Rethinking heat

A utility based approach for ground source heat pumps

A discussion paper by Regen – March 2021

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Contents

Foreword 04
Executive summary 05
Rethinking heat – summary graphic 09
1 Heat pumps will become part of the mainstream 10
2 Why the type of heat pump deployed is important 14
3 Building a new growth scenario for the GSHP market 18
4 Analysis of network impacts 21
5 New business models to unlock the market 26
6 Additional value through flexibility 29
7 Falling costs with market growth 31
8 Supporting jobs and UK manufacturing 35
Appendix 1 37
References 38

Some 86% of homes in GB are heated by burning natural gas[1]. Heating our homes by burning a fossil fuel will not be possible in a net zero world. The key technology, at present, to generate low carbon heat is the heat pump.

Although heat pumps are a well-established technology, they have not been widely deployed in the UK. This is partly because gas delivered via the gas grid has typically been much cheaper per kWh, and was historically lower carbon than the equivalent amount of electricity.

The government's 2020 Energy White Paper set out a commitment to a step-change in heat pump deployment and set a target for 600,000 heat pumps a year to be installed by 2028.

At the same time, as highlighted in the Energy White Paper, "We need to electrify heat in buildings in a way which reduces the need for additional generation and network capacity[2]." The mix of heat pump types deployed is a key factor in ensuring both of these targets are met.

There are two types of domestic heat pumps for domestic use: air source (ASHP) and ground source (GSHP). It has been widely expected that ASHPs will make up most of the majority of this growing market as they are deemed cheaper and easier to install. However, there are advantages to GSHPs, which, amplified to the millions to be installed by 2030, could deliver significant benefits to householders, our electricity system and the environment.

As we stand on the brink of a radical shift in how we heat our buildings, the aim of this paper is to assess the potential role of GSHPs in meeting the government's targets.

> This paper challenges policymakers to rethink the heat pump mix, considering the benefits of different heat pump technologies in a net zero world, with an energy system that increasingly values flexibility and reduction in peak demand.

This paper is one of a series looking at the decarbonisation of heat. Regen, in collaboration with industry and key stakeholders will be providing further insight to aid and inform decision making to better shape our net zero future. In particular, we will be examining the extent of flexibility that domestic heat pumps can offer to the electricity system, and how this could be unlocked.

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The right mix of heat pumps will be key

Heat pumps will become a mainstream solution in the coming decade as we strive to decarbonise how we heat our homes.

Limited analysis of the optimal pathway for heat pump deployment has so far been carried out. However, the right technology mix will be key to delivering benefits to households in terms of comfort and overall energy bills and to mitigating the electricity system costs.

Policymakers have assumed ASHPs will remain the dominant technology due to the lower capital cost and the cost and hassle of installing ground infrastructure for GSHP solutions.

GSHPs, however, often offer a lower annual and peak day electricity demand, and the opportunity to boost efficiency through use of waste heat. These are significant advantages in the context of the goal set in the Energy White Paper to minimise the costs to the electricity system of the electrification of heat.

For this discussion paper, Regen has examined the system benefits of a greater proportion of GSHPs within a 'high electrification' scenario, where most domestic heat is provided by heat pumps. Technically, GSHPs could make up 80% of the total heat pumps, rather than the 10% often assumed in future energy scenario modelling.

> Analysis of our illustrative 'GSHP growth' scenario suggests that if 40%, rather than 10%, of the millions of to-be installed heat pumps were GSHPs, the GB winter electricity peak demand could be reduced by approximately 10%. Indicative modelling suggests a reduction in peak electricity demand that ranges from less than 1 GW to as much as 7 GW, depending on the modelling assumptions adopted.

More detailed modelling is required to capture the numerous nuances and spatial variants that could affect this figure.

In addition to peak reduction, GSHPs offer additional benefits. As shown in the table on the next page, these benefits are likely to be more highly valued as we move to a smarter, more flexible and high renewables energy system.

GSHP feature	Impact of a more flexible energy system
Higher annual efficiency	Running cost benefit can be increased by flexibility and use of waste heat in shared arrays
Better performance in cold, humid conditions	The UK can often see weather conditions that prove challenging for ASHPs, with high humidity around freezing point causing icing of evaporator coils, reducing output or efficiency. GSHPs are not directly impacted by air temperature or humidity.
Better fit for future flexibility	Markets will reflect the value of flexibility to all aspects of the energy system, reducing peak demand and pressure on electricity networks.

Unlocking the potential for GSHPs

Regen's analysis indicates that, with the right design, up to 80% of all homes could be suitable for a GSHP – and that these could be delivered at a comparable cost to ASHPs.

An important shift in approach to the design of GSHPs is to install shared ground arrays, developed and financed as a new utility similar to the gas or water networks. As with other utilities, householders connected to this common network would then pay an annual connection fee, the equivalent of the gas standing charge.

> **Treating ground arrays as a new utility would allow GSHPs to be deployed where they are best suited, rather than only where property owners are able to make significant investments in long-term infrastructure.**

Due to the smaller current market, GSHPs appear to have greater potential for cost reduction than ASHPs. Given the right support to scale up, the GSHP industry can deliver product improvements and cost reductions that will bring costs into line with ASHPs, allowing the heating system market to offer consumers the choice to install the most appropriate technology.

GSHP feature	Impact of removing barriers to GSHPs
Capital cost	With market scale, costs can reduce to match ASHP costs
Ease of installation/end user convenience	Shared arrays can be connected to without need for consumer capital or their plumber to design the array

> **Regen analysis suggests that this combination of product innovation and market scale could see GSHP appliance costs fall by 50%, leading to a near 40% fall in first-time installation prices.**

Uncertainty and risk

This paper is intended to open a discussion about some of the nuances associated with heat pump deployment, and highlight the scale of some of the potential benefits that could be unlocked by challenging conventional assumptions.

Even a brief review of the published literature on heat pumps yields a wide range of data on performance, cost and network impact. This, coupled with the highly varied building stock and climate in the UK, means that outcomes are likely to vary by building and region so careful consideration needs to be given to deploying the appropriate technology in each instance.

For high level modelling, as described in this paper, a range of reasonable assumptions made around climate, performance and costs can have a significant impact on model outputs. Further work to refine this understanding is critical to optimise the decarbonisation of heat in the UK, and deliver best outcomes for energy networks, our environment and consumer bills.

Recommendations

Whilst the actual mix of heating solutions deployed will be determined by consumer decisions, the current heating market which does not value carbon, or the reduction of peak demand, is dysfunctional. Government needs to work with the sector at this early stage to correct these issues, and ensure that the right solutions are developed for householders, the environment and energy system as a whole. These include technological solutions such as improved heating appliances and controls, as well as strategic spatial energy planning in partnership with local authorities.

Regen recommends that in the Heat and Buildings Strategy the government:

- Commissions analysis of the system to provide a better evidence base on the impacts of different mixes of ASHPs and GSHPs, with a particular focus on: real world heat pump performance; spatial analysis of temperatures and heat demand to understand the significance of peak demand both for National Grid and DNOs; potential for flexibility, to mitigate a proportion of peak day demand
- Uses the current 'Electrification of heat demonstration project' to better understand the comparative network impacts of ground source, air source and shared loop heat pump systems[10]
- Changes the environmental levies on the electricity bill into a carbon levy on electricity, gas and oil bills, based on their carbon impacts
- Ensures the update of the Smart Systems and Flexibility plan incentivises domestic customers to switch their electricity use to off peak times where possible
- Supports the financing and deployment of shared ground arrays as a new utility
- Provides confidence in the scaling up of demand for GSHPs so that UK companies can invest in the opportunities for manufacturing and installation
- Encourages local authorities and regional heat planners to prioritise opportunities for ground source and shared loop heat pump solutions.

Rethinking heat

600k The UK government has committed to installing 600,000 heat pumps a year by 2028

10% Most modelling assumes that only 10% of these heat pumps will be ground source heat pumps (GSHP)

40% BUT… there could be significant benefits if this were increased to 40%

Regen's analysis suggests that supporting the deployment of more GSHPs in a net zero scenario could:

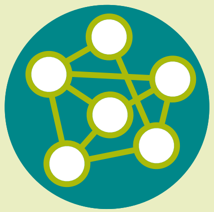
- Unlock new business models that separate the capital cost of the ground array
- Enable 11m more homes (49% of housing) to be suitable for a GSHP
- Make GSHP costs comparable with ASHP, delivering better outcomes for householders

- Reduce peak electricity demand by 10% in a scenario with 20m heat pumps deployed
- Enable running costs to be minimised through flexibility in domestic heat demand
- Support UK manufacturing and develop more jobs in the supply chain

As our energy system evolves to deliver net zero, we are likely to place a higher value on the scale and timing of domestic electricity demand, magnifying some of these benefits

To unlock this potential, Regen is calling for:

Policies that support the finance and deployment of shared ground arrays as a new utility, similar to broadband, water, electricity and gas networks.



A focus in planning policies to prioritise heat pumps using shared ground loops and heat networks.

Reform to enable a more flexible electricity system that incentivises a shift of energy demand away from peak periods.

1 Heat pumps will become part of the mainstream

The UK must achieve net zero carbon dioxide emissions by 2050. Whilst we are making strong progress in some areas, such as decarbonisation of our electricity system[3], there remain significant challenges in achieving this target. One significant challenge remains how to reduce emissions from the heat sector, where emissions are largely generated by millions of small boilers.

Some 37% of the UK's carbon emissions arise from demand for heat, which is predominantly met by burning natural (fossil) gas, releasing CO_2 into the atmosphere; this is not compatible with a net zero world. Whilst in the future some large-scale processes may be able to capture and store CO_2, this will not be the case for domestic and light commercial applications, which account for 60% of annual gas consumption[4].

With an aging building stock, we must deploy energy efficiency measures in our buildings at scale, to lower demand for heat and use those interventions as a once in a lifetime opportunity to improve living conditions, health outcomes and comfort.

However, even with substantial demand reduction through implementing energy efficiency measures, there will still be hundreds of terawatt hours (TWh) of heat to be provided from low carbon sources. There are several pathways to achieve low carbon heat, but it is critical we make strategic decisions based on which solutions are best in the long term, not just the cheapest to install.

Fuel consumption for heat in the UK, 2017

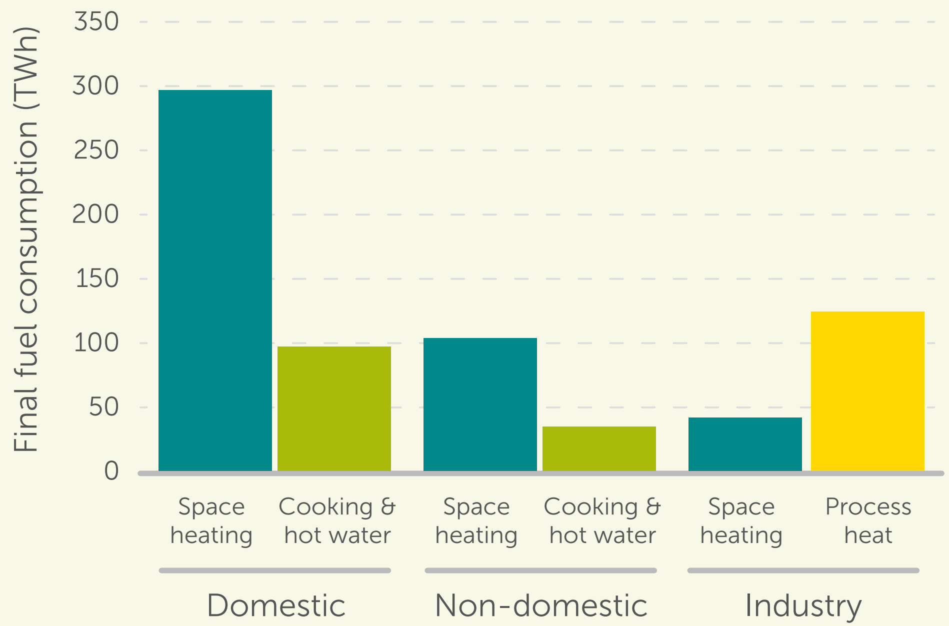


Figure 1. Domestic space heating is the largest single demand for heat in the UK

Low carbon gas role in heating remains uncertain

Efforts are underway to understand the potential for production and delivery of low-carbon networked gases such as hydrogen[5]. However, current government ambition is limited to a single trial town heated by hydrogen by 2030[2]. There is also uncertainty over the volumes that would be available and the end user price of these fuels, which may limit their widespread use in space heating.

More heat pumps are a feature of all scenarios

The recent Energy White Paper set a target to deploy 600,000 heat pumps a year by 2028, 20 times current levels and equivalent to approximately 1/3 of the annual gas boiler market in the UK[1]. The government is due to issue a Heat and Buildings Strategy that will set out the measures designed to enable this target to be met.

Regen analysis (see Figure 3) suggests that to reach these figures, almost all new build homes would have to switch to heat pumps, and at the current rate of replacement of off-gas boilers, householders in some on-gas properties would also need to choose heat pumps when replacing their boiler.

However, at present, most consumers are unlikely to upgrade their properties' fabric and heating, as the policy framework and consequently local supply chains, are skewed heavily towards the incumbent fossil gas industry.

Trajectory of current government heat policy

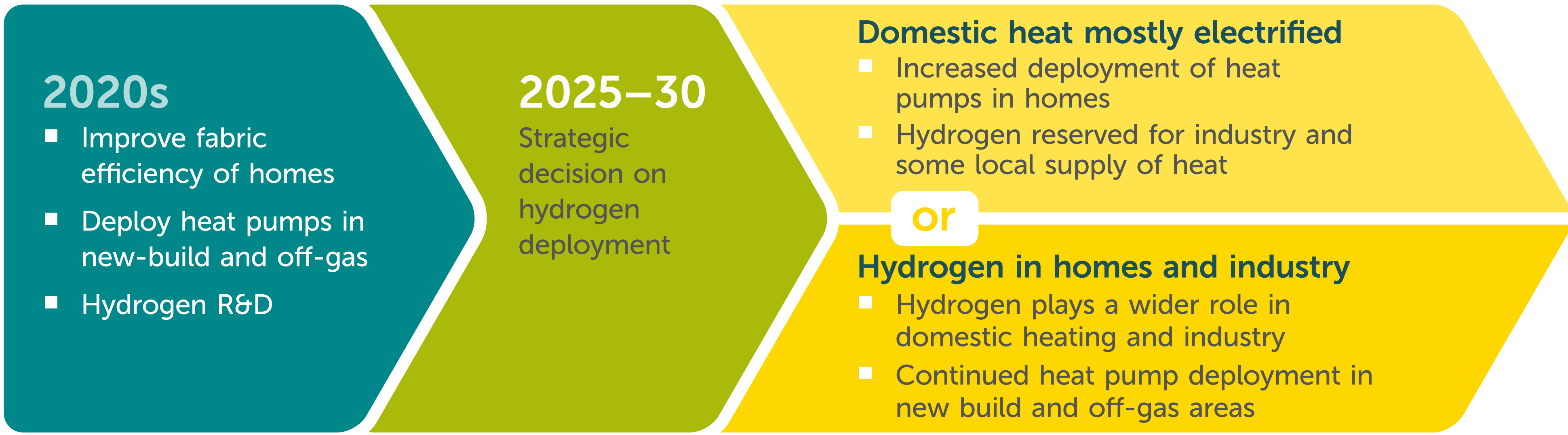


Figure 2. Indications are that a decision on the widespread use of hydrogen for domestic heat may not come until the end of the decade.

Consumer focus

The fact that natural gas can deliver high-powered heat relatively easily and cheaply is acting as a sticking plaster, allowing us to overlook the fact that our building stock is the oldest and least efficient in Europe.

A rapid transition to high volumes of heat pumps creates an opportunity for householders to benefit from improved comfort, as well as engage with new ways of controlling and paying for heat. It also carries a risk of damaging consumer confidence and creating expensive peak demand for our electricity networks, unless the impact is properly understood.

Ultimately, the most successful approaches will be those with the best outcomes for the householder, rather than simply the cheapest or least disruptive. The best value technologies will be those that are future-proofed to take advantage of new variable-led tariffs, onsite battery storage and access to local flexibility markets. Already, the limitations of technology that isn't smart are hampering householders' ability to participate in emerging markets or access certain tariffs. A 'smart-divide' should not be allowed to develop.

It is essential that policy and the supply chain enables the most appropriate technology to be deployed and supports the industry in delivering this, bringing all consumers along with the transition to net zero.

How domestic heat pump installations might increase to 2028

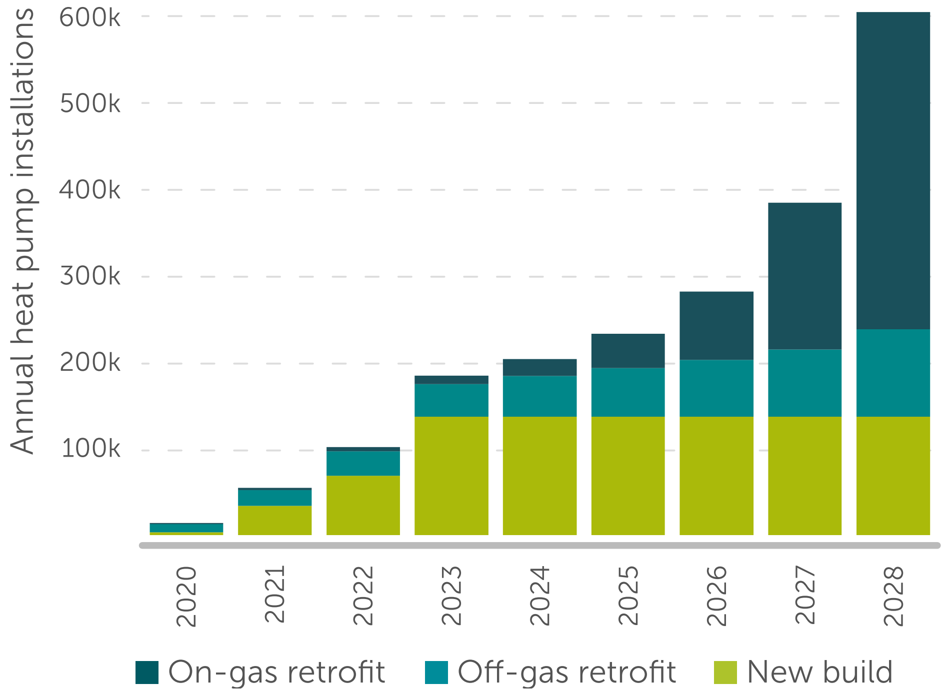


Figure 3. How domestic heat pump installations would need to increase to match the Energy White Paper target, if fossil fuel appliances are replaced at the natural rate

While policy makers grapple with the long-term potential of new technologies such as hydrogen production and carbon capture, use and storage (CCUS), the next decade must see widespread improvement of the fabric of our buildings and replacement of many fossil-fuelled heating systems with heat pumps. New quality standards are currently being embedded in policy to ensure that the right types of energy efficiency measures are correctly applied to buildings. It is essential that policy supporting deployment of heat pumps is equally balanced in delivering the right solutions for consumers, networks and policy makers.

Why the type of heat pump deployed is important

A domestic heat pump extracts heat from the outside air or ground, upgrades this to a useful temperature and transfers it into a heating circuit. For each kWh of electricity consumed, a heat pump will typically deliver 2 – 5 kWh of useful heat, effectively operating at 200% - 500% efficiency most of the time. By comparison, a direct electric heater offers just 1 kWh of heat for 1 kWh of electricity or a gas boiler just 0.9 kWh of heat for 1 kWh of gas.

Typical heat pump configuration

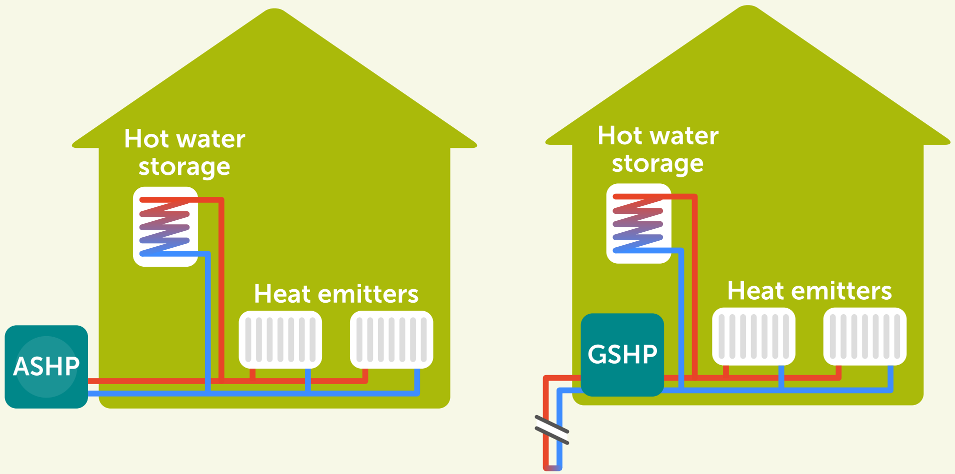


Figure 4. GSHP and ASHP share similar arrangements for hot water storage and heat distribution

The high level of efficiency is the reason that heat pumps are widely expected to deliver the majority of electrified heat, making best use of low carbon electricity generation.

However, the broad range of potential operating efficiencies could threaten consumer confidence if heat pumps that are installed perform poorly.

Air Source Heat Pumps

A typical ASHP consists of an outdoor unit that extracts heat from the surroundings and feeds an indoor heating system. These vary in size and noise generated in proportion with the size of the heat load, with some planning restrictions over unit location and acceptable noise levels[6]. The efficiency of the system is dependent on the external air temperature, operating at highest efficiency on warmer days and lowest efficiency on the coldest days. Ice formation on the outdoor unit occurs at temperatures between 0˚C – 5˚C and high humidity. This can further reduce the performance by up to 20% as defrost cycling occurs, dependent on the specific appliance[7].

Ground Source Heat Pumps

A typical GSHP consists of an indoor appliance that connects an outdoor ground array and the indoor heating system. The ground array is effectively a long loop of water-filled plastic pipe buried horizontally or vertically in the ground; the heat pump extracts heat from the liquid in the array which is then re-warmed by the ground as it is circulated. The efficiency of the system is dependent on the ground temperature, which is typically around 10˚C in the UK, regardless of ambient conditions.* This gives GSHP a higher seasonal and cold day efficiency than ASHP.

Table 1. Example heat pump efficiencies, assuming appliance is sized to meet demand at ambient temperatures as low as -8˚C (average of data provided by a number of manufacturers)

Air temperature and time of year	Coefficient of performance	
	ASHP	GSHP
5˚C October	4.2	4.6
5˚C March	4.2	3.5
0˚C October	3.4	4.6
0˚C March	3.4	3.5
-8˚C October	2.6	4.6
-8˚C March	2.6	3.5

* When a GSHP is installed the ground temperature around the array gradually falls over the course of a heating season, regenerating in the summer months. Strict MCS guidelines are in place in relation to the heat demand and local geology to ensure appropriate sizing and prevent exhaustion of the ground temperature.

Factors that impact performance

As the source temperature decreases, a heat pump has to work harder to deliver heat. A closed-loop ground source heat pump is not impacted by daily temperature changes, but will see slowly declining performance over the course of a heating season as energy is extracted from the ground, recovering in the summer months[8]. Conversely, an air source heat pump will lose efficiency on colder days.

Table 1 gives an indication of typical performance for low temperature heat pumps of both types, highlighting performance at the beginning and end of the heating season to reflect a typical falling ground temperature for a GSHP system. It is worth noting that this is example data taken from manufacturers' specifications, based standardised testing regimes. There is some evidence emerging that questions whether these accurately reflect real world performance of the products. The UK that often has cool, moist days likely to require ASHPs to run defrost cycles, reducing efficiency[9]. A key aim of the current BEIS-funded electrification of heat demonstration project should be to provide clarity on this potentially significant issue[10].

As shown, with milder air temperatures at the end of the heating season when ground temperatures are low an ASHP will typically out-perform a GSHP system. However at lower air temperatures (or higher ground temperatures) GSHPs perform more efficiently and thus make lower demands on the electricity network.

Individual GSHP systems can boost these efficiencies by using the system to provide cooling in the summer, increasing the ground temperature at the start of the heating season. Larger systems that share ground arrays are able to connect to local sources of waste heat to boost system performance all year round.

Past and future GSHP deployment levels

Despite the fact that GSHP typically offer a more efficient, durable and often quieter heat pump solution, they only represent ~10% of the UK market[11]. European markets show that there is much higher potential with GSHPs representing ~20% of the EU market, with significantly higher levels in nations such as Germany and Sweden[12].

Whilst a UK householder would expect a typical GSHP to use less electricity in a normal year than a typical ASHP, with notably lower demand on the coldest days, the current energy market where flat tariffs dominate does not value these differences significantly so in current cost terms these differences are often relatively small[13].*

In addition, the way that costs, disruption and risk for each heat pump type are typically presented leaves GSHPs looking significantly more expensive or challenging. The cost and disruption associated with investing in a private ground array to serve a single dwelling or building represents an obstacle for the majority of householders and indeed domestic heating engineers.†

Future deployment scenarios

In most modelled scenarios for future growth of the heat pump market, the split tends to remain 90% ASHP / 10% GSHP[14,15].

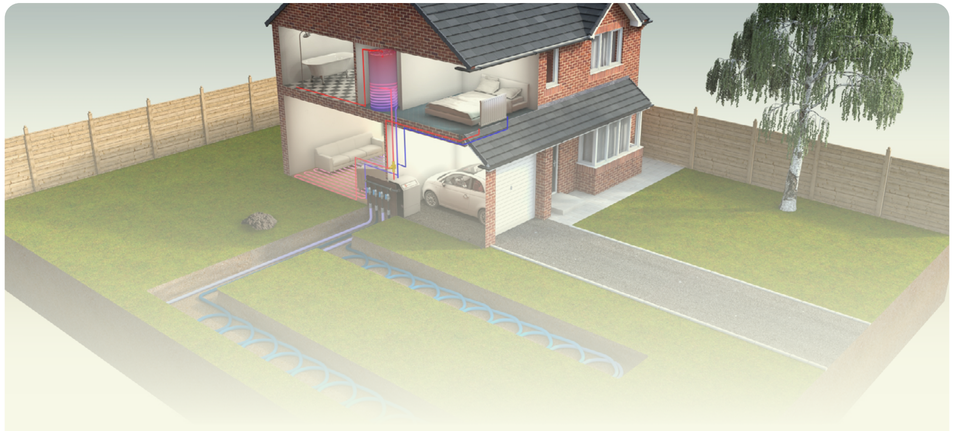
However, future modelling is often based on current deployment rates and traditional benchmarks and continues to reinforce the message to markets that ASHPs will be the dominant technology and GSHPs will remain niche. Emerging business models that use shared ground arrays may change this dramatically, challenging the received wisdom that a GSHP requires a large garden and the additional hassle of developing a private ground array.

* The section *'Providing future proof solutions'* contains discussion of how this is likely to change in the future.

† The section *'New business models to unlock the market'* examines how separating ground array costs from the appliance installation could change this.

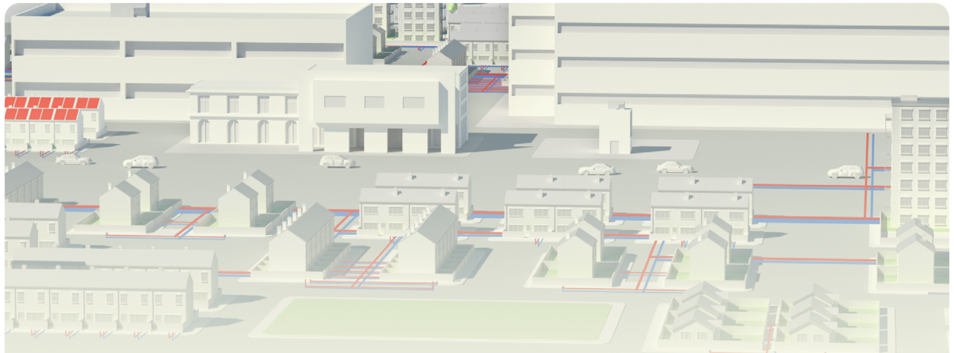
Revised assumptions about how and where GSHPs might be deployed in the future are shown on the following page, these are then used to develop a new growth scenario for the UK GSHP market in the following section of this paper.

Rethinking GSHP deployment modelling assumptions



Typical assumptions currently used in projection or scenario planning

- Marginal efficiency improvement over an ASHP, making GSHPs only relevant in larger buildings with a higher heat load
- High unit cost, risk and disruption associated with installing a private ground array
- Perceived difficulty of siting and delivering the ground array – need for a large garden with access for heavy machinery
- Limited opportunity to reduce costs with volume
- Space within a property



Alternative, more accurate assumptions

- Ground arrays are long-duration infrastructure with a useful life of 30–50 years, lowering replacement unit costs
- If the ground array is costed separately, the cost of a GSHP is similar to an ASHP
- GSHP units have a longer life with lower maintenance due to the lack of exposure to the elements
- ASHPs are vulnerable to high electricity demands on cold humid days and peak days, increasing consumer exposure to future time of use electricity tariffs
- GSHPs efficiency can be increased by taking locally available waste heat into a shared array
- Certain types of GSHPs can provide low cost cooling in summer, serving to either increase winter efficiency or reduce the size of array required

Building a new growth scenario for the GSHP market

Using the updated assumptions outlined in the previous section, and in Appendix 1, Regen has undertaken its own scenario modelling to build an illustrative growth scenario with a higher deployment of GSHPs. This scenario has been used to understand the potential impacts of this different balance in terms of consumer, network and policy outcomes.

One of the core assumptions challenged by our new analysis is the type of property deemed likely to install a GSHP. Much modelling to date has assumed that a GSHP project must be:

- instigated by the property owner,
- capital funded by the property owner, or
- installed in the land owned by the property owner.

Ignoring the potential for shared ground arrays in flats and terraced houses discounts GSHPs as a potentially appropriate solution for 49% of the housing stock in England[16,17]. In fact it could be argued that it would be more challenging to serve these homes by siting an ASHP outside for a terraced house or flat.

The new scenario has been built using English Housing Survey data, breaking down the housing stock by tenure and age band, to reflect different market responses from different tenures and using property age as a proxy for ease of adaptability to low temperature heat sources such as heat pumps[17]. It has been assumed that shared ground array heat pump systems would be unlikely in rural areas or in highly space constrained dwellings (<50m^2).

This initial high-level filtering shows that most housing could be suitable for a shared array GSHP system (see Table 2). This has been used to establish the absolute upper threshold for shared array GSHP deployment.

Table 2. Using shared ground arrays, most housing in England could be suitable for a GSHP

Tenure	% existing housing likely suitable for a shared array GSHP (non-rural and non-space constrained)
Owner occupied	79%
Private rented	81%
Social	74%

Having established the high upper-threshold, a bottom-up model of annual installations was constructed (see Figure 5). The model is based initially on current installation rates, with the future level of uptake then based on a proportion of the annual fossil-fuelled boiler replacement market moving to a shared array GSHP system. These proportions were guided by the high-level scenario assumptions matrix shown in appendix 1, with differing behaviours by tenure and property age.

This illustrative scenario shows near-term strong market growth in the new build and social housing sectors, unlocking the economies of scale and consumer confidence required by the owner occupier and private rented sectors. The scenario results in 8 million domestic GSHP installed by 2050, making up ~40% of all heat pumps deployed and serving ~30% of the housing stock.

GSHP growth scenario modelling

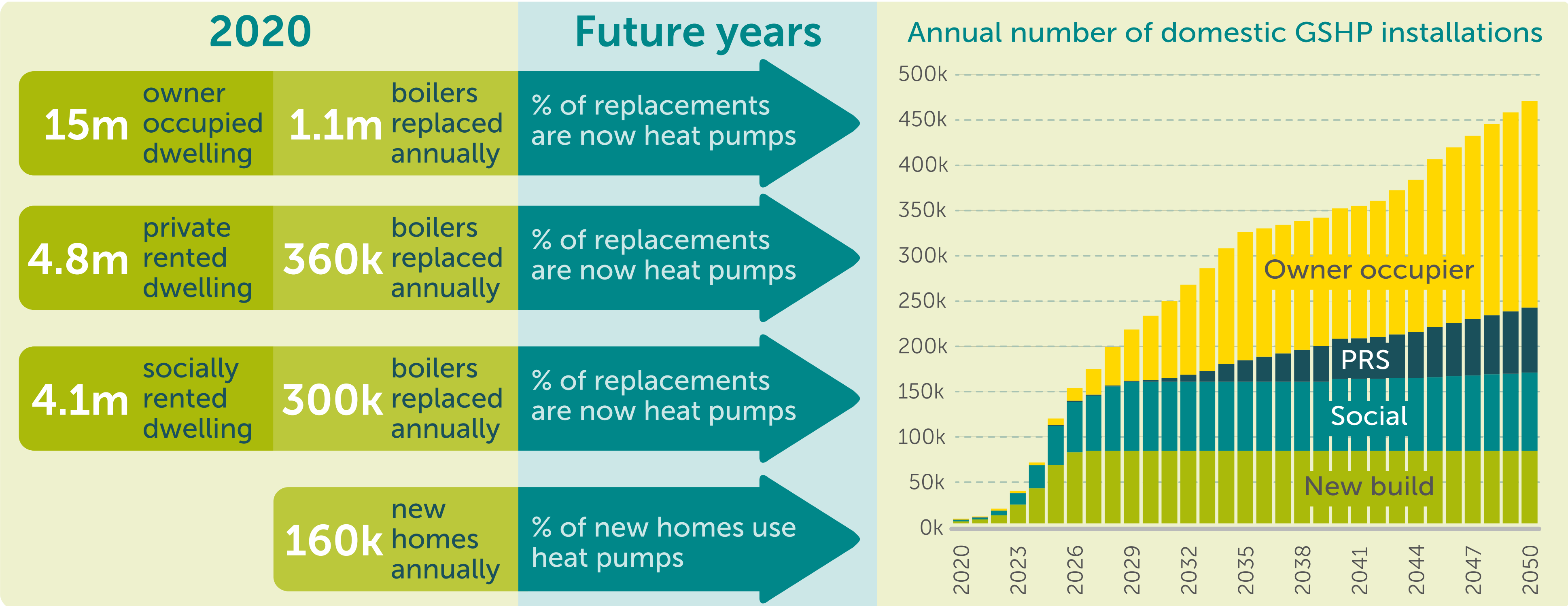


Figure 5. Outline of the modelling approach used to create the Regen 'high GSHP scenario' for this report

As outlined in appendix 1, this scenario sits within a policy context coherent with net zero, the aims outlined by the 2017 Clean Growth Strategy, and the more recent Energy White Paper. The longer-term projections reflect a 'high electrification scenario' in which low carbon hydrogen is too high value to be widely used for domestic heat and consequently domestic heat is largely electrified using heat pumps and heat networks.

The recently published work by the Committee on Climate Change included similar modelling outcomes in their 'balanced pathway' scenario, where GSHPs made up 33% of heat pumps deployed, serving 19% of the domestic stock[18].

Cumulative domestic installations, GSHP growth scenario

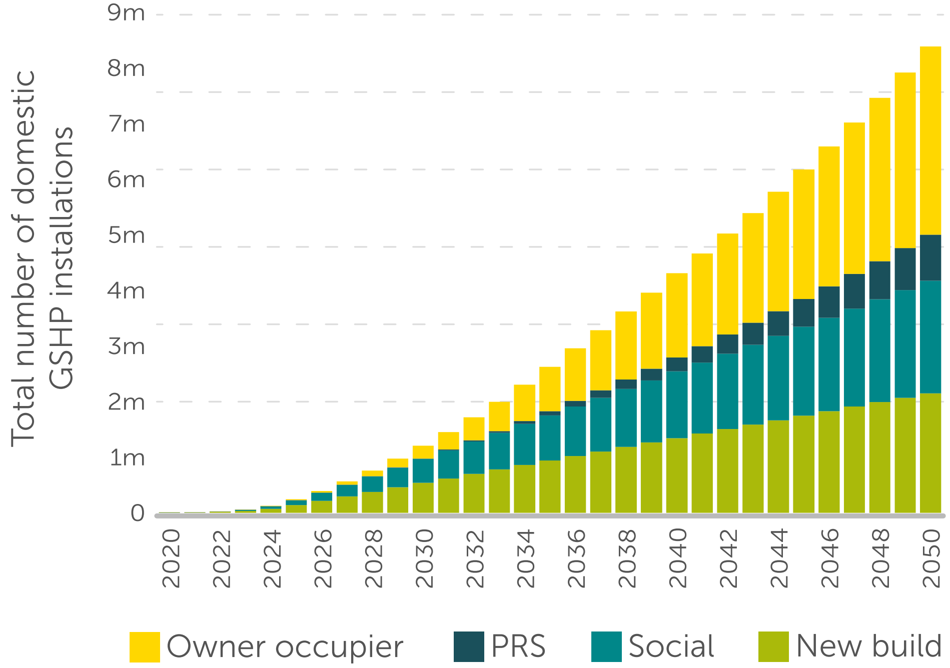


Figure 6. Regen 'GSHP growth scenario' total GSHP installations in GB by tenure

Considering a scenario where ground arrays are a utility that building owners can choose to connect to has allowed traditional assumptions about where a GSHP might be suitable to be revisited. Regen analysis shows that removing the need to own the land in which a ground array is sited could unlock a significant market for this solution. Under this scenario, early adoption would be seen in new housing developments as an alternative to installing a gas network, with social housing providers also investing earlier than owner occupiers.

4 Analysis of network impacts

Any discussion of electrification of heat inevitably leads to a question of peak winter demand and the ability of our existing infrastructure to balance and deliver it. With a potentially larger market for GSHPs identified in the previous section, it is important to understand the network benefits that may result from a larger deployment of GSHPs in GB.

Several studies have sought to model the potential impact that electrification of domestic heat may have on the network, producing estimates ranging through 7.5 GW, 'in excess of 45 GW', to 75 GW additional peak electricity demand[14,19,20,21,22]. Peak demand is, of course, a function of the heat demand of our housing stock as much as the quantity and type of heat pumps installed.

Much of the modelling (both trial-based or theoretical) is not clear on the impact of varying the mix of heat pumps types, or assumptions around the impact of climatic conditions and appliance sizing on heat pump performance on peak days. Given the significant impact that millions of new heat pumps will have on the electricity network and its balancing, it is imperative that more accurate modelling of deployment is undertaken.

Analysis commissioned by BEIS[16] concluded that when considering a '1-in-20 year' winter peak scenario, the current network could support more GSHP installations than ASHPs, primarily due to the ASHP relying more on backup heaters on cold days.

Regen analysis

For this paper, Regen has carried out some illustrative modelling of potential peak demand on a cold winter's day from residential heat pumps. This modelling has used two high-electrification scenarios; one based on typical modelling to date with a low proportion of GSHP, and the other using the 'high GSHP scenario' described in the previous section.

Heat pump deployment scenarios

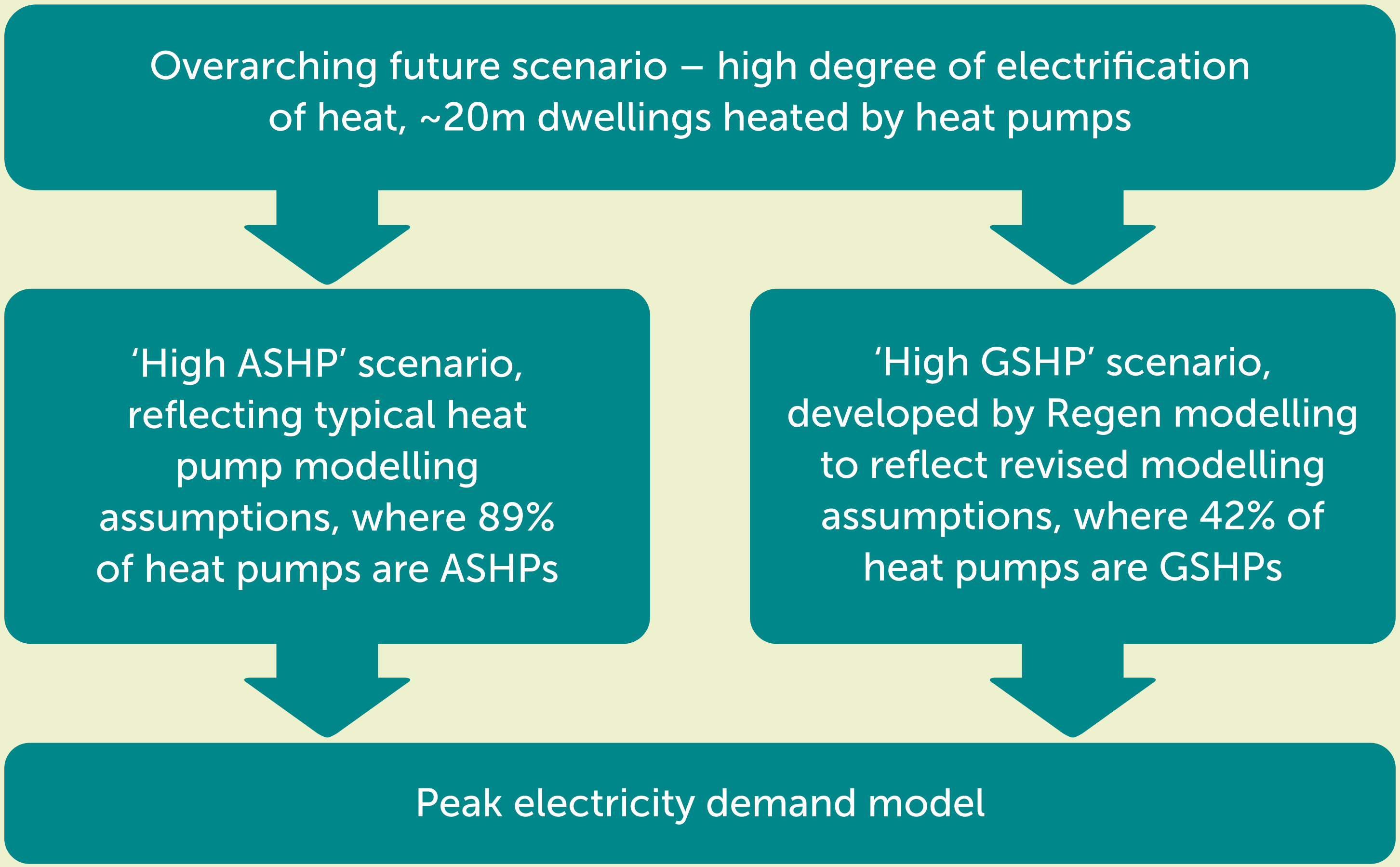


Figure 7. Overview of the two heat pump scenarios developed for this paper

As shown in Figure 8, Regen modelling incorporates typical heat demand profiles[20], a range of temperature profiles, and heat pump performance data related to source temperatures and appliance sizing. This allows a range of scenarios to be assessed and various hourly electricity demand profiles to be generated.

Peak demand modelling approach

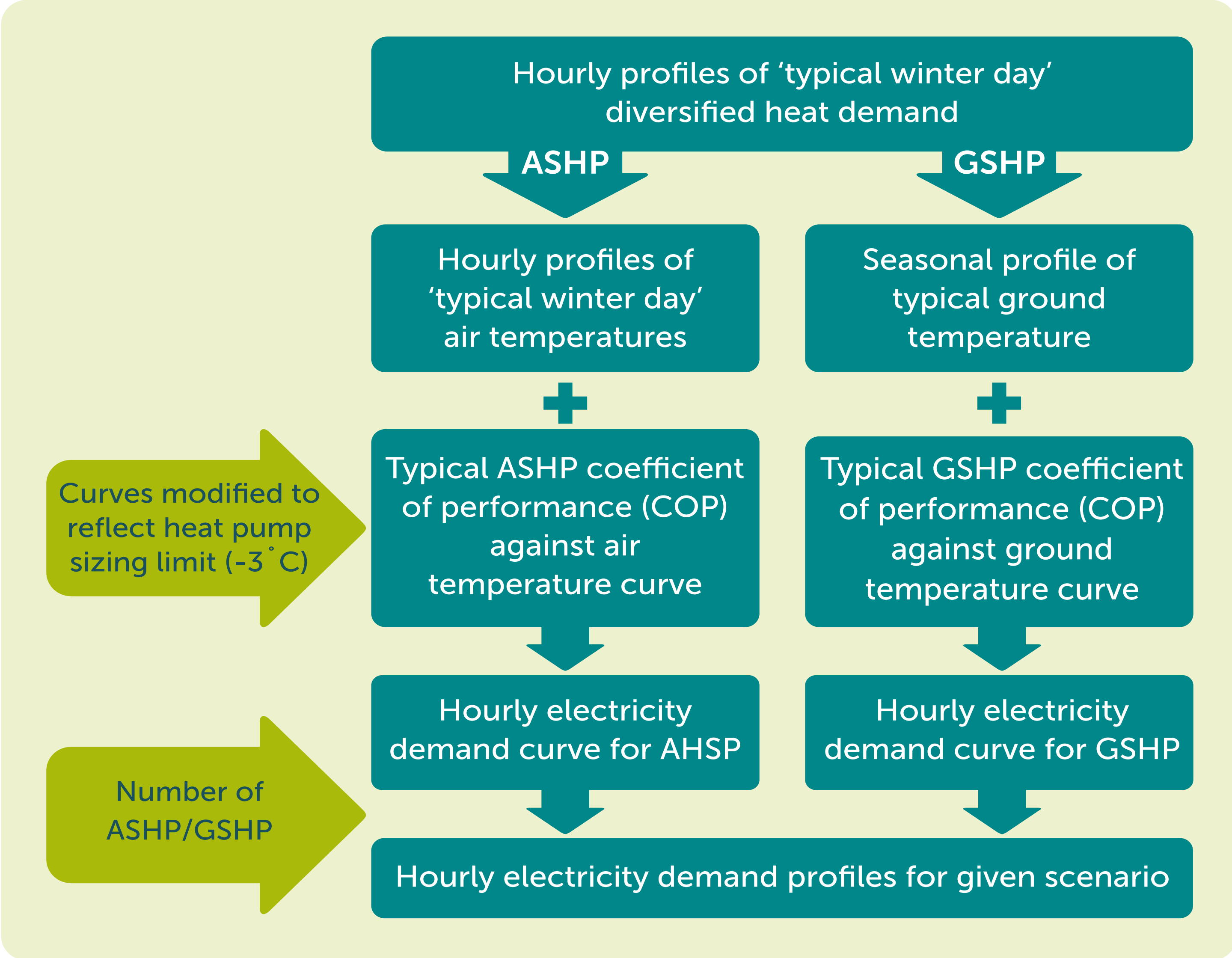
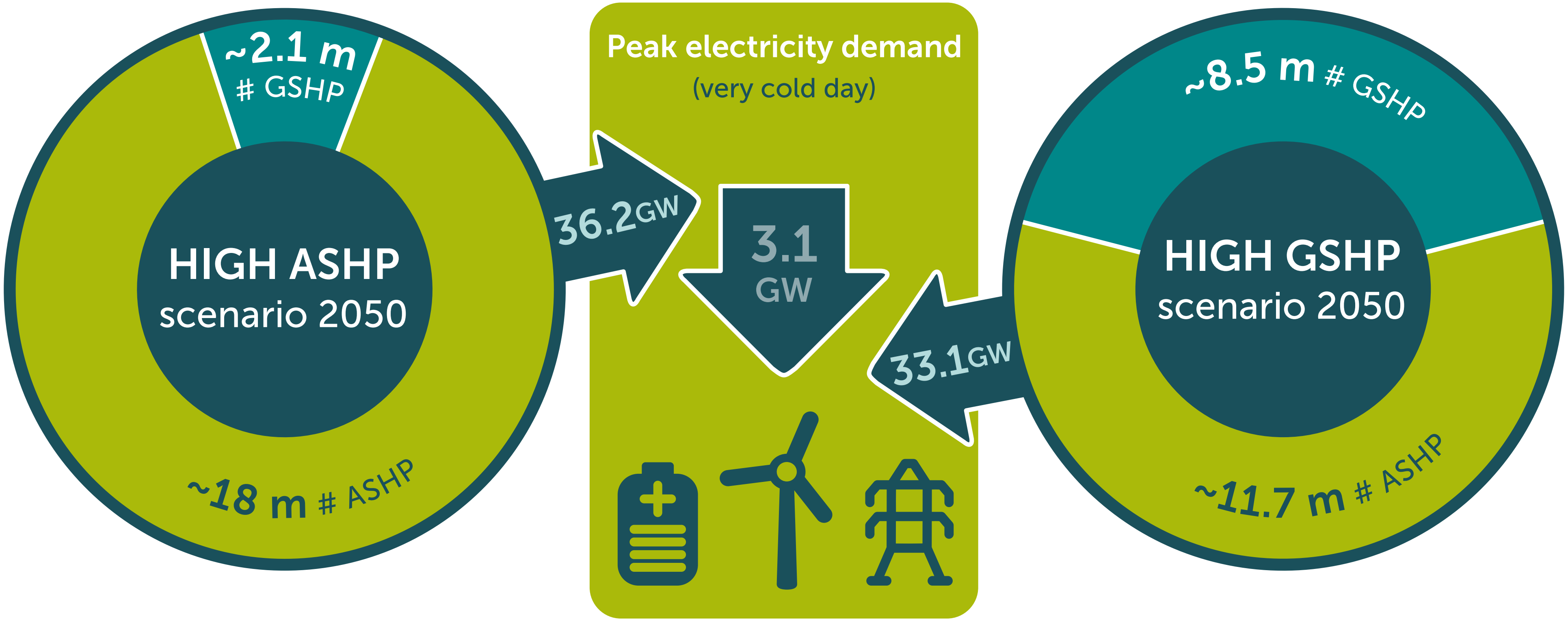


Figure 8. Overview of the approach taken to model peak electricity demand for this paper

Illustrative peak demand modelling outputs



The resulting peak electricity demands on an example very cold day are shown in Figure 9, suggesting that peak demand in this example could be lowered at a scale equivalent to a typical nuclear power station. This illustrative modelling highlights that much more detailed analysis of this peak day demand is required, particularly if considering a more extreme '1-in-20 year' cold winter day that could see these impacts multiplied.

Figure 9. Regen modelling suggests that in a high-heat pump scenario, a higher proportion of GSHPs could reduce peak demand by 3.1 GW

Our recommendations for key areas of analysis that would need further development to understand the full scale of this peak impact would be:

- **Incorporating spatial analysis of temperatures and heat demand to understand the significance both for National Grid and DNOs** – the example very cold winter day assumes uniform national temperatures with the peak demand occurring at 5PM with 0.5˚C air temperature. The reality would be more nuanced and could be more significant during extreme weather scenarios; for example, at 5PM on Feb 28th 2018 (the peak of 'beast from the East') air temperatures were -1.5˚C in Plymouth, -2˚C in Cardiff and -4.2˚C in Glasgow.
- **Determining typical real world heat pump performance.** The modelling presented here has used a selection of available test data, however, as highlighted in previous sections, this may not be reflective of real world performance.
- **There could be significant potential for flexibility in demand, which could mitigate a proportion of this peak** – an area where further work to understand the technical potential, as well as likely consumer uptake, is required.

The future electricity system will deliver a higher volume of energy, potentially lowering the per kWh network costs. However, minimising peak is still important as the cost of dispatchable generation and balancing required to meet this peak difference could ultimately be passed to the consumer as higher electricity bills.

As the UK increases deployment of electrified heat, network operators, industry bodies and regulators are commissioning trials and studies to understand the potential impact. It is crucial that those trials and studies challenge the benchmarks and assumptions used in modelling to date to identify the true costs to householders now and in the future. Approaches that use concepts like 'average winter day' can mask many significant impacts that need to be considered and planned for.

New business models to unlock the market

With the potential for a larger GSHP market and nationally significant benefits identified, business models that could unlock these benefits need to be developed. When installing a single GSHP the installation of the ground infrastructure is a high proportion of the overall system cost and is the principal reason that GSHPs are more expensive per unit when compared to ASHPs.

Since March 2018, GSHP systems that use shared ground arrays have qualified for non-domestic RHI support, stimulating a boost in installations. Industry intelligence suggests that approximately 4,000 GSHP attached to a shared array have been installed under this support in the last two years, indicating market growth of at least 30%.

This early market has developed mainly with social landlords (who are able to take advantage of their role as owners of multiple homes and the adjacent land) but has shown that there is potential for a much larger market, where individual householders need not own a large plot of land in which to install a ground array, and cost and risk can be shared or taken on by a private utility entity.

Social landlords have found that sharing the cost of installing a ground array amongst tens or even hundreds of homes reduces the cost, hassle, and risk per unit, making a GSHP a much more attractive prospect[23].

Figure 10. Flats in Enfield, now served by GSHP and a shared ground array

Up to a point, the more homes that share a ground array, the cheaper the 'per-home' cost, but to achieve equivalent capital costs to an ASHP, the cost of the ground array must be eliminated from the upfront cost paid by the householder or homeowner.

> This can, and is, achieved by considering the ground array as infrastructure, run as a new utility with an ability to attract a revenue stream.

Water, gas, electricity, and heat networks are all considered as separate, long-lived assets that have their costs distributed across all connections by charging for use of the asset. GSHPs using shared arrays should be no different. A shared array can be owned and financed completely separately from the heat pumps in peoples' homes, drastically reducing the deployment cost to each householder and providing a long-term revenue stream to the array owner. It is likely that standing charges for shared GSHP ground arrays would be similar to those for gas or heat networks[24].

Householders already pay for many of their basic services and products by subscription or standing charge. In the case of users already connected to the gas network, the ongoing financial arrangement may be as simple as swapping a gas standing charge for a similar ground array standing charge.

Separating the ground array also significantly reduces the burden on the heating engineer and householder, removing responsibility for the design and installation of an appropriate array, leaving just the task of of sizing and installing the heat pump and emitters.

Regen analysis suggests that replacing the up-front cost of the ground array with a standing charge, in combination with appliance price reductions (see the following section), would bring the typical 30-year total cost of ASHP and GSHP ownership at least to parity.

This would better enable the most appropriate type of heat pump solution to be installed in any given instance, opening up opportunities where either heat pump solution may have proven challenging. One example could be the use of shared ground array GSHP where the installation of individual ASHPs in space or noise constrained areas such as dense urban terraced or high-rise environments would not be possible. Another example may be where there is useful waste heat, but the logistics of household collaboration to utilise this would have proven too burdensome. In this example, a third-party entity could install a shared ground array offering connections to users who would benefit from reduced running costs in comparison to a stand-alone GSHP or ASHP.

Shared GSHP ground arrays are in many ways simpler than heat or gas networks, being almost entirely passive once built. This makes investment in shared ground arrays an attractive, long-term prospect that could open up a significantly larger market for GSHPs. Further, making GSHPs easier to install in some properties could also reduce heating costs for consumers who may not otherwise access the technology, as outlined in the following section.

Additional value through flexibility

The UK energy industry is taking significant steps to migrating our centralised, fossil-fuel led electricity system to a decentralised, more flexible, responsive system that makes the most of all the assets connected to it. As part of this transition, there is the opportunity for domestic consumers to be rewarded for being flexible in how they use energy.

The National Infrastructure Commission has previously estimated that transition to a smart energy system, which would include flexibility in domestic energy demand, could save consumers £8 billion a year by 2030[25]. Progress has been made in a transition to a smarter energy system, and the recent Energy White Paper has committed to publish a new Smart Systems Plan in 2021. However, flexibility provided by domestic consumers is still relatively limited[2].

For a typical domestic property with a heat pump, electricity demand for heating will make up over 50% of the total annual electricity demand*. As such, in a highly electrified scenario, if all the UK domestic heating systems could be finely tuned to ramp up and down in response to price signals tied to electricity carbon intensity and local constraints, then nationwide balancing costs and network reinforcement could be drastically reduced.

Some domestic consumers are already taking advantage of flexible time of use tariffs, using storage to shift their demand to avoid peak times and to minimise running costs[26]. Table 3 shows a modelled example of the reductions in running costs that can currently be achieved by shifting demand on a very cold winter day.

Table 3. Running costs can be significantly reduced by incorporating energy storage so that demand on the network is minimised at peak times.

Example domestic heating system running cost (very cold day)			
Electricity tariff	ASHP	GSHP	Gas
Flat rate	£5.32	£3.81	£4.68
Variable (half hourly time of use)	£3.73	£2.70	£4.68
Variable, with load shifting	£3.32	£2.38	£4.68

* Regen analysis based on OFGEM typical domestic consumption values

Whilst this demonstrates that there is value to the consumer in being flexible, understanding the ongoing annual scale of this value will be essential if homeowners are expected to invest additional capital into storage systems that are both flexible and smart.

Given the potential scale of flexible demand identified in the previous section, it is clear that flexible domestic assets will continue to be of value to the energy system however it is difficult to predict how time of use tariffs will evolve, particularly as larger numbers of consumers adopt them.

Current flexible tariffs offer consumers a way to reduce heat pump running costs and maximise the value of their low carbon heating system. However, a greater level of research is needed into the scale of flexibility that domestic heat pumps could offer, as well as into whether systems such as GSHPs, that do not see reduced performance in cold weather have a greater ability to be flexible and so offer greater value to a net zero energy system.

7 Falling costs with market growth

The costs used in future scenario models can have a huge impact on the numbers of heat pumps expected to be deployed. These costs for a GSHP are based on the current relatively small market, and assumptions about economies of scale /ground arrays that do not represent the potential future market.

Whilst the running cost of a heat pump can be very competitive (in many cases it is similar to that of gas[13]), the high upfront costs (partly due to heat pumps requiring hot water cylinders and additional pipework that the popular combi boilers don't need) can still leave the lifetime costs higher than the gas alternative. This is not helped by current market distortions, where high environmental levy costs push up the price of electricity, whilst virtually no levies are placed on gas, despite a similar or higher carbon impact[27].

With higher lifetime costs and the highly developed and competitive gas boiler market to compete with, it is no surprise that heat pump prices remain relatively high and consumers are reluctant to switch to a relatively unfamiliar, albeit low carbon, alternative[24,28].

However, as shown in Figure 16, there are four areas that could contribute to a significant reduction in the installation cost of GSHP systems, and which should be reflected in scenario modelling moving forward. Two of those (sharing the cost of arrays and subscribing their cost) were considered in the previous section, the further opportunities offered by familiarity with the technology and innovation are covered in the following section.

Potential cost reductions in the GSHP supply chain

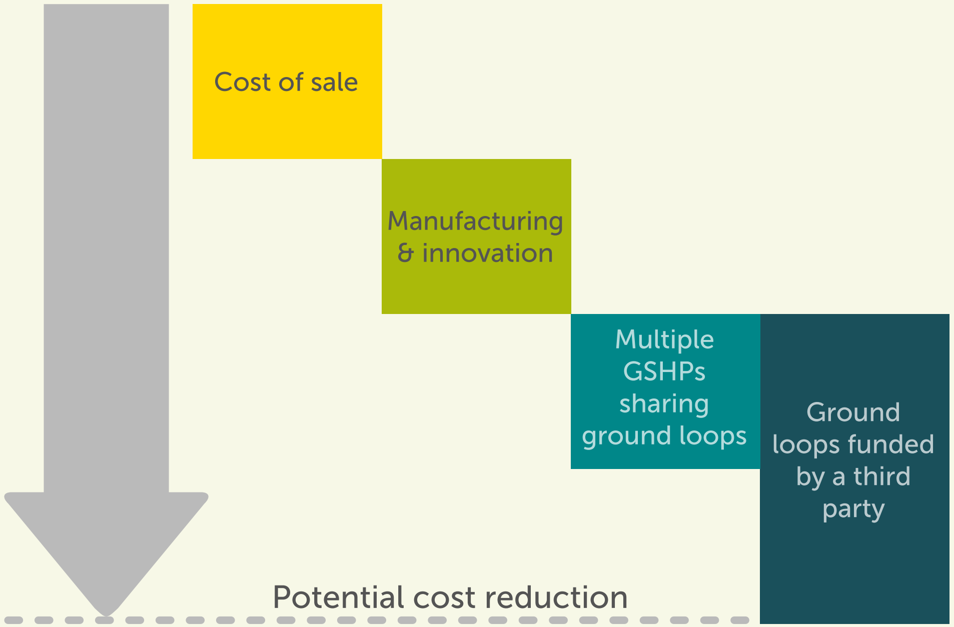


Figure 11. Sources of GSHP cost reduction as the market scales up

Familiarity and the cost of sale

In 2019, domestic gas boilers outsold heat pumps more than 50 times over.

Compared to the well-developed market for domestic gas boilers, the annual market for heat pumps in the UK is still relatively nascent, with 31,000 heat pumps sold in 2019[29] in comparison to gas boiler sales of 1.6 million[30].

A benefit currently enjoyed by the incumbent gas appliance manufacturers is that 130,000 registered gas engineers in the UK are the most trusted source[31] of information for homeowners on changes to their heating systems and they (naturally) largely recommend gas appliances.

Conversely, a relatively niche product such as a heat pump necessitates a margin on each appliance sold, to cover the significant cost of identifying and 'converting' a customer.

As heat pumps become a more familiar technology choice for consumers, mainstream heating installers recommend heat pumps, and traditional boiler wholesalers begin to stock heat pumps, the cost of each heat pump sale will reduce, which can be reflected in appliance costs.

Manufacturing and product innovation

Industry stakeholders that Regen engaged with for this report are generally in agreement with a report produced for DECC in 2016[32] that reported that labour costs could come down by as much as 50% if the market for heat pumps were to grow significantly.

This represents not only a reduction in installation time brought about by increased workforce efficiency, but also product improvements (unlocked by market scale) that simplify installation processes.

Product innovation in heat pumps is also required, so that installations can be significantly simplified, reducing installation time and improving appeal to heating engineers and consumers alike. Examples would be the development of more integrated, factory-assembled systems that reduce the need for multi-trade site work assembling site specific pipework, pumps, sensors and controls. Whilst these innovations may balance out some savings made in appliance production costs, this approach has been used in many industries to reduce on-site materials and labour costs significantly. Additional benefits are found in the improved quality assurance that off-site assembly and testing can deliver, reducing system commissioning and maintenance issues associated with poor installation practices.

Resulting cost reductions

As has been seen with other low carbon technologies, such as solar PV[33] and offshore wind[34], consistent support for the heat pump market will unlock cost efficiencies in manufacture, sales and installation of heat pumps. Regen analysis suggests that this combination of product innovation and market scale could see GSHP appliance costs fall by 50%, leading to a near 40% fall in first-time installation prices, as shown in Figure 13.

Potential reductions in GSHP installation prices

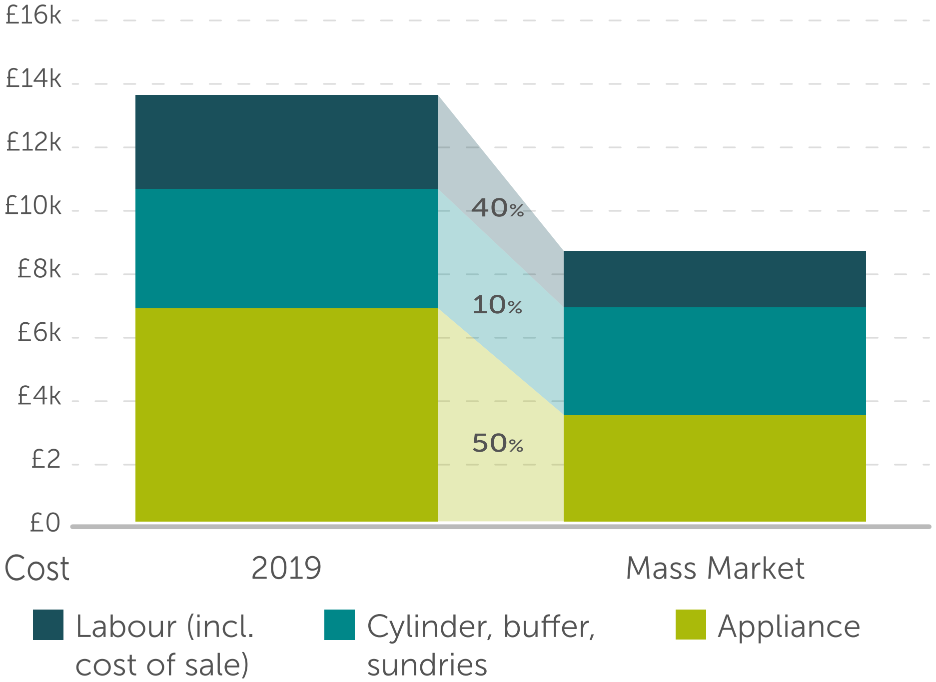


Figure 14. Regen analysis showing current and potential 'mass market' GSHP cost

Potential future cost of domestic heating appliances

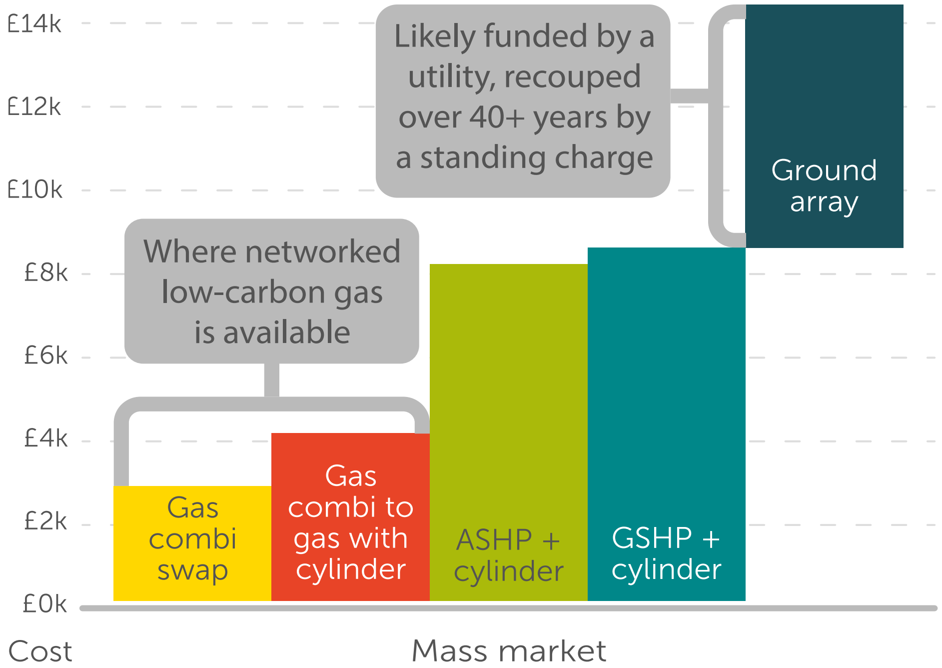


Figure 15. Regen analysis showing potential domestic heating appliance installed prices once a mass market for heat pumps exists

As shown in Figure 13, if the cost reductions outlined in this report are realised, GSHP costs (which have greater potential for reduction) become comparable to those of ASHPs. It is worth noting that even with mass market cost reductions, heat pumps in general remain a higher cost solution than the current cost of a typical gas combi boiler. This cost differential will have to be addressed at some point as part of the UK's decarbonisation journey.

Given the right support to scale up, the GSHP industry can deliver product improvements and cost reductions that will allow consumers the choice to install the most appropriate technology rather than simply the one they can afford. There is also a significant opportunity for UK jobs and manufacturing, as outlined in the following section.

Supporting jobs and UK manufacturing

The UK domestic heating market is dominated by gas fired boilers, with 55% of demand met by boilers manufactured in the UK and 130,000 engineers certified to install and maintain them[15,27]. There is no shortage of competent engineers, and a supply chain that could add heat pumps to their skillset relatively quickly, if the market pull was there incentivising them to do so.

Manufacturing

UK manufacturing produced 10,830 heat pumps in 2019, accounting for 32% of the domestic heat pump market, with the remainder produced in a wide range of other nations[15]. The widespread uptake of heat pumps in the UK would provide an opportunity to build on this manufacturing base and develop more jobs in manufacturing, as well as securing those that already exist in the UK boiler manufacturing industry, where many manufacturers produce both heat pumps and boilers.

Recent research suggests that a number of manufacturers would consider opening new facilities withing the UK, given a growing market supported by clear strategy from government. This could lead to an increase in UK heat pump manufacture to a value of £5.5 bn annually in the next 15 years[15].

Installation

Over the next 10 years, it is estimated that 50,000 heat pump installers will be needed to keep up with demand, compared to the 1,800 currently operating, as shown in Figure 16[35].

Domestic heat pump installers needed

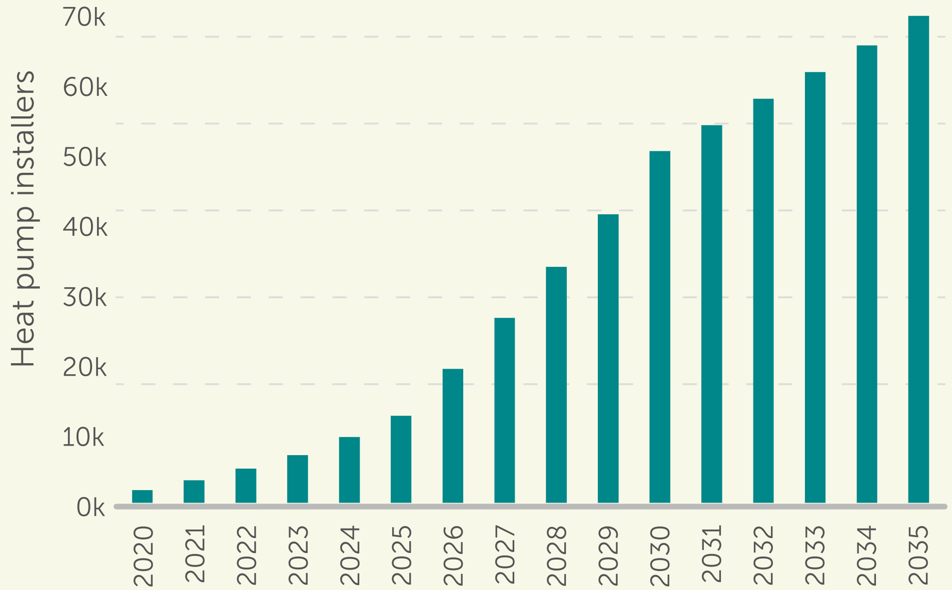


Figure 16. The Heat Pump Association estimates that nearly 70,000 heat pump installers will be needed by 2035

This increase in installer numbers is entirely possible provided the additional training, time and certification costs to sole traders and SMEs (who make up the majority of the installation workforce) are low and there are clear signals of a sustainable pipeline of work. However, there are two areas that would still need to be addressed strategically to support a rapid increase in ground source heat pump installers:

1. Designing and drilling of boreholes

Modern drilling plant is expensive and would require substantial investment from businesses looking to expand operations. However, with sufficient confidence in a pipeline of demand, many existing and new businesses would grasp the opportunity.

2. Appropriate certification and competent persons schemes

There is always much work undertaken with any new incentive scheme or grant by government, local authorities, trade bodies, training providers and others to prepare the ground for a peak in demand and ensure there are qualifications, training courses and support for businesses to become ready. All these things are important and further education colleges and private training providers should certainly be given support to access and deliver heat pump installation courses. But, timing matters.

For businesses to engage with the process of training and upskilling, the first step is for them to have confidence that the market is going to be long-lived and worth the investment. The demand must come first, signalling to the market to implement the accreditations and standards developed behind the scenes. If there is sufficient 'pull' from the market, suppliers will invest to meet the requirements.

The downside of that is lag. The purpose of encouraging businesses to invest in skills ahead of demand is so that when the market floodgates open there is a supply chain ready and waiting to deliver. Sadly, too many initiatives have now asked SME installers to invest in additional qualifications and not delivered a long-term pipeline of work. Government and skills providers must recognise this in relation to the deployment of low carbon heating technology and trust that if demand is strong, the supply chain will quickly engage.

A growing heat pump market offers a significant opportunity to secure UK jobs in existing specialisms such as heating appliance manufacture and installation. In addition, there is potential for the development of new jobs in UK manufacturing, provided that clear policies that indicate a stable growing market are put into place. A higher proportion of GSHPs in the mix could further open this opportunity out to a greater range of suppliers, including borehole designers and drilling companies.

Appendix 1: Regen GSHP growth scenario model assumptions and drivers

	2020-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050	% of tenure using shared array GSHP by 2050
GSHP market	Relatively small market served by a handful of manufacturers and specialist heating engineers	As annual sales exceed 100k units, economies of scale begin to reduce manufacturing costs	Rapid market growth to over 300k units sees further reduction in product, installation and ground array costs as regional supply chains develop	Market matures and regional supply chains are strenghtened, product development delivers innovative solutions for better consumer experience and to enable ease of installation			N/A
All tenures	Electricity prices fall slightly as evironmental levies are restructured. Continued support for shared arrays, similar to RHI	Energy efficient retrofit market growing. Retail price of gas increases based on carbon content, heat pumps cheaper to run than gas in most cases. Government aim for 600k heat pump installations annually by 2028	Energy efficient retrofit market scales to mass engagement. Retail price of fossil gas continues to increase based on carbon content	Energy efficient retrofit market can cost-effectively treat pre 1945 buildings. Retail price of fossil gas continues to increase based on carbon content			29%
New build	2025 fossil fuel ban and Future Homes Standard due	Separate financing for shared ground arrays becomes available, 50% of new build use a shared array. Shared array rather than gas connection is standard for 50% of new builds					43%
Social housing	Uptake grows in post-1960s stock, driven by fuel poverty and gas removal aims	Separate financing for shared ground arrays becomes available, combined with continued energy efficiency retrofit allows continued growth in post-1945 stock			Uptake in pre-1945 stock as it is made more energy efficient		50%
Private rented			Uptake in buildings with communal heating as shared arrays become more common	Continued growth in post-1945 stock as consumer confidence grows	Uptake in pre-1945 stock as it is made more energy efficient		17%
Owner occupier		Utilities entities finance and develop shared arrays for household connection, driving some uptake in post-1945 stock	Continued growth in post-1945 stock as consumer confidence grows		Uptake in pre-1945 stock as it is made more energy efficient		22%

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Click the reference numbers to go back to the respective page.

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