more advanced or convenient technology (for instance quieter, faster, and more concealed). The hot water storage tank and slower responsiveness in temperature control were notable drawbacks for HPs. Additionally, participants highlight the perceived effort and cost involved in installing and adapting to a new system (Becker *et al.*, 2023).

2.4.4 Other challenges

At least 80% of buildings expected to be in use in 2050 have already been constructed and the UK housing stock is among the least efficient in Europe, accounting for around 13% of GHG emissions. Homes that require energy efficiency improvements or

electrical connection upgrades, are not connected to the gas grid, or lack sufficient space for a HP - such as those in densely populated areas or flats without outdoor space - may be exempt from the planned 2035 phase-out of fossil fuel boilers (UK Parliament, 2024).

Although the government's approach to decarbonising home heating is expected to focus primarily on HPs, DESNZ recognises the need to trial alternative technologies for properties without outdoor space. These include heat batteries and infrared heating systems. Heat networks are also being considered as an important low-carbon option for homes that are unsuitable for HPs (UK Parliament, 2024).

In October 2023, the National Infrastructure Commission, which advises the government on long-term infrastructure challenges, recommended that hydrogen should not be supported for domestic heating. While the government has stated that further evidence is needed before making a final decision on hydrogen, it has also made clear that households should not delay installing HPs or connecting to heat networks in anticipation of hydrogen becoming a future option (National Audit Office, 2024).

2.5 Benefits of moving to heat pumps for building space heating

2.5.1 Efficiency and decarbonisation

85% of UK homes are heated by natural gas - representing approximately one-third of its total gas consumption (Digest of UK Energy Statistics (DUKES), 2025; Energy Systems Catapult, 2026)

In 2025, average UK electricity carbon emissions were approximately 245 gCO_2e per kWh.[1] With a typical seasonal coefficient of performance (SCoP) of 3.3, this results in HP emissions of around 74 gCO_2e per kWh of heat. By comparison, average UK gas emissions were about 212 gCO_2e per kWh (UK Government, 2025).[2] Assuming a gas boiler efficiency of 90% (Terry and Galvin, 2023), this equates to roughly 191 gCO_2e per kWh of heat - substantially higher than HPs.

This contrast highlights the importance of the widespread deployment of HPs to decarbonise the UK heating sector (UK Government, 2026). Also, as UK renewable electricity generation increases, carbon emissions of electricity will continue to fall (CCC, 2025a). HPs are therefore a future-proof solution, becoming cleaner over their operational lifetime without requiring system replacement.

2.5.2 Improved air quality

By eliminating on-site combustion, HPs avoid emissions of air pollutants such as nitrogen oxides (NO_x), contributing to air quality. While natural gas combustion produces fewer pollutants than more carbon-intensive fuels such as coal, it still generates NO_x and other harmful emissions at the point of use. In contrast, heat pumps produce no direct emissions, providing clear air quality benefits and supporting better health outcomes (IEA, 2022; EHPA, 2025; World Health Organisation, 2026).

[1] comprising 177 g from generation, 18.53 g from transmission and distribution, 45.90 g from well-to-tank generation, and 3.97 g from well-to-tank transmission and distribution.

[2] 182 g from combustion plus 30.21 g from well-to-tank processes.

3 Conclusion

Low-carbon heating systems and energy efficiency improvements are essential for achieving net zero. Although the UK has made good progress on decarbonising electricity generation, natural gas still supplies around 85% of fuel used for domestic heating and cooking.

The Government should rebalance policy costs to lower the price of electricity relative to gas, creating stronger financial incentives to support the adoption of HPs, while discouraging fossil fuel heating in homes.

Case studies from Norway and China illustrate differing rates of HP deployment and their varied impacts on GHG emissions. China has achieved the highest level of HP roll-out globally, with some evidence suggesting it may have reached its peak emissions target ahead of its 2030 goal. In contrast, while Norway also has widespread adoption of HPs, their impact on reducing national GHG emissions is more limited. However, the transition still delivers important benefits, particularly for building space heating efficiency and energy use, enhancing air quality and supporting better health outcomes.

4 References

Becker, S. *et al.* (2023) 'Public perceptions of heat decarbonization in Great Britain', *Wiley Interdisciplinary Reviews: Energy and Environment*, 12(6), p. e492. Available at: https://doi.org/10.1002/wene.492.

BEIS (2021) 'Heat and building strategy (accessible webpage) - GOV.UK'. Available at: https://www.gov.uk/government/publications/heat-and-buildings-strategy (Accessed: 24 March 2026).

Burnett, N. (2026) *The UK's Plans and Progress to Reach Net Zero by 2050*, *House of Commons Library*. Available at: https://researchbriefings.files.parliament.uk/documents/CBP-9888/CBP-9888.pdf (Accessed: 13 March 2026).

CCC (2025a) *Progress in reducing emissions - 2025 report to Parliament - Climate Change Committee*. Available at: https://www.theccc.org.uk/publication/progress-in-reducing-emissions-2025-report-to-parliament/ (Accessed: 12 March 2026).

CCC (2025b) *The Seventh Carbon Budget - Climate Change Committee*. Available at: https://www.theccc.org.uk/publication/the-seventh-carbon-budget/ (Accessed: 15 March 2026).

CRIPPA, M. *et al.* (2025) 'GHG emissions of all world countries', *GHG EMISSIONS OF ALL WORLD COUNTRIES JRC SCIENCE FOR POLICY REPORT*, p. ISSN 1831-9424. Available at: https://doi.org/10.2760/5917997.

Department for Business, E. and I. strategy [BEIS] (2021) 'BEIS Annual report and accounts 2021-22'.

DESNZ (2026) *Heat pump deployment statistics: December 2025 - GOV.UK*. Available at: https://www.gov.uk/government/statistics/heat-pump-deployment-statistics-december-2025 (Accessed: 15 March 2026).

Digest of UK Energy Statistics (DUKES) (2025) *Digest of UK Energy Statistics (DUKES) - GOV.UK*. Available at: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes (Accessed: 28 March 2026).

EHPA (2025) *Air pollution: heat pump switch crucial for health - European Heat Pump Association*. Available at: https://ehpa.org/news-and-resources/news/air-pollution-heat-pump-switch-crucial-for-health/ (Accessed: 28 March 2026).

EHPA (no date) *Market data - European Heat Pump Association*. Available at: https://ehpa.org/market-data/ (Accessed: 16 March 2026).

Ember (2025) *Solar and wind growth meets all new electricity demand in the first three quarters of 2025 | Ember*. Available at: https://ember-energy.org/latest-updates/solar-and-wind-growth-meets-all-new-electricity-demand-in-the-first-three-quarters-of-2025/ (Accessed: 12 March 2026).

Energy Security and Net Zero Committee (2025) 'Energy Security and Net Zero Committee Retrofitting homes for net zero First Report of Session 2024-25 HC 453'. Available at: www.parliament.uk/copyright. (Accessed: 15 March 2026).

Energy Systems Catapult (2026) *Heat Decarbonisation Guide | Energy Systems Catapult*. Available at: https://es.catapult.org.uk/guide/decarbonisation-heat/ (Accessed: 22 March 2026).

Eppe, P.S. *et al.* (2025) 'Sustainable energy technology adoption for a low-carbon future: A global meta-analysis of psychological determinants', *Energy Research & Social Science*, 126, p. 104152. Available at: https://doi.org/10.1016/j.erss.2025.104152.

European Commission (2025) *5 things you should know about heat pumps - European Commission*. Available at: https://energy.ec.europa.eu/news/5-things-you-should-know-about-heat-pumps-2025-12-05_en (Accessed: 21 March 2026).

Gasparrini, A. *et al.* (2015) 'Mortality risk attributable to high and low ambient temperature: a multicountry observational study', *The Lancet*, 386(9991), pp. 369–375. Available at: https://doi.org/10.1016/S0140-6736(14)62114-0.

Georgiadou, M.C., Hacking, T. and Guthrie, P. (2012) 'A conceptual framework for future-proofing the energy performance of buildings', *Energy Policy*, 47, pp. 145–155. Available at: https://doi.org/10.1016/j.enpol.2012.04.039.

Home Builders Federation (2023) 'HOUSING HORIZONS: EXAMINING UK HOUSING STOCK IN AN INTERNATIONAL CONTEXT'.

IEA (2017) *Energy Policies of IEA Countries: Norway 2017 Review – Analysis - IEA*. Available at: https://www.iea.org/reports/energy-policies-of-iea-countries-norway-2017-review (Accessed: 21 March 2026).

IEA (2022) *The Future of Heat Pumps – Analysis - IEA*. Available at: https://www.iea.org/reports/the-future-of-heat-pumps (Accessed: 21 March 2026).

IEA (2023) *Energy Efficiency - Energy System - IEA*. Available at: https://www.iea.org/energy-system/energy-efficiency-and-demand/energy-efficiency (Accessed: 14 March 2026).

IEA (2024a) *Building technical regulations (TEK17) – Policies - IEA*. Available at: https://www.iea.org/policies/19558-building-technical-regulations-tek17 (Accessed: 20 March 2026).

IEA (2024b) 'The Future of Heat Pumps in China In collaboration with'. Available at: https://doi.org/10.1007/9.

IEA (2025) *CO2 Emissions – Global Energy Review 2025 – Analysis - IEA*. Available at: https://www.iea.org/reports/global-energy-review-2025/co2-emissions (Accessed: 12 March 2026).

IEA (2026) *Heating - IEA*. Available at: https://www.iea.org/energy-system/buildings/heating (Accessed: 14 March 2026).

Myllyvirta, L. (2026) *Analysis: China's CO2 emissions have now been 'flat or falling' for 21 months - Carbon Brief*. Available at: https://www.carbonbrief.org/analysis-chinas-co2-emissions-have-now-been-flat-or-falling-for-21-months/ (Accessed: 12 March 2026).

National Audit Office (2024) 'Decarbonising home heating'.

National Institute for Health and Care Excellence (2019) '2019 surveillance of excess winter deaths and illness and the health risks associated with cold homes (NICE guideline NG6) Surveillance report-and-conditions#notice-of-rights)'. Available at: www.nice.org.uk (Accessed: 22 March 2026).

Olympios, A. V., Justo Alonso, M. and Pantaleo, A.M. (2025) 'Heat pumps in Europe: perspectives and innovation challenges', *Progress in Energy*, 7(3), p. 032004. Available at: https://doi.org/10.1088/2516-1083/ade94a.

Organisation for Economic Co-operation and Development [OECD] (2022) ‘Making Norway’s housing more affordable and sustainable’. Available at: https://doi.org/10.1787/c740833e-en.

Petrovich, B. (2026) *Wind and solar generated more power than fossil fuels in the EU for the first time in 2025 | Ember*. Available at: https://ember-energy.org/latest-updates/wind-and-solar-generated-more-power-than-fossil-fuels-in-the-eu-for-the-first-time-in-2025/ (Accessed: 9 March 2026).

Rosenow, J. *et al.* (2024) ‘Economics of Heat Pumps and Policy Choice: The Case of the UK’. Available at: https://doi.org/10.2139/ssrn.4700647.

Rosenow, J. *et al.* (2025) ‘Total cost of ownership of heat pumps and policy choice: The case of Great Britain’, *iScience*, 28(2), p. 111784. Available at: https://doi.org/10.1016/j.isci.2025.111784.

Sadeghi, H., Ijaz, A. and Singh, R.M. (2022) ‘Current status of heat pumps in Norway and analysis of their performance and payback time’, *Sustainable Energy Technologies and Assessments*, 54, p. 102829. Available at: https://doi.org/10.1016/j.seta.2022.102829.

Sarsentis, D.O. (2023) *How the UK compares to the rest of Europe on heat pump uptake | Nesta*. Available at: https://www.nesta.org.uk/report/how-the-uk-compares-to-the-rest-of-europe-on-heat-pump-uptake/?gad_source=1&gad_campaignid=23293265263&gbraid=0AAAAADrOw2bXfF1Y16PyOtPwNNIWx6TdL&gclid=CjwKCAiAkbbMBhB2EiwANbxtbVzzCBC7DvmRxX-9rKnjrXWw8V0lwPiKUO-1cLxKFUW4gdiYmvCt7xoC4IMQAvD_BwE%20(Accessed:%20February%2014,%202026). (Accessed: 15 March 2026).

Terry, N. and Galvin, R. (2023) ‘How do heat demand and energy consumption change when households transition from gas boilers to heat pumps in the UK’, *Energy and Buildings*, 292, p. 113183. Available at: https://doi.org/10.1016/j.enbuild.2023.113183.

The SAIS Review of International Affairs (2026) *China’s Coal-to-Gas Program: A Developing Environmental Governance Regime - The SAIS Review of International Affairs*. Available at: https://saisreview.sais.jhu.edu/china-coal-to-gas/ (Accessed: 27 March 2026).

The United Nations Framework Convention on Climate Change [UNFCCC] (2026) ‘Annex Nationally Determined Contribution (NDC) of Norway for 2035’.

UK Government (2021) ‘HM Government – Heat and Buildings Strategy’.

UK Government (2023) *English Housing Survey: local authority housing stock condition modelling, 2023 - main report - GOV.UK*. Available at: https://www.gov.uk/government/statistics/english-housing-survey-local-authority-housing-stock-condition-modelling-2023/english-housing-survey-local-authority-housing-stock-condition-modelling-2023-main-report (Accessed: 18 March 2026).

UK Government (2025) *Greenhouse gas reporting: conversion factors 2025 - GOV.UK*. Available at: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2025 (Accessed: 28 March 2026).

UK Government (2026) ‘2024 UK Greenhouse Gas Emissions, Final Figures’. Available at: https://assets.publishing.service.gov.uk/media/6982292019d3abdb495f37cd/2024-final-greenhouse-gas-emissions-statistics-statistical-release.pdf (Accessed: 14 March 2026).

UK Parliament (2024) ‘Decarbonising home heating Thirty-Seventh Report of Session 2023-24 Report, together with formal minutes relating to the report by authority of the House of Commons’. Available at: www.parliament.uk. (Accessed: 22 March 2026).

UK Parliament (2025a) *Retrofitting homes for net zero*. Available at: https://publications.parliament.uk/pa/cm5901/cmselect/cmesnz/453/report.html (Accessed: 15 March 2026).

UK Parliament (2025b) *Retrofitting homes for net zero*. Available at: https://publications.parliament.uk/pa/cm5901/cmselect/cmesnz/453/report.html (Accessed: 24 March 2026).

UK Parliament (2026) ‘Gas and electricity prices during the “energy crisis” and beyond’. Available at: https://commonslibrary.parliament.uk/research-briefings/cbp-9714/ (Accessed: 23 March 2026).

UK Steel (2026) *Electric Arc Furnaces in the UK*. Available at: https://www.uksteel.org/electric-arc-furnaces-1 (Accessed: 10 March 2026).

UN (no date a) *Net Zero Coalition | United Nations*. Available at: https://www.un.org/en/climatechange/net-zero-coalition (Accessed: 13 March 2026).

UN (no date b) *The Paris Agreement | United Nations*. Available at: https://www.un.org/en/climatechange/paris-agreement (Accessed: 13 March 2026).

UNEP (2026) *The world is likely to exceed a key global warming target soon. Now what?* Available at: https://www.unep.org/news-and-stories/story/world-likely-exceed-key-global-warming-target-soon-now-what (Accessed: 14 March 2026).

Wang, H., Zhou, S. and Zhang, P. (2024) 'Clean heating and clean air: Evidence from the coal-to-gas program in China', *China Economic Review*, 85(4), p. 102179. Available at: https://doi.org/10.1016/j.chieco.2024.102179.

Welsh Government (2022) *Solar farm powers Morriston Hospital for 50 hours without back-up from the grid in winter months | GOV.WALES*. Available at: https://www.gov.wales/solar-farm-powers-morriston-hospital-50-hours-without-back-grid-winter-months (Accessed: 10 March 2026).

Wong, C. and Karplus, V.J. (2017) 'China's War on Air Pollution: Can Existing Governance Structures Support New Ambitions?', *The China Quarterly*, 231, pp. 662–684. Available at: https://doi.org/10.1017/S0305741017000947.

World Bank Group (2026a) *Population, total - China | Data*. Available at: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=CN (Accessed: 26 March 2026).

World Bank Group (2026b) *Population, total - World | Data*. Available at: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=1W (Accessed: 26 March 2026).

World Health Organisation (2026) *Air quality, energy and health*. Available at: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants (Accessed: 28 March 2026).

Wu, J., Yang, L. and Zhang, C. (2025) 'High-temperature heat pumps: key technologies and industrial applications toward carbon–neutral process heating', *Carbon Neutral Systems 2025 1:1*, 1(1), pp. 21-. Available at: https://doi.org/10.1007/s44438-025-00021-z.

Yan, X. *et al.* (2024) ‘Unpacking energy consumption in China’s urbanization: Industry development, population growth, and spatial expansion’, *Research in International Business and Finance*, 70, p. 102342. Available at: https://doi.org/10.1016/j.ribaf.2024.102342.

Żelazna, A. and Pawłowski, A. (2025) ‘Review of the Role of Heat Pumps in Decarbonization of the Building Sector’, *Energies 2025, Vol. 18, Page 3255*, 18(13), p. 3255. Available at: https://doi.org/10.3390/en18133255.