

Heat Pumps for Decarbonising in the Domestic Sector

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Contents:

i. Contents

ii. Abstract

1 – Introduction [1-5]

1.1 – Historic Context [1-1]

1.2 – Heat Pump Models [1-5]

2 – Discussion [6-15]

2.1 – The UK Energy Market [6-7]

2.2 – UK Government Warm Homes Plan [7-9]

2.3 – Energy Efficiency of Existing Housing Stock [9-10]

2.4 – Installation Factors [10-12]

2.5 – Successes in Scandinavia [12-13]

2.6 – Other Related Technologies [13-15]

3 – Conclusion [16-17]

4 – Reference List [18-19]

Abstract

Due to growing concern surrounding unstable fuel prices and the climate crisis (regarding the Climate Change Act, 2008), heat pumps have become a focus of many countries looking to decarbonise and diversify energy use in the domestic sector. In recent years, the UK has struggled with heat pump uptake owing to several socioeconomic factors which have inhibited its progress towards the 2050 net zero target.

This paper first reviews the UK energy market, which has been characterised by market privatisation and convoluted energy efficiency schemes since the 1980s. Due to this history, high electricity tax is one of the biggest hurdles in tackling mass heat pump uptake. As of now, government support is available for heat pump installation, mainly through a £7500 grant offered to those upgrading, and the creation of the Warm Homes Plan, an £15 billion initiative aiming to cut fuel poverty, protect vulnerable groups and incentivise electrically heated homes.

The nature of retrofitting in the UK, considering the large proportion of ageing housing stock with low energy efficiency, is another key theme in this study. On the consumer level, the retrofitting process is often complicated and can entail many hidden costs and risks. Public perception of the technology and apprehension has been reinforced by examples of poorly carried out work and projects failing to meet expectations.

Despite the UK's overall position, progress has been made in isolated cases such as district heating in Dalmarnock, using a WSHP in conjunction with a wastewater processing plant. Successes elsewhere in the world, especially parts of Scandinavia, have demonstrated that there is potential for the UK to greatly expand its heat pump portfolio with effective governance, technological innovation and district heating networks (specifically in urban centres).

1 Introduction

1.1 Historic Context:

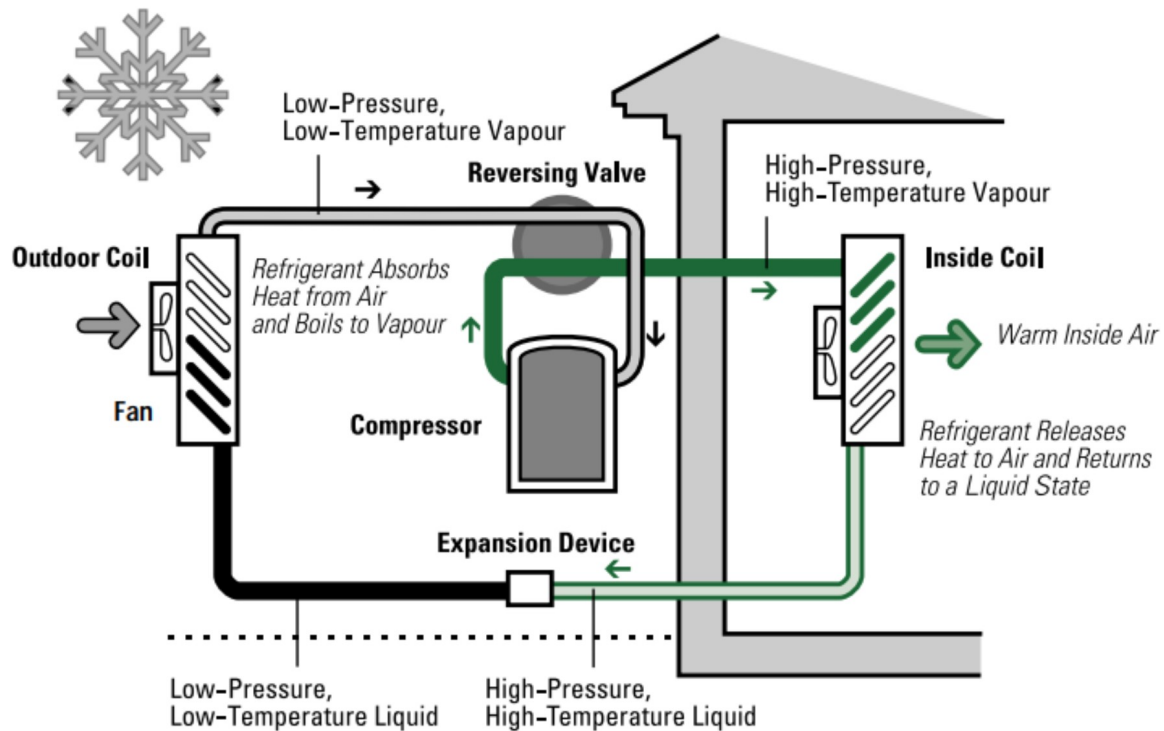
Heat pump technology has existed for over 150 years, with ground-source variants being developed in the 1950s (Aridi et al, 2025; Zogg, 2008). Since then, the base technologies have undergone significant refinement throughout the 21st century, becoming competitors with conventional boilers. Given their potential for CO₂ reductions, their uptake is central to achieving the UK 2050 net zero target.

At present, the government recognises the need for financial assistance in order to achieve the aim, and has created a number of support avenues for consumers looking to increase their heating efficiency (UK Government, 2020). Most notably, this includes a widespread grant of £7500 per household upgrading to a heat pump system.

1.2 Heat Pump Models:

Air Source (ASHPs)-

The vast majority of heat pumps utilised in the domestic sector are air source (depicted in figure 1), due to their cost and ease of installation (relative to alternatives) (Bell, 2024). One of the notable requirements of ASHPs is large pipe diameters, which typically require retrofitting of existing radiators and pipework (contributing to overall installation cost).



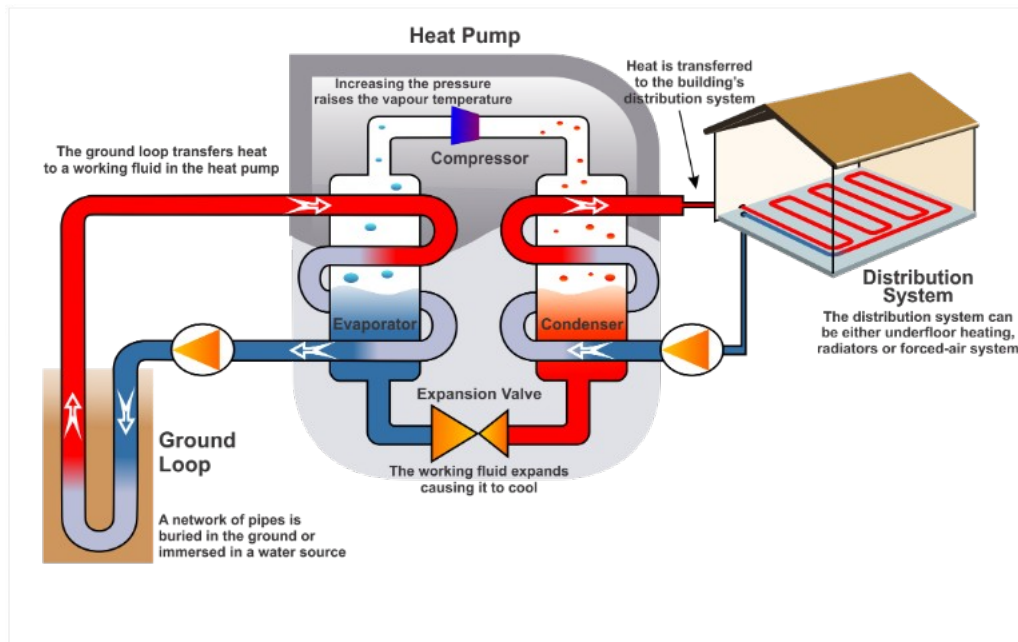
[Figure 1: Air Source Heat Pump Structure (HVRA, 2026)]

Ground Source (GSHPs)-

GSHPs boast higher efficiency in comparison with ASHPs (between 50-200% more efficient), due to the stability and density of heat storage underground (Heat Pumps: Are They Really Worth It?, 2025). Unlike ASHPs, they are significantly more expensive up front, requiring more expensive technology and deep drilling (typically 100-200m), but have a longer lifespan and operate effectively in all climates (Violante et al, 2022). Larger properties which may otherwise require multiple ASHPs to support an effective heating system, may opt for GSHP, given their efficacy, potential for long term savings and benefit to property value.

Whilst renowned for their reliability and efficiency, GSHPs (figure 2) are a more complicated and expensive alternative to ASHPs, mainly due to the depth which they have to be installed at (potentially hitting the water table) (Richardson, 2019). Due to these complications, they are generally less common. Specifically, a GSHP can cost between

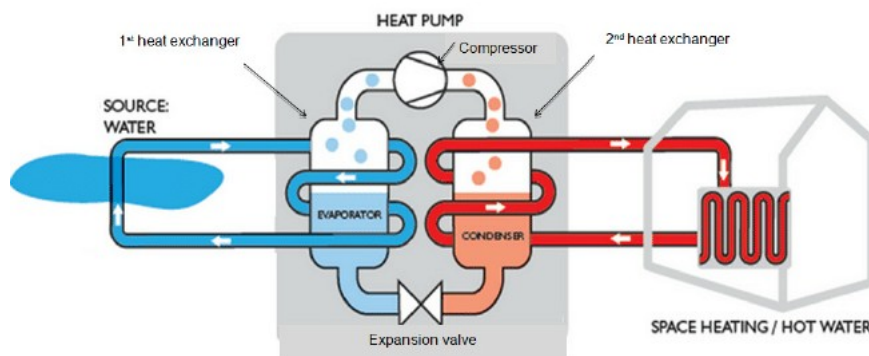
£25,000 and £27,000 (2024), and is eligible for the same £7,500 government grant.



[Figure 2: Ground Source Heat Pump Diagram (GHANZ, 2026)]

Water Source (WSHPs)-

WSHPs, although less common, are a pioneering technology with great scope for application in large building space and heating networks (UK Government, n.d.). They come in either in open (directly drawn from source) or closed loop (sealed network submerged in water) form, and excel at high efficiency for similar reasons to GSHPs (temperature stability / density) (figure 3). They are more expensive than ASHPs but cheaper than GSHPs. Critically, they require close proximity to a water source, meaning WSHPs see limited use in the domestic sector for geographic reasons.



[Figure 3: Water Source Heat Pump Diagram (Emmanuel, 2014)]

A UK Government survey (2020), revealed that less than 1% of homes in England and Wales have a heat pump, despite being a commercially proven technology across the globe, especially in Europe (Brandford and Roberts, 2022). Deployment of heat pumps has remained relatively low, with the latest reports (2023-24) suggesting the proportion has remained roughly stable (around 1% of homes) (Office for National Statistics, 2025; UK Government, 2025). Lacking public confidence has been identified as a key barrier in achieving the heat pump rollout (Thomas, 2024).

Linked with the issue of confidence, is the high proportion of older properties which typically suffer from poor energy efficiency, and require significant work to make a heat-pump viable (only 11% of UK homes estimated to be ‘heat pump-ready’) (Lamb and Elmes, 2024). In spite of grant schemes, preparation alone can become a complicated and expensive process, with associated risks to the consumer.

Although there has been low uptake so far, the projection set by the government is 600,000 heat pump installations per year by 2028, aiming to provide up to 20,000 jobs by 2030. They have also stated that they are working closely with Ofgem (Office of Gas and Electricity Markets) to ensure fair pricing for consumers (UK Government, 2020).

According to Lamb and Elmes 2024 paper, the UK's heat pump adoption barriers can be summarised into three categories:

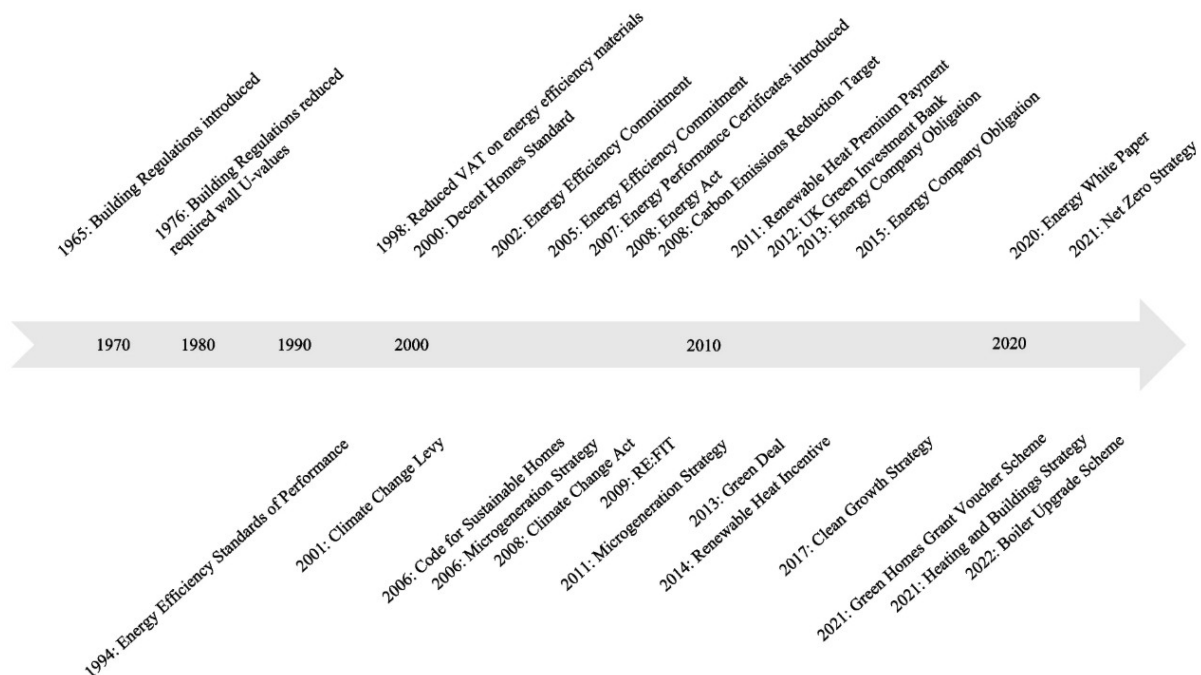
- The 'Eligibility-Readiness Gap' – describes the difference between homes eligible for the Government Boiler Upgrade Scheme (around 50%) and properties being 'heat pump ready' (currently estimated at 11%)
- Infrastructure Limitations – which can be summarised as a lack of capacity to deliver the necessary works to make homes heat pump-ready
- Lack of Public Awareness – according to surveys, many homeowners were identified to be unaware of the requirements for heat pump installation, as well as unwilling to spend without support from the government.

2 Discussion

2.1 The UK Energy Market:

Since the 1980s, the UK's domestic energy policy has been marked by market liberalisation, and privatisation of state-controlled energy companies (Lamb and Elmes, 2024). As such, competition between private bodies has taken hold as government intervention has diminished (including since the Competition Act of 1998).

Consolidation in recent years has resulted in energy suppliers developing monopolies across the market, driving higher prices which disproportionately affect consumers in vulnerable groups (Lamb and Elmes, 2024).



[Figure 4: UK Energy Efficiency Schemes (Lamb and Elmes, 2024)]

Regarding the UK's energy efficiency strategies, Kern et al (2017), proposed that:

"these measures have generated a complex, fragmented policy environment for homeowners and companies, which has failed to encourage sufficient improvements in the housing stock"

Moving forward, arguments have been made that the government should aim to take further control of the energy market in order to relieve pressure on consumers, and drive the rollout of heat pumps (the Warm Homes Plan has attempted to address this to some extent) (UK Government, 2026).

Electricity is heavily taxed in the UK (more than three times higher than gas). This is largely due to policy history and reliance on gas for production (where major gas plants set high default rates) (Kern, Kivimaa and Martiskainen, 2017). In practice, this results in unfairly reduced savings for households with heat pumps. Electricity tariffs specifically designed for heat pumps can assist with energy bills, but the government must address this imbalance if the heat pump rollout is to be successful (Heat Pumps: Are They Really Worth It?, 2025).

2.2 UK Government Warm Homes Plan:

The Government's Warm Homes Plan (2026) is a new initiative created to lower energy bills and support decarbonisation in the domestic sector. In it is stated the "case for change" which addresses the cost of living crisis and energy insecurity in the UK (UK Government, 2026). Leading on from this is the vision of the government (cheap, clean power in the home), and the offer to consumers. Notably this involves financial support for low-income households as well as renters, demonstrating a strengthened commitment to an equitable transition to net zero, whilst maintaining blanket support for upgrading homes.

In terms of lowering bills, the programme has supplied £2.7 billion in grants as well as £2 billion in low-interest loans. Included in this is an overhaul of the boiler upgrade scheme, which maintains the offer of £7500 for new installations but expands consumer choice of technologies such as heat batteries and heat pumps. Additional financial investments include a £5 billion investment in the "Warm Homes Fund", aiming to assist British businesses in technology innovation and reduced costs for consumers.

A major aim of the scheme is to incentivise electrically heated homes through lower electricity costs (average heat pump user can make savings of over £200 from April + potential £442 savings for electric storage heated homes). This is directly combating the existing issue of high electricity tax.

In addition to financial support, the programme aims to ensure that every new house includes solar panels, high energy efficiency and clean heat (solar panels on up to 3 million homes, and 450,000 heat pump installations per year by 2030, in line with the "Future Homes Standard"). They also aim to streamline the installation process, by committing to a three day target for simplified heat pump installation.

Consumer Protection –

- Creation of the Warm Homes Agency to co-ordinate transition and protect consumers
- Reforming EPCs to more accurately reflect and reward electrification of homes
- Strengthening consumer protection for home upgrades by bringing the system under government control
- Regulating heat networks to ensure fair prices for consumers

Cutting Fuel Poverty –

- £5 billion support for low-income households via increased investment from social housing providers and partnership with local authorities
- £150 off winter heating bill for around 6 million low-income households ("Warm Home Discount")

Delivering Good Jobs and Growth Across The Country -

- £15 billion investment in Warm Homes Plan as part of the total investment of £38 billion
- Supporting 180,000 additional high-quality jobs throughout the UK
- 70% target for UK-based heat pump manufacturing (for consumption)
- £30 million fund for driving innovation in British companies
- £21 million grant for upskilling of heating engineers + £8 million for qualifications in solar ("Warm Homes Skills Programme")
- £1 billion for investment in heating networks in urban areas (creating 18,000 jobs by 2030 and representing a £60 billion industry by 2050)

2.3 Energy Efficiency of Existing Housing Stock:

Studies have revealed that up to 90% of people's time is spent indoors in the developed world, with 69% of that occurring in the home.

Improving thermal energy performance is arguably the most important (and difficult) area for development of existing UK housing stock.

It is estimated that around 17 million UK homes may have to have an installed heat pump to meet the net zero target (Brandford and Roberts, 2022). Under UK policy, current retrofit schemes encounter multiple issues in practice. Before addressing these, literature has revealed that there is insufficient knowledge of existing UK housing stock, preventing decision-makers from implementing realistic plans for reducing carbon emissions. In addition, generic retrofitting packages are likely to fail when considering the range of requirements

for the existing stock. Alabid, Bemmadji and Seddiki argue that attention should be focused on factors such as social sustainability, with emphasis on low embodied carbon and energy products. As stated earlier, the issue of lacking accurate data has to be tackled in order for contractors and government bodies to effectively assist with thermal and energy performance of buildings – further data collection and surveying could assist in this.

Aside from gaps in data, it is understood that much of the existing housing stock requires “deep retrofitting”, which entails high costs and long-term strategic planning. In some cases, increased risk of interstitial condensation can be an issue, where there is not enough space to correctly install insulation material (can also exacerbate asthma issues caused by indoor dampness). Current research recommends the use of breathable insulation materials to remedy this issue, but for many consumers it may still be additional reason for apprehension.

Alabid, Bennadji and Seddiki (2022) place emphasis on the environmental / health benefits of retrofitting, which is often overlooked by other sources, and more difficult to gauge the value of than economic factors. As well as this, the importance of working grass-roots, starting with the most vulnerable groups is highlighted. In accordance with other studies, their research has concluded that it is vital to invest in technology progression and publicise mass-resource data on retrofitting schemes to give consumers a better understanding of the market, and allow them to make better informed decisions.

Adding to current potential, research has demonstrated opportunity for development of strategic mass-scale plans to include new and retrofit building schemes.

2.4 Installation Factors:

Installing an air source heat pump can be an arduous process, requiring planning permission and other regulations (Heat Pumps: Are

They Really Worth It?, 2025). As well as requiring more space than boilers, installation of an air source heat pump typically takes between two and ten days, with ground source taking even longer (between one and two weeks). Whilst the three day target specified in the Warm Homes Plan aims to tackle this, it has yet to come to fruition (time pressure being a major factor in achieving net zero by 2050).

Thomas (2024), also identified that public opinion has been greatly swayed by historic cases of poorly carried out work, initially incentivised by government grants but with limited consideration for long-term effects. The example of cavity wall insulation serves as a key lesson which demonstrates a typical approach of many installers, which significantly damages trust.

If installed correctly, heat pumps can be 3-4 times more efficient than gas boilers. The MCS certification scheme has certified installers which can provide this (with the additional benefit that successful retrofitting can drastically increase the value of a property). Brandford and Roberts (2022), recommend the concept of a 'competency card system' to reduce incidence of poor quality work, particularly since poor quality installations heavily discourage consumers. Achieving the net zero target requires effective communication with the general public, to better establish strategic energy-efficiency pathways (Thomas, 2024).

Assuming heat pump uptake takes place as predicted by the government, there will be a significant installer skills gap in the sector, creating a requirement for a potential 69,500 trained installers by 2035. This is hoped to benefit young people, with growing job opportunities provided (relevance of apprenticeships, urgency of upskilling).

High capital costs must be addressed otherwise lower income households are likely to be disadvantaged. Generally speaking, the average payback period of an ASHP is between five and fifteen years, which can deter those looking for quick savings. Current consumers installing these technologies are, at best, looking elusively on the

basis of long-term financial gain (generally decades). To help with this, the government specifies that low income homes which install heat pumps could save up to £600 a year on energy bills, aided by their £2bn green homes grant voucher scheme (UK Government, 2020). Also recognised as a key component of the transition is the importance of robust electrical distribution networks in order to accommodate widespread uptake.

Whilst WSHPs are rarely seen in the domestic sector (at present), they may have increased application moving forward. In Dalmarnock, Glasgow, heat energy is harvested from a wastewater treatment plant using a large-scale water source heat pump setup. This energy is then distributed to the surrounding area, removing the need for individual heat sources (local heating service). This reduces strain on grid infrastructure for technologies with high electrical consumption, subverting one of the biggest barriers for green technology (Liu et al, 2023).

Aside from economic factors, the environmental aspect can be of varying importance depending on the consumers viewpoint. Noise is related feature which is concerning for many consumers, although modern units are typically very quiet. One study based in Ruda-Huta, Poland, found that rural areas are likely to have alternative criteria for heating systems, primary resulting from the lack of district heating services (Gradziuk et al, 2024). Switching to GSHPs in one district proved to be economically competitive with traditional systems, and led to a reduction in local pollution levels (although this doesn't account for the higher electricity tax the UK faces).

2.5 Successes In Scandinavia:

Despite the common perception of poor performance in low temperatures, Norway, Finland, and Sweden have all established themselves as leading nations on heat pump infrastructure since the early 2000s (Resilience, 2023). Norway is currently leading this, with 60% of households having a heat pump installed as of 2020 (majority

being air source). This has resulted in vastly reduced carbon dioxide emissions from heating (-95% in Sweden, -83% in Norway), although heating networks have also played a role in this reduction. Effective governance is a critical factor in these country's successes; carbon taxation has played a major role in making heat pumps financially viable, with Finland being the first country in the world to introduce a carbon tax. Norway introduced a similar system in 1991 which reached 76 euros per tonne of carbon dioxide in 2023 (projected to reach 196 euros per tonne by 2030), further incentivising the switch to low carbon heating.

2.6 Other Related Technologies:

Whilst heat pumps are a key area of development in the governments net zero plan, other green heating alternatives are being considered such as bio-methane and clean hydrogen, as part of a wholistic approach.

Fossil Fuel Boilers –

Conventional boilers have several key attributes which has led to their widespread adoption. Their overarching two strengths are their low cost and reliability / familiarity (as a technology which has been in use since the industrial revolution). Despite higher efficiency, heat pumps struggle to compete financially (Ahmad, 2023). Thomas (2024), points out that a far safer and simpler solution for the average consumer, is to upgrade to a more efficient boiler which guarantees savings.

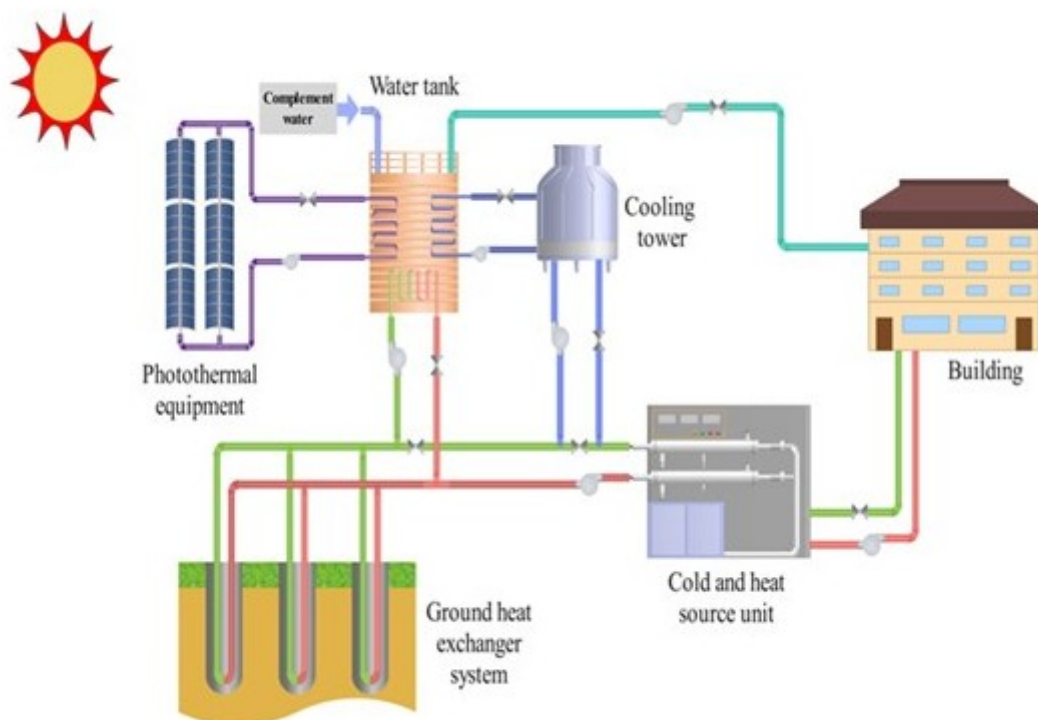
Hydrogen Boilers –

These fit the same niche as conventional boilers, and offer a green alternative to fossil fuels (Gao et al, 2025). However, when compared with heat pumps, they only deliver around a sixth of the economic

benefits. Currently, this makes them financial unfeasible for the domestic sector, although future development could close this gap.

Solar Water Heating (SWH) –

Solar water heating systems operate by using solar power (generally from solar panels) to heat water locally, bypassing any additional costs (conversion / transmission losses, plus tax) (Blewden, 2024). Considering their application as cheap, green heating technologies, they offer an attractive option for assisting with energy bills, particularly in suiting climates (figure 5).

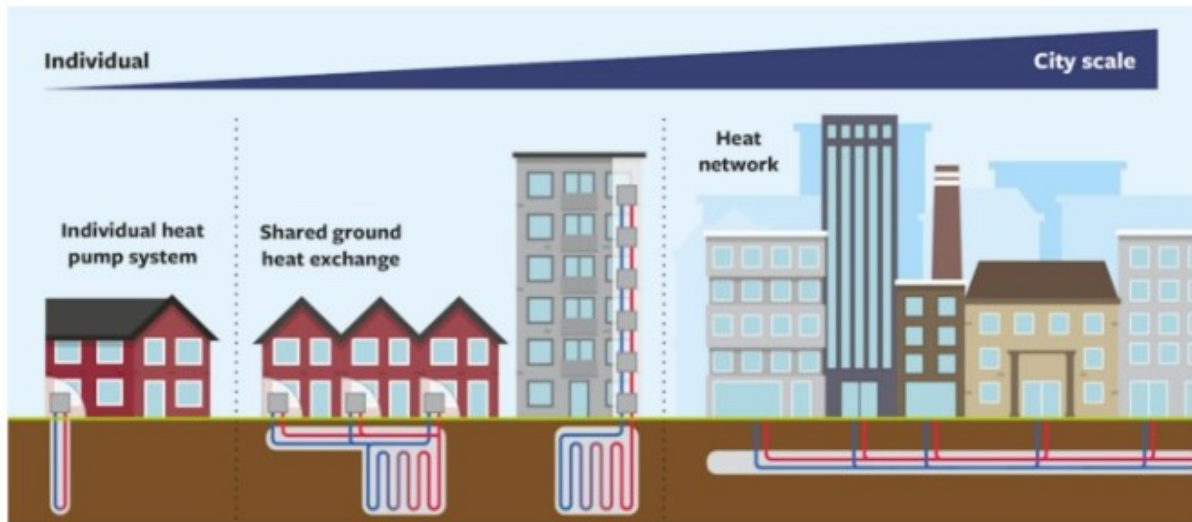


[Figure 5: Coupled system – solar heating with GSHP (Tong, Yu and Jia, 2025)]

Heating Networks –

Heating networks are cited by the government as being able to supply multiple properties in densely populated areas [figure 5], cutting costs for the consumer and reducing emissions (operating on similar

principals to traditional central heating) (UK Government, 2020). This technology has been widely adopted in Norway, where it has seen a great degree of success in reducing energy consumption (Resilience, 2023).



[Figure 6: Depiction of a Heat Network (Brown, Hampton and Fawcett, 2024)]

3 Conclusion

Given the significant difference in efficiency, heat pumps should be far more cost effective. Whilst the governments grant of £7500 assists with capital costs, the individual consumer switching to a heat pump is still at a financial disadvantage due to electricity tax (government support doesn't account for three times higher tax). On the other hand, more money is diverted for research and development, which is also driving down costs for consumers (although the rate at which this occurs is unpredictable).

There is a great deal of misinformation surrounding heat pumps, and many of the public's anxieties are not ill-founded. Widespread examples of heat pumps failing to meet expectations exist, mainly occurring from poor retrofitting work leading to high inefficiencies / costs. This is why building standards and technology innovation (stated in the Warm Homes Plan) is vital; simply pushing heat pumps onto the public has consistently failed. Ultimately, the government has to address the perception of heat pumps in the UK by proving their ability, and putting financial incentives in place (particularly to close the gap between gas and electricity tax, emulating the Scandinavian situation to some extent). At present, the grant offered only accounts for a portion of the unit price itself, meaning customers are still spending more than traditional boilers, whilst taking on additional risk (newer, less proven technology).

Given the limited scope for time, increasing energy efficiency generally (through better insulation and heat networks where applicable), should be further incentivised by the government, as they will reduce bills (regardless of technology) and ease the transition to heat pump technology, reducing the impact mass adoption will have to grid infrastructure, as seen in the Dalmarnock case. Creating new builds which meet high efficiency standards and include renewable heating technology by default, is also key as it reduces potential wasted cost associated with retrofitting further down the line. The government has consistently made efforts to reduce societal

inequities with a substantial degree of success, conveyed particularly well in the Warm Homes Plan, where low income households and renters are offered subsidies for bills (warm homes discount).

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