Department for
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& Industrial Strategy

HEAT PUMP MANUFACTURING SUPPLY CHAIN RESEARCH PROJECT

FINAL REPORT

Research carried out by Eunomia Research & Consulting Ltd on behalf of the Department for Business, Energy and Industrial Strategy

November 2020

TOGETHER FOR OUR PLANET

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Disclaimer

The views expressed in this report are those of the authors, not necessarily those of the Department for Business, Energy & Industrial Strategy (nor do they reflect Government policy).

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List of Acronyms

ASHP – Air source heat pump

ATA – Air to air

ATW – Air to water

BSRIA – UK Building Services Research and Information Association

CAGR – Compound annual growth rate

CCC – The UK Committee on Climate Change

COP – Coefficient of performance

EHPA – European Heat Pump Association

EINA – UK's Energy Innovation Needs Assessment

F-gas – Fluorinated gas

GMI – Global Markets Insights

GSHP – Ground source heat pump

GTW – Ground to water

GWP – Global warming potential

HFC – Hydrofluorocarbons

HVAC – Heating, ventilation, and air conditioning

IEA – International Energy Agency

MCS – Microgeneration Certification Scheme

RHI – Renewable Heat Incentive

WSHP – Water source heat pump

WTW – Water to water

List of Definitions

Air source heat pump	A heat pump that extracts heat from the air.
Air to air heat pump	A heat pump that extracts heat from air and delivers heat in the form of warm air.
Air to water heat pump	A heat pump that extracts heat from air and delivers heat in the form of warm water.
Coefficient of performance	The ratio of thermal energy output to electrical energy input.
Ground source heat pump	A heat pump that extracts heat from the ground.
Ground to water heat pump	A heat pump that extracts heat from the ground and delivers heat in the form of warm water.
Heat pump	A machine that uses a small amount of electrical energy to transfer a greater amount of thermal energy from a heat source to a heat sink, or vice versa.
Hybrid heat pump	A single heating unit combining a traditional fossil fuel boiler with a renewable system, such as an ATW or GTW heat pump. It will automatically switch between the two energy sources using the most efficient at the time.
Hybrid system	A heating system comprised of a heat pump and a traditional fossil fuel boiler, connected in parallel, with a control system to optimise heating system performance.
Hydronic heat pump	Any heat pump that delivers heat in the form of warm water. Hydronic heat pumps can be air, ground, or water source.
Monobloc system	An ASHP in which the entire refrigeration cycle is contained within one unit (usually located outdoors).
Split system	An ASHP in which the refrigeration cycle is split between an indoor and outdoor unit, connected by piping.
Water source heat pump	A heat pump that extracts heat from water.
Water to water heat pump	A heat pump that extracts heat from water and delivers heat in the form of warm water.
Refrigerant	A heat transfer fluid with a boiling point and latent heat of vaporisation chosen to match the thermodynamic characteristics of the unit and its duty cycle.
F-Gas	Fluorinated gases are a group of manmade chemicals that contain fluorine and are commonly used as refrigerants.
Tier 1 manufacturing	The manufacture and assembly of components to produce a final heat pump product.
Tier 2 manufacturing	The manufacturing of heat pump components.

Contents

Executive Summary

The Department for Business, Energy and Industrial Strategy (BEIS) has commissioned Eunomia Research & Consulting Ltd (Eunomia) to research the practical steps needed to grow the UK heat pump manufacturing supply chain. This report contains the findings of research into the existing supply chain and heat pump market, and the risks to and opportunities for growth. The potential for growth of the heat pump market was based on BEIS estimates of potential growth in the deployment of heat pumps in the domestic and non-domestic sectors. Alongside a literature review, the findings in this report were supported by interviews with organisations involved in the manufacture of heat pumps and an online workshop, held with a range of businesses throughout the supply chain.

Background

The greenhouse gas emissions associated with heating domestic and non-domestic buildings (excluding industry) were responsible for 23% of the UK's emissions in 2016.[1] Natural gas has been the predominant fuel used to heat the UK building stock, however, if the UK's target of net-zero greenhouse gas emissions by 2050 is to be achieved, then it is unlikely that natural gas will have a significant role. There are several technologies that could play an important role in decarbonising the heat sector. These include low carbon heat networks, heat pumps, hydrogen and biogas. Given the diversity of heat demand, no single technology is likely to be suitable for all buildings; instead, the UK is likely to require a mix to decarbonise the heating sector. It is therefore critical that the risks, opportunities, barriers, and drivers associated with all of these technologies be understood. Heat pumps already play a role in heat decarbonisation and facilitated by the decarbonisation of the electricity grid, are likely to play an increasing role in the future decarbonisation of the UK heating sector. An important step in an optimal roll-out of this technology will be understanding the potential for growth of the UK heat pump manufacturing supply chain.

Aims

This research sought to investigate the current heat pump manufacturing supply chain in the UK, to better understand how to unlock the potential of heat pumps as a low-carbon heating technology and increase heat pump manufacturing in the UK. The research was focused on the following research questions:

- What are the risks and opportunities for the UK heat pump supply chain?
- How fast can the UK heat pump manufacturing sector and supply chain grow?
- What is the role of government in supporting a thriving UK heat pump manufacturing sector?

[1] Department for Business, Energy & Industrial Strategy (2018) Clean Growth - Transforming Heating: Overview of Current Evidence, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf

Methodology

The following overall methods were used to answer the research questions:

- Desk-based research was carried out to capture and synthesise existing information on supply chains in the UK, build an initial evidence base, and inform the questions for the subsequent manufacturer interviews.
- A supply chain mapping exercise developed a picture of Tier 1 (heat pump product) and Tier 2 (heat pump components) suppliers and manufacturers in the UK heat pump market, their products, and their relative market shares.
- UK based and international manufacturers of heat pumps, boilers and other related technologies were interviewed to provide insights not covered in the literature, including (but not limited to) the opportunities for and barriers to the growth of the UK heat pump manufacturing industry and information to support the development of growth rate scenarios to show the potential for UK manufacture.
- Overall market growth and change in market shares were forecast, based on illustrative scenarios provided by BEIS. The Compound Annual Growth Rate (CAGR) was calculated for each of the scenarios.
- The results were validated in a workshop with manufacturers and heat pump trade associations (hosted online due to the COVID-19 pandemic); reasons for agreement and disagreement with the conclusions drawn were discussed further.
- Finally, all evidence gathered was systematically analysed through a thematic grid analysis and synthesised into this report.

Key Findings

What are the risks and opportunities for the UK heat pump supply chain?

UK Heat Pump Market

The deployment of heat pumps in the UK heating market is currently small relative to the size of the market. Approximately 240,000 heat pumps are operational in the UK in total.[2] [3] This figure is low compared to the 26 million fossil fuel (including oil) boilers estimated to be installed in UK buildings and represents less than 1% of all installed heating systems.[4]

Heat pumps are classified by where they source their heat from (ground, air or water) and whether they distribute heat using warm air or hot water which moves through pipes to radiators or underfloor heating (hydronic). Air source heat pumps (ASHPs) extract heat from the air, ground source heat pumps (GSHPs) extract heat from the ground, and water source heat pumps (WSHPs) extract heat from water. The combination of the source and

[2] Statista UK: number of heat pumps in operation 2013-2018, accessed 23 April 2020, https://www.statista.com/statistics/740491/heat-pumps-in-operation-uk/
[3] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/
[4] Building Services Research and Information Association (BSRIA), BSRIA: Global boiler market heats up as the UK is no Longer the largest market, accessed 17 July 2020, https://www.bsria.com/uk/news/article/global-boiler-market-heats-up-as-the-uk-is-no-longer-the-largest-market/

heat distribution then form the description for the heat pump system, which includes air-to-air (ATA), air-to-water (ATW), ground-to-water (GTW), ground-to-air (GTA), water-to-water (WTW), and water-to-air (WTA). All of these heat pump systems can provide both heating and cooling, however for hydronic systems fan assisted radiators are required.

In the UK, air source heat pumps (ASHPs) account for 87% of units sold, with ground source heat pumps (GSHPs) and water source heat pumps (WSHPs) claiming 9%, and hybrid systems (containing both a heat pump and a traditional fossil boiler in a compact unit) representing the remaining 4% of the market.

Air to air (ATA) units comprise the bulk of the global market. Conversely, almost all heat pumps sold in the UK are hydronic. This is driven by several factors. The UK housing stock is poorly insulated compared to countries with similar climates and as ATA heat pumps require a warm air circulation system to distribute heat they are less effective in poorly insulated houses. The majority of current heating is delivered by water-filled radiators. Traditionally there has been no demand for cooling, where ATA is the dominant technology. In 2019 there were 34,896 hydronic heat pumps (including hybrids) sold in the UK (at a total value of £78 million at manufacturer sales price) — a 24.3% increase on 2018.[5] The majority of these (62%) were replacing existing heating systems (retrofit applications), with the remaining 38% in new-build buildings.

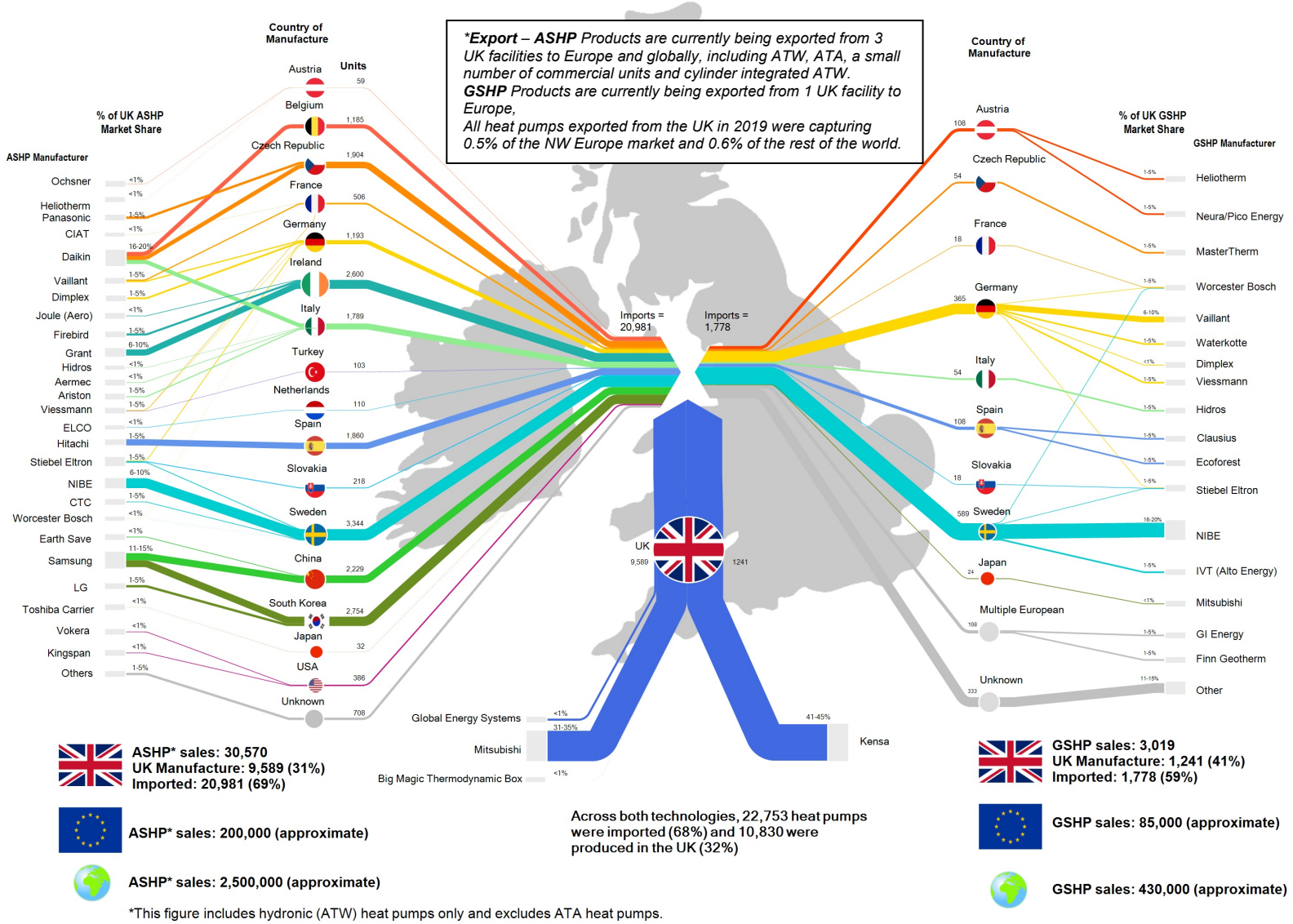
There are two types of air to water (ATW) heat pumps:

- Monobloc systems: all components are contained in a single outdoor unit, in which heat is transferred to the circulating water. Installation is simple and does not require the handling of refrigerants outside of the factory. The monobloc ASHP is functionally very similar to an air conditioning unit as it operates the same refrigeration cycle in reverse; the chassis, the evaporator, compressor, and printed circuit boards are all similar.
- Split systems: these have both outdoor and indoor units. A refrigerant is used to transfer heat between these units, meaning installers must be F-gas qualified to install pipework containing refrigerant—not all installers have this qualification. Because of this extra plumbing, split systems can be installed further from the building, giving more flexibility and opportunity to reduce sight and noise pollution.

Figure E- 1 shows the ASHP (ATW), and GSHP (GTW) markets in the UK, including manufacturers' market shares and units sold in 2019, as well as their country of manufacture.

[5] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/

Figure E- 1: UK 2019 ASHP (left) – ATW and GSHP (right) – GTW Market Shares and Units Sold[6]



*This figure includes hydronic (ATW) heat pumps only and excludes ATA heat pumps.

[6] The ASHP and GSHP parts of the diagram are not to relative scale: the GSHP market is significantly smaller.

ASHP

In general, low-temperature ATW monobloc systems dominate the UK domestic heat pump market (69% of the total 2019 UK market share). There are at least 33 manufacturers that supply the UK with ASHPs, three of which manufacture in the UK (Mitsubishi, Global Energy Systems and Big Magic Thermodynamic Box, accounting for total market share of 32%).[7] The dominance of ASHPs is understood to be greater in the retrofit market. The market is dominated by three large players: Mitsubishi, Daikin, and Samsung who accounted for nearly two-thirds of annual sales in the UK in 2019. The rest of the market is distributed amongst around 30 firms.

GSHP

At least 17 manufacturers compete in the GSHP market; only one of these organisations (Kensa, 41% UK market share) is known to manufacture its heat pumps in the UK. As in the ASHP market, the GSHP market is highly concentrated, with two firms (Kensa and NIBE) accounting for approximately two-thirds of the UK market. There is one company with roughly 6% market share, twelve companies with a 1-5% market share and an unknown number of manufacturers, which make up roughly 11% of the GSHP market in 2019. GSHPs are stronger in the new build market than they are in the retrofit market.

Star Renewables also manufactures large commercial scale WSHPs and ASHPs in the UK (3 commercial units in 2020) primarily serving district heating networks, and exports globally, for example to Norway.

Jobs in the Heat Pump Sector

The heat pump industry supports around 2,000 full-time jobs in the UK, required to build, install and maintain heat pumps in 2019.[8] It is hard to estimate the number of jobs that the industry will support in the future but can be assumed that this figure will increase many-fold if heat pump deployment and UK-based manufacturing increase as forecast.

Similarities Between Boilers and Heat Pumps

Boilers and heat pumps are technologically different but are manufactured from similar raw materials, and hydronic systems have comparable plumbing systems. The UK has an established boiler industry, and after air conditioning manufacturers, traditional boiler companies hold the next largest UK heat pump market share amongst companies that also manufacture other technologies. Fifteen of the manufacturers (who account for around 40% of ASHP units sold) also sell boilers[9]—see Table E-1 for the breakdown of UK market share of key boiler manufacturers. Currently, only Vaillant offer a hybrid heat pump (one unit) to the UK market, however other manufacturers have hybrid products in development for the UK market.

[7] Star Renewables produce large-scale ASHPs, but very few of these are for the UK market. Furthermore, Ground Heat do kit assembly of Heliotherm heat pumps in the UK but are not included in this figure.
[8] European Heat Pump Association (2018) EHPA Stats - Country Cards, 2018, http://www.stats.ehpa.org/hp_sales/country_cards/
[9] Nibe, Dimplex, Enertech (CTC), Earth Save, Ecoforest, Daikin, Vaillant, Viessmann, Vokera, Worcester Bosch, Grant, Firebird, Ariston, Elco and Toshiba Carrier.

Table E-1: The market shares of key manufacturers who make both boilers and heat pumps sold in the UK.

Manufacturer	Boiler market share	ASHP market share	GSHP market share
Worcester Bosch	~30%	1-5%	1-5%
Vaillant	~20%	1-5%	6-10%
Ideal	~16%	<1%	-
Baxi	~15%	<1%	-
Viessman	2%	1-5%	1-5%
Vokera	2%	<1%	-

Similarities Between Air Conditioners and Heat Pumps

Heat pumps and air conditioning units require similar components and manufacturing techniques. The majority of heat pumps sold in the UK are imported from Asia (China, South Korea and Japan) and Europe. In such locations heat pumps are often manufactured in the same facilities as air conditioning systems that heat as well as cool, these are primarily ATA systems, and where hydronic heat pumps are responsible for only a small proportion of the factories' overall output. For example, one manufacturer quoted *"on a two-week production cycle, so maybe nine days out of ten there would be air conditioning on the production line, and on one day in that two-week cycle, they'll (the factory) change tooling over and manufacture heat pumps, I'd be surprised if any of our competitors are different to that."* These facilities have the potential to increase shifts on the hydronic heat pump production line.

Increasing UK Heat Pump Deployment

The future level of deployment of heat pumps and other low carbon heating technologies is currently uncertain. The Committee on Climate Change (CCC) modelled heat pump deployment under a pathway where the UK reaches net zero carbon emissions by 2050, finding that in one scenario—involving both electrification of heat and deployment of hydrogen gas networks—19 million heat pumps would need to be deployed in existing homes (excluding new build) by 2050.[10] It was ascertained in interviews with manufacturers that reaching this indicative figure is not considered to present any significant difficulties across the global industry in terms of manufacturing capacity.

Manufacturers were very confident that they could increase supply into the UK market, through both import and domestic manufacture, by a minimum of 25-30% year on year for the next 15 years. Year-on-year increases in the range required have been achieved before, albeit not consistently for many years, or decades as required now. However, the

[10] Committee on Climate Change (2019) Net Zero Technical Report, May 2019, https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-Technical-report-CCC.pdf

extent to which this demand could be met from domestically based manufacturing is less clear.

Location of Manufacture

Manufacturers would consider opening manufacturing facilities in the UK given a significant increase in demand that would give greater certainty of a return on investment. What would constitute a significant increase in demand however, varied from one manufacturer to the next, but would be based on economic calculations in the context of their own, and competitors' facilities in the UK and overseas.

Demand alone would not be enough for all interviewees to begin manufacturing in the UK—mainly just those with existing UK manufacturing facilities. The following were identified as key aspects to making the UK attractive to heat pump manufacturing:

- clear strategy and commitment from government, including future policy that is consistent and designed for the long-term, not short term, and providing clarity on the need for heat pumps;
- stable regulatory system;
- placing additional standards and quality requirements on heat pumps being installed in the UK, however this should be carefully thought out to avoid making heat pumps uncompetitive;
- lower-cost space for manufacturing through tax-breaks, start-up grants or interest-free loans, which could offset set-up costs to make the UK more competitive with other European countries, and support for up-skilling and re-skilling; and
- innovation funding to focus on areas identified with added value to the UK, such as smart control systems to facilitate demand-side response and management, efficient use of hybrid heat pumps, improved performance monitoring, increasing heat pump output temperature (and therefore lowering the overall cost of equipment like new radiators) or greater integration with other low-carbon technologies.

The decision to manufacture in the UK would in each case be based on economic calculations. However, consistently the most important single factor identified by manufacturers in deciding whether manufacturing would take place in the UK was confidence in the long-term demand supported by long-term policy (i.e. longer than the electoral cycle).

Those manufacturers that have large factories, or made a recent investment in Asia or Europe were more negative in their views on the prospect of establishing UK manufacturing facilities in the short to medium term (e.g. 1-10 years). The size and efficiency of these manufacturing facilities act as limiting factors in shifting manufacturing to the UK, as new UK manufacturing capacity would have to compete with large, efficient and established facilities.

Those that were already manufacturing in the UK (including both heat pump-only and boiler- and heat pump manufacturers), or less tied into existing international facilities, were more positive about the ability to expand or introduce manufacturing in the UK in the short to medium term. It is worth noting that at present these manufacturers generally represented a smaller share of the current UK heat pump market, however are expected to, and intend on, increasing their market shares going forward.

For those that saw increased manufacturing in the UK as an opportunity, the cost of manufacture was ultimately a major contributing factor. There is a tipping point at which the additional cost per unit—the marginal cost—associated with manufacturing in the UK (including the investment in new manufacturing facilities) was lower than the shipping, export and import costs per unit, which on average were about 6-12% of each unit's cost. Improved shipping and delivery times would also be a key driver for UK manufacture if demand were to increase substantially.

Heat Pump Components

The majority of heat pump components are sourced from outside the UK. The exception to this is compressors where one UK manufacturer–Emerson Copeland, Northern Ireland, serves a large proportion of the UK heat pump market.

Several factors drive the location of manufacture beyond the UK. Currently, there is not enough Tier 1 (i.e. heat pump) manufacturing demand in the UK to support local Tier 2 (i.e. components) manufacturing. Manufacturing hubs have also developed around the concentration of specialist expertise often based around the original location of companies that have grown to dominate the market. Furthermore, manufacturers of these components also serve several other markets—heating, cooling, ventilation, air conditioning—so growth in heat pump manufacturing may not be sufficient to stimulate re-location. European and Asian manufacturers have the volume required to justify investment in automation and other efficiency technologies. Respondents suggested that this divergence has become so entrenched that it would be effectively impossible to establish large-scale manufacturing in the UK for specialised Tier 2 components as the markets for components are all international, and have been developing in the absence of the UK for so long, the barrier to entry would now be prohibitive. However this was not seen as a determining factor in the growth of UK Tier 1 manufacturing, for example the UK has an established boiler industry, but a less evident skilled Tier 2 component supply chain, as most boiler components are manufactured outside the UK and then assembled in the UK.

Current supply chain arrangements would therefore likely persist in the short to medium term if there was little growth in the deployment of heat pumps. Components would continue to be sourced from businesses that specialise in their manufacture, regardless of where they may be located globally. Heat Pump manufacturers suggested that if the UK Tier 1 heat pump manufacturing industry grew substantially in line with a scenario where 19 million heat pumps were deployed in homes by 2050 then establishing UK manufacturing of some Tier 2 components would be more likely.

As with the establishment of heat pump manufacturing itself in the UK, long-term market predictability is the key to economic decisions to onshore component manufacturing. This effect is already seen among those manufacturers who do have an established presence in the UK (e.g. Kensa or Mitsubishi), where the proportion of components sourced locally has increased significantly with growing demand, as local businesses develop capacity.

As noted above, many components are not specific to heat pumps, and sourcing is closely linked to related industries such as boiler, air conditioning, and refrigeration manufacturing. Key components of both heat pumps and air conditioners include:

- Compressors - Compressor design and manufacture is a specialised industry and has become dominated by a small number of global suppliers (e.g. Danfoss, Bitzer, Emerson Copeland, Mitsubishi). Some of the larger electronics manufacturers such as Hitachi and Daikin also manufacture their own compressors. One slight concern raised by some tier 1 manufacturers in the interviews was the ability of compressor

manufacturers to scale up production volumes if there was a rapid increase in global demand, given the small number of manufacturers. However, if a market prevails then manufacturers in countries such as China may look to produce compressors for heat pump applications. Respondents also noted that even the most ambitious increase in heat pump deployment in the UK would hardly be noticed in the context of international production levels, so this risk would not be created by UK policy alone.

- Refrigerants - The refrigerant manufacturing industry (dominated by China and the USA) is an obvious beneficiary of the potential expansion of heat pump deployment. More importantly for the UK is the innovation, research and development around refrigerants, which presents a valuable opportunity, as opposed to manufacture itself. Driven by EU F-gas regulation, there has recently been a move away from synthetic refrigerants with high global warming potential (GWP) to natural refrigerants, such as carbon dioxide and propane. These require higher pressures to work, which can lead to higher manufacturing costs, however, they are cheaper so lead to lower materials costs and they have proven popular among customers wishing to eliminate high-GWP refrigerants. Propane is also able to work efficiently at higher temperatures, allowing the efficient generation of hot water. In the UK, deployment of propane-based heat pumps in all buildings is constrained by legislation restricting the amount of compressed propane that is permitted inside buildings.

- Smart control systems - There is a growing demand for the deployment of smart control systems (particularly where hybrid systems are employed, for example in a combined boiler and heat pump system). Heating systems are not only becoming more sophisticated in their own right, but they are also becoming more connected, allowing installed systems to vary their output in response to occupancy and usage patterns, weather forecasting, grid carbon intensity, time-of-use tariffs, connected devices, and other factors. The UK is at the forefront of developments in energy technology markets, and has made some progress with key technologies such as smart metering; this opens up the potential for differentiation of the proposed UK heat pump deployment programme through the development of novel business models such as “heat as a service,” whereby ownership of the physical equipment is retained by the energy company, who sells the service of heat to the consumer. This is being explored as a business model by manufacturers and energy companies at present.

- Certain key heat pump components are also common to other heating and cooling applications, including heat exchangers, fans, pumps, housings, expansion tanks, and (non-smart) control systems. These are generally less specialised and distributed among a wider range of companies worldwide.

- The components accounting for significant portions of the total value of a heat pump are the compressor (~25%), the electronic controls (~25%), the heat exchanger (~15%), housing (~13%), valves (~10%), fan (~5%), pipework (~2%) and refrigerant (~2%).

Skills, Challenges and Opportunities for UK Heat Pump Manufacturing

F-gas Certified Installers – Monobloc Manufacturing

A potential shortfall in F-gas certified installation engineers in the UK (of which there are currently ~50,000) could have an impact on the type of ASHP deployed, and their rate of deployment. This is likely if significant heat pump growth takes place in the short term. Split systems, in particular, have indoor and outdoor components and their installation requires F-gas certified installation engineers. Monobloc systems are sealed units, so installation does not require F-gas certified installation engineers.

Without a promotion of training, there could be an under-capacity in F-gas certified installation engineers in the short to medium term, which could benefit the deployment of monoblocs over split systems. Historically split systems are on average more efficient than monoblocs. If monoblocs are the heat pump type of choice in the UK, the development of more efficient monoblocs could be an area of UK specific R&D.

UK Specific Heat Pumps

Several manufacturers highlighted that the UK's housing stock is different from other European countries that have established heat pump markets or which have seen recent industry growth. For example, Scandinavian countries have substantially higher heat pump deployment rates because they historically have better insulated homes, which are more suitable for heat pumps. There may be the need for bespoke UK heat pump designs to accommodate smaller, often older properties with poor insulation and a high-temperature differential between outdoor and distribution temperatures. Other factors also come in to play, for example, GSHPs may require reinforced boreholes, suitable for clay and soft material.

Cooling is also becoming more of a requirement in certain locations in the UK. This may act as an additional driver for heat pump systems that can provide both heating and cooling.

Several manufacturers commented that if a bespoke specification was required for the UK, it would help drive local production, largely because it would reduce the competitive advantage of mass production facilities in Asia.

Boiler Manufacturers

55% of the UK demand for boilers is met through domestic manufacturing.[11] The UK workforce for boilers and radiators manufacturing is around 6,000 people.[12] The UK boiler manufacturing workforce has a complementary skillset to those in heat pump manufacturing. Transferring the boiler manufacturing workforce to making heat pumps is critical both for safeguarding UK employment and harnessing existing skills. Whilst the technology is different, many of the engineering and component assembly processes are similar (except for pipe brazing and the handling of refrigerant, which are specific processes associated with heat pumps). The consensus from stakeholders interviewed suggested that if a transition from gas boilers to heat pump manufacture in the UK occurs, the workforce would also be in a good position to transition in parallel. The boiler

[11] Building Services Research and Information Association (BSRIA) (2020) Domestic boilers market analysis - United Kingdom, April 2020, https://www.bsria.com/uk/market-intelligence/market-reports/heating/domestic_boilers/

[12] IBISWorld (2020), Radiator & Boiler Manufacturing in the UK - Market Research Report, Jan 2020, available at: https://www.ibisworld.com/united-kingdom/market-research-reports/radiator-boiler-manufacturing-industry/

manufacturers felt that in the short term their industry would remain relatively stable, especially while wholesale gas prices remain stable and lower than electricity (per unit of heat supplied). Furthermore, the boiler manufacturers are large organisations with heat pump product offerings and would simply follow market demand.

Hybrid Heat Pumps

Hybrid heat pumps typically include both a heat pump and a gas or oil boiler, as well as a control system to control their relative outputs based on the outside temperature. Hybrids were regularly discussed during the interviews, with a number of the manufacturers producing gas/oil boiler hybrid heat pumps, whilst developing other forms of hybrid systems such as hybrid hydrogen boiler/ heat pump systems or hybrid heat pumps with heat recovery.

Traditional gas/oil boiler and heat pump hybrid systems were seen by some interviewees as possibly posing a risk by 'locking in' dependency on fossil fuels and thus slowing the rate of decarbonisation. In contrast, a number of interviewees highlighted that hybrids could act as a 'bridging technology' that allows the benefits of heat pumps to be realised sooner, particularly in retrofit programmes where achieving high levels of insulation (and therefore reduced energy demand) are challenging.

For the gas and oil boiler manufacturing sector (which already offers hybrids), the uptake of hybrids could slow the rate of transition to stand-alone heat pumps, allowing the manufacturing of boilers and their spare parts, as well as the demand for maintenance services, to decline at a slower rate.

How fast could the UK heat pump supply chain grow?

A total of three illustrative scenarios (agreed by BEIS) were examined in the research.[13] Each scenario had a different target demand for heat pump sales at 5-year intervals, determined as follows:

- **A low growth rate scenario**. This represents a very modest growth in the annual deployment of heat pumps to 2025 (~268,000), at which point the market is forecast to reach a steady state.
- **A medium growth rate scenario**. This represents strong growth in the annual deployment of heat pumps between 2020 (~32,000) and 2035 (~1,071,400). This scenario represents approximately two-thirds of gas and oil boiler replacements—being heat pumps by 2035; and
- **A high growth rate scenario**. This represents rapid growth in the annual deployment of heat pumps between 2020 (~32,000) and 2035 (~1,714,300). This scenario would result in almost all gas and oil replacements being heat pumps from 2035 onwards.

Manufacturers emphasised in interviews that they would be able to respond and supply in any eventuality to all three deployment scenarios, with no obvious or significant supply limitations or bottlenecks. It was noted by manufacturers that the availability of refrigerant and compressor manufacturing could limit the most rapid expansion, but overall, no real concern has been raised over the future resource availability for the materials required for

[13] These scenarios are entirely indicative and were used for the purposes of examining the effect that different future deployment scenarios would have on UK manufacture, amongst other things. They do not reflect BEIS or UK Government policy.

heat pump components. The consensus was that global production capacity would not be a limiting factor in achieving growth scenarios; this included the CCC recommended deployment rate of over 1 million heat pumps per year by 2035, as well as the high growth rate scenario of 1.7 million by 2035.

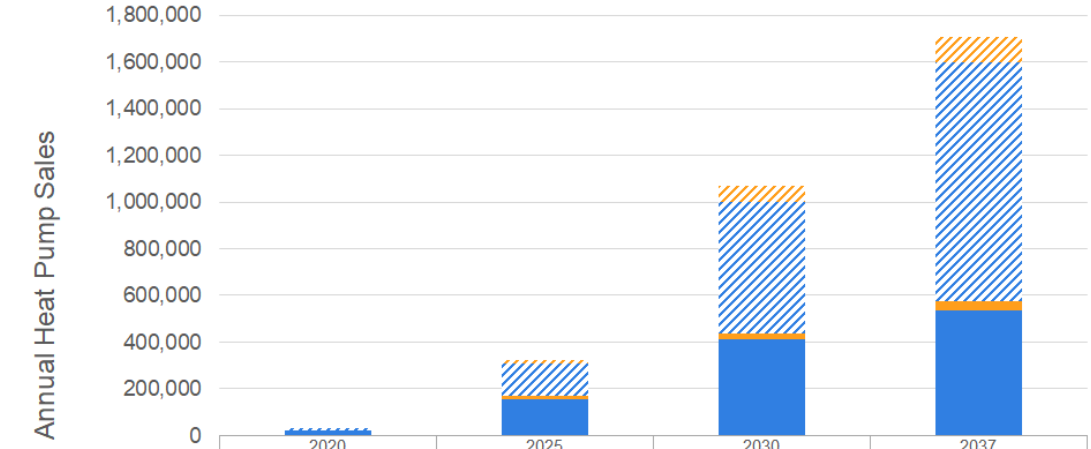
Imports vs Domestic Manufacture

There is currently a high reliance on heat pump imports in the UK. To meet future demand, it is anticipated that there will continue to be a high reliance on imports, in particular for ASHPs. There is a large international manufacturing capacity that can easily meet any envisaged growth in UK demand. Even if rapid growth takes place across several countries, manufacturers forecast potential markets for growth so they can direct investment into their facilities to cope with the increased demand across several countries at the same time.

Some stakeholders suggested that in all scenarios the majority of heat pumps would likely continue to be imported. Particularly in the highest-demand cases where some manufacturers believed that under this scenario import would gain more market share than present levels to deal with increased demand, with the cost of manufacturing in the UK being cited as too high for some organisations at present.

The UK manufactured an estimated 31% of the ASHP units and 41% of GSHPs units installed nationally in 2019; overall, 32% of heat pumps installed nationally were manufactured in the UK. Currently, only Mitsubishi, Kensa, Global Energy Systems, Big Magic Thermodynamic Box, Star Renewables (industrial ammonia heat pumps), and Ground Heat (kit assembly of heat pumps made by Heliotherm) are manufacturing in the UK. However, interviewees suggested that there is much scope for UK production volumes to increase: manufacturing in the UK is feasible, would be beneficial to the UK economy and can be scaled-up quite quickly. Figure E-2 shows the breakdown between potential domestic manufacture of heat pumps and imports under a high growth scenario.

Figure E-2: UK Heat Pump Manufacture vs Import - High Growth Scenario



	2020	2025	2030	2037
Total	32,000	321,000	1,071,000	1,714,000
UK Manufacture	11,000	151,000	636,000	1,139,000
Imports	21,000	170,000	436,000	575,000
% Import	66	53	41	34
% UK Manufacture	34	47	59	66
UK Manufacture - GSHPs	1,000	13,000	73,000	117,000
UK Manufacture - ASHPs	10,000	138,000	563,000	1,022,000
Imports - GSHPs	2,000	16,000	23,000	37,000
Imports - ASHPs	20,000	154,000	412,000	538,000

Note: Individual Figures have been rounded to the nearest thousand, and therefore may not add up to the totals provided.

Many of the manufacturers provided an estimate of the number of annual unit sales required to move their production to the UK. This number varied significantly between manufacturers and had a direct relationship with the scale of their current annual production volumes. When asked how quickly facilities could be established, some manufacturers stated that, given sufficient demand, new UK-based manufacturing could be introduced relatively quickly (some saying this could be achieved in less than 12 months, some saying a couple of years).

Many UK-based gas boiler manufacturers also offer heat pumps, and there appears to be potential for reconfiguring and transitioning current UK boiler manufacturing facilities to concurrent heat pump and boiler manufacture on different assembly lines. A couple of manufacturers are also in the process of developing hybrids, and hydrogen-ready boilers. Manufacture of any combination of these in the same facility is possible and would be developed depending on forecast demand as a result of policy.

Relatively few potential challenges were identified for rapid UK manufacturing growth. Two of note that were raised were as follows:

- There may be a short-term need for skilling up the workforce to handle refrigerants and for the shaping and brazing of pipework, a skill that is not easily automated (these are not seen as limiting factors to industry growth in the medium-long term). Refrigerant handling in the manufacturing process requires F-gas (Category 1) certification, which is a 4-day course costing £910+VAT.[14] Individuals with these skills could come from other sectors like air conditioning manufacture in the case of refrigerants, and the automotive industry for shaping and brazing.

- There is uncertainty surrounding the EU-exit and the transition period, and it is unclear whether the supply of labour used during peak manufacturing demand could be limited. Theoretically, this labour demand could be met locally.

Table E-2 shows an estimate of the value added to the UK economy in terms of the product value from heat pumps in the three illustrative BEIS scenarios (Low, Medium, High) for UK manufactured products. This is based on Eunomia's analysis of the potential for UK manufacture based on feedback received from manufacturers through interviews. Under the high scenario, there is the opportunity for 5.5 billion pounds of the product value to be met by UK manufactured products, meaning that income would be coming into the UK rather than going outside of the UK where heat pumps are manufactured abroad. Furthermore, this figure does not include exported units which could further increase this benefit to the UK economy.

[14] PPL Training (2020) F-Gas (Category 1) | City & Guilds 2079-11 (FCAT1), accessed July 2020, available at https://www.ppltraining.co.uk/training-course/mechanical-and-electrical-technical/f-gas/f-gas-category-1-city-and-guilds-2079

Table E-2: Estimated product value of heat pumps (both total and those manufactured in the UK) under the low, medium and high scenarios[15][16]

	Low Scenario		Medium Scenario		High Scenario	
Product Value	**Value (£m)**	**Value (£m) – UK manu.**	**Value (£m)**	**Value (£m) – UK manu.**	**Value (£m)**	**Value (£m's) – UK manu.**
2019	170	60	170	60	170	60
2035	1,550	850	5,140	3,100	8,220	5,510

UK Export Potential

Based on interviews with UK based manufacturers, it is understood that collectively the UK is exporting heat pumps to Europe and the rest of the world (including ATA, ATW and GTW). This is currently generating a substantial amount of GVA per annum.[17] The Energy Innovation Needs Assessment (EINA) report produced for BEIS (when the UK's 2050 emissions reductions target was 80% and the Net Zero target had not yet been implemented) found that a Gross Value Added (GVA) from exporting heat pumps and related technologies could feasibly be £500 million by 2050 (based on 210,000 heat pumps and 3,000 commercial HVAC systems), in a future where the UK captures about 10% of the EU's market. Given this assessment of the value of export from UK manufactured heat pumps, there is a demonstrable ability for UK manufacturers to capture the economic benefit of exporting heat pumps.

UK heat pump products are currently being exported across Europe, in particular to France, the Netherlands and the Republic of Ireland, as well as to countries further afield such as New Zealand. Some UK-based related sectors are already exporting other products, such as boilers and heating, ventilation and air conditioning (HVAC) units; if the UK can grow the domestic capability and market, by attracting inward investment into the UK, then there may be greater export opportunities in the future.

The consensus from manufacturers was that currently the products manufactured in the UK can be tailored relatively easily to be suitable for different countries; UK manufacturing covers many different technology variants including both monobloc and split ASHPs and GSHPs. If UK production increased, this would present an opportunity for UK facilities to increase their share of the international market. Whilst it is unlikely that the UK will penetrate the already well-served Asian market, Europe presents a key opportunity. If UK-

[15] This is based in real terms 2020 product value figures for ASHP's of £3,500-£6,500 and GSHP's of £7,000- £10,000 - provided in the report - BEIS (2020), The Cost of Installing Heating Measures in Domestic Properties, accessed October 2020, available at https://www.gov.uk/government/publications/cost-of-installing-heating-measures-in-domestic-properties

[16] All totals have been rounded to the nearest £10 million, to account for any uncertainties in the 2020 product value figures.

[17] Exact figures not disclosed due to confidentiality concerns.

specific heat pump designs or specifications were adopted, these might need adaptation to meet the needs of other countries' climatic and housing stock conditions.

Several manufacturers also highlighted that the UK has a strong reputation for manufacturing quality products—especially boilers—and they thought this could also be a unique selling point for UK manufactured heat pumps. It is recognised amongst manufacturers that having a 'Made in the UK' product badge will support an increased international market share with the quality association that this brings.

Manufacturers often raised the uncertainty associated with the impacts of the UK's future trading arrangements with EU and non-EU countries, a fundamental factor in any investment decisions in UK manufacture. This relates to moving manufacturing to the UK, importing materials, and exporting manufactured goods. The complexities of the heat pump supply chain, including the reliance on imported materials from Tier 2 manufacturers, could mean that it is more exposed than other sectors. The implications of the availability of skilled labour were also raised but were less of a concern than import and export tariffs.

1) Introduction

In January 2020, the Department for Business, Energy and Industrial Strategy (BEIS) commissioned Eunomia Research & Consulting Ltd (Eunomia) to research the practical steps needed to grow the UK heat pump manufacturing supply chain (including hybrid heat pumps). The research considers synergies with other industries and the possibility of building on the UK's current expertise in the transition away from fossil fuel heating.

Background

For over 50 years, the UK has relied principally on natural gas to heat its buildings and homes. The transition to natural gas from coal fires was seen as a significant triumph for the UK, creating warmer homes, lowering emissions, improving air quality, generating skilled jobs, and creating a world-leading gas boiler manufacturing sector. However, it is increasingly evident that using natural gas (and other fossil fuels) for heating buildings must be completely (or very nearly) phased out as the UK aims to achieve its climate targets.

The greenhouse gas emissions associated with heating domestic and non-domestic buildings (excluding industry) was responsible for 23% of the UK's emissions in 2016. The majority of these heat emissions (17%) come from space heating and cooling, with hot water and cooking making up the remaining 6% of the total.[18] Decarbonising heating will require a fundamental change as the UK transitions away from fossil fuels towards low-carbon energy sources. There are many different pathways that the transition to low-carbon energy sources could follow, with varying reliance on the development of a hydrogen network or electrification of heat with, predominantly, heat pumps in combination with the decarbonisation of electricity production.

However, the economic and social impacts of different technology scenarios remain unclear. In particular, it is unclear how the UK can capture the benefits of the low-carbon heating transition and ensure that the country capitalises on existing expertise in related sectors.

Currently, the deployment of low carbon heating systems including heat pumps and district heat networks is below the level required to meet future carbon budgets. Whilst established in some European countries, the market for heat pumps in the UK is relatively immature, with 83% of domestic space heating currently being gas central heating.

Gas boilers have been the dominant form of heating in homes for several decades because of the extensive gas grid, the efficiency of using gas as a means of space heating, the UK's own gas supply, and the fuel's low cost internationally. As of the beginning of 2020, there are approximately 240,000 heat pumps in operation in the UK.[19] [20] This is a fraction of the total estimated 26 million domestic fossil fuel boilers in

[18] Department for Business, Energy & Industrial Strategy (2018) Clean Growth - Transforming Heating: Overview of Current Evidence, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf, accessed May 2020

[19] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/

[20] Statista UK: number of heat pumps in operation 2013-2018, accessed 23 April 2020, https://www.statista.com/statistics/740491/heat-pumps-in-operation-uk/

operation, and is orders of magnitude below the levels of deployment that will be needed in the context of meeting net zero targets.[21]

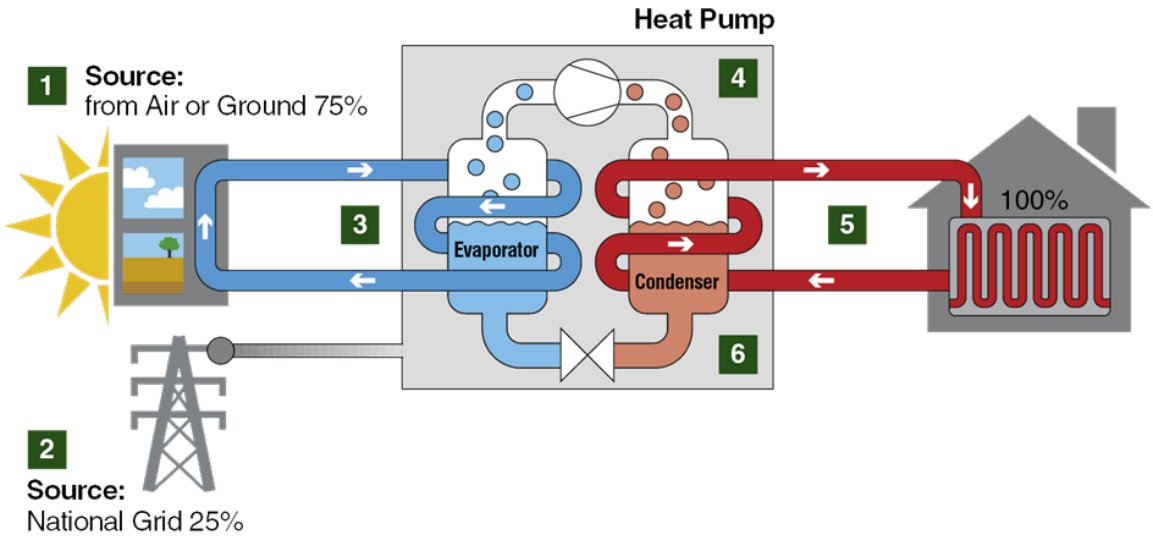
Heat pumps account for a very small proportion of new space heating installations in the UK, with around 34,896 new units (including hybrids) in 2019 in comparison to the volume of the UK boiler market (1.7 million units a year).[22]

Heat Pump Technologies

Heat pumps use electricity to transfer heat from the environment into a building, as shown in Figure 1-1.

- Energy from the environment (air, ground or water) is the primary input to the system (1).
- Cold liquid refrigerant is heated with the energy from (1) in the evaporator (3).
- The gas from the evaporator is compressed (4) using energy from the electricity grid (2), increasing its temperature further.
- This heat is then transferred to the building through a heat exchanger and water flowing through radiators or underfloor heating (5). For an air output heat pump, heat is delivered to the building via warm air.
- The now cooled, condensed high-pressure liquid refrigerant is returned to the evaporator through a restriction that reduces its pressure and thus boiling point (6).
- The low-pressure liquid is then boiled off in the evaporator because its boiling point is now below that of the ambient heat source.

Figure 1-1: A diagram showing how a hydronic heat pump works



Source: https://www.dimplex.co.uk/professional/heat-pumps

[21] Building Services Research and Information Association (BSRIA) (2017) Global boiler market heats up as the UK is no longer the largest market, accessed 15 April 2020, https://www.bsria.com/uk/news/article/global-boiler-market-heats-up-as-the-uk-is-no-longer-the-largest-market/

[22] Ibid

Heat pumps can be categorised by where they source their heat from (ground, air or water) and whether they distribute heat using warm air or hot water. Air source heat pumps (ASHPs) extract heat from the air, ground source heat pumps (GSHPs) extract heat from the ground, and water source heat pumps (WSHPs) extract heat from water. A heat pump that heats water is called 'hydronic'. Hydronic heat pumps can be used for both water and space heating (via radiators or underfloor heating), whereas heat pumps which distribute heat using warm air can only be used for space heating. This is summarised in Table 1-1 below.

Table 1-1: Heat Pump Categories

	Heat extracted from air (ASHP)	Heat extracted from ground (GSHP)	Heat extracted from water (WSHP)
Hydronic (i.e. heat transferred to a building via water in radiators or underfloor heating)	Air to water (ATW) Monobloc Split	Ground to water (GTW)	Water to water (WTW)
Air output (i.e. heat transferred to a building via air ducts)	Air to air (ATA) Monobloc Split	Ground to air (GTA)	Water to air (WTA)

A compressor, which uses electrical energy, is required for heat pumps to extract heat from a source (air, water or ground) which is at a lower temperature than the space they are heating. The amount of electrical energy used by the compressor is less than the heat energy that the heat pump is delivering. The ratio between the heat energy delivered and the electrical input is known as the Coefficient of Performance (COP). For a typical domestic heat pump, the normal range of operation would be a COP of 2-4. Conversely, gas or oil boilers deliver less heat output for each unit of fuel energy input. For example, an average gas condensing boiler has a COP of 0.85.

The COP of a heat pump is highly dependent upon the temperature of the heat source, reducing substantially as the heat source gets colder. This means, for example, that Air Source Heat Pumps (ASHPs) become less efficient as the outside air temperature drops, just at the time when maximum heat is needed. Ground Source Heat Pumps (GSHPs) have a distinct advantage in that the temperature of the ground 0.5 to 1m below the surface remains more or less constant throughout the year and is substantially warmer than air temperatures during the winter. This means that a GSHP can deliver heat more efficiently than an ASHP, particularly when it is most needed. GSHPs typically have a COP of 3.5 to 4.5[23] and ASHPs typically have a COP of 2.5 to 3.5.[24]

[23] Green Match (2020) Boilers vs Heat Pumps, accessed July 2020, available at https://www.greenmatch.co.uk/blog/2015/09/boilers-vs-heat-pumps

[24] Mempuo, Blaise (2014) What is the most effective way to enhance Heat Pumps (ASHP/GSHP) efficiency (COP)?, accessed July 2020, available at https://www.researchgate.net/post/What_is_the_most_effective_way_to_enhance_Heat_Pumps_ASHP_GSHP_efficiency_COP2

Hydronic heat pumps are most relevant to the UK, because they better cater for the UK's existing water-filled radiators and the UK historically has had a minimal need for cooling. Hydronic heat pumps can provide cooling, however require additional system requirements such as fan assisted radiators to do so. Unlike hydronic heat pumps, air output heat pumps can provide both heating and cooling with no additional system requirements and are more common in regions where both are needed.

ASHPs are further broken down into 'monobloc' systems, where the entire refrigeration cycle is contained within one (outdoor) unit, and 'split' systems, where the refrigeration cycle is split between indoor and outdoor units which are connected by piping. Split designs use a cascade of (usually) two heat pump circuits, each with a different refrigerant. Although this would seem to be less efficient than just using a single circuit, the split approach allows the physical properties of the refrigerants to be tuned to their particular roles, so the outside system is optimised for lower temperature operation, absorbing ambient heat, while the inside system is capable of achieving higher temperatures, making it more suitable for heating water or replacing a conventional boiler.

Heat pumps and fossil fuel (e.g. natural gas) boilers can be combined to make an integrated 'hybrid' heating system. On particularly cold days two factors interact: firstly, the demand for heat increases and secondly the COP of the heat pump and its output decreases. Therefore, the purpose of a hybrid system is to use the heat pump to provide heat/hot water under normal ambient temperatures and use another heat source (fossil fuel to 'top-up' the heat on very cold days. This is useful in situations such as retrofit of old houses, where a heat pump may be effective for most of the year but may struggle in extreme temperatures.

There are two fundamental differences between heat pumps and boilers that will affect their suitability and uptake. The first is their physical size – a heat pump is many times bigger than a boiler, requiring outdoor and indoor units (for split systems), and a hot water tank is likely required. The second is that heat pumps work best at low flow temperatures. However, most UK heating systems are designed to deliver the heat needed at much higher flow temperatures as can be delivered by a gas boiler. Heat pumps function best at lower 'delivery' temperatures (i.e. the temperature of the water running through the radiators in the building). This high heat delivery capability combined with the low cost of gas has contributed to the historically poor energy efficiency of the UK's housing stock.

Research Aims

In the context of the need to grow the UK heat pump manufacturing industry, this research study aimed to investigate how quickly the supply of heat pumps can grow to be in line with net-zero targets and remaining carbon budgets, as well as to gain a thorough understanding of the existing market. The major focus of this study is the UK's heat pump Tier 1 (the manufacturing of heat pumps—or assembling of components to produce a final product) and Tier 2 (the manufacturing of the parts used in heat pumps) supply chains, and the supply chains of some other relevant technologies are also studied. Although relevant to the UK's heat pump manufacturing industry (and so some limited commentary is made), the topic of stimulating final demand for heat pumps is outside the scope of this work. The specific aims of this research were as follows:

- To investigate the manufacturing supply and value chains for different sectors of the heat pump and related markets (e.g. gas boilers, refrigeration, air conditioning, ventilation). The installation aspect of the supply chain was out of the scope of this

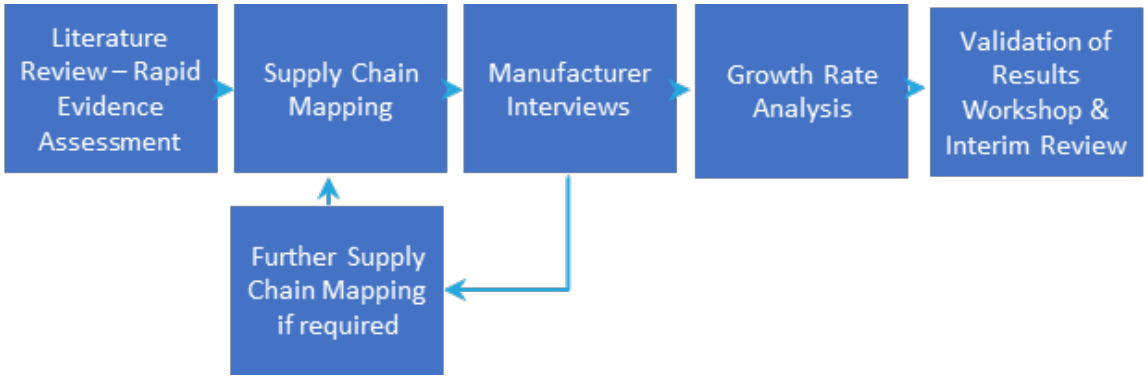
research. However, areas of interaction between manufacturers and installers (e.g. training) were considered.

- To identify where heat pump components are currently manufactured; where in the heating supply chain the UK has particular expertise that could make it internationally competitive; where there are opportunities for innovation; and which aspects of the supply chain would deliver the highest value return on investment, and are therefore deserving of particular focus.
- To understand how the UK can become an attractive proposition for heat pump manufacturers and to understand the barriers to growth of the UK heat pump manufacturing supply chain.
- To understand the realistic growth potential, and how that might vary in time, of a) the supply of heat pumps to the UK market and b) the UK's own heat pump supply chain (including components), considering the expansion of current heat pump manufacturers and the conversion of other related sectors (e.g. gas boilers, refrigeration, air conditioning, ventilation) to heat pump manufacturing.
- To determine which policy levers could maximise the growth of the UK's heat pump supply chain and minimise disruption to other sectors during the transition to low carbon heating, leading to the development of a sustainable industry that is incentivised to innovate for the UK market.
- The research questions for this study can be found in Appendix A – 1, and fall under the three overarching themes:
    - What are the risks and opportunities for the UK heat pump supply chain?
    - How fast could the UK heat pump supply chain grow?
    - What is the role of government in supporting a thriving UK heat pump manufacturing sector?

2) Methodology

Addressing the research objectives and answering the research questions involved both primary and secondary data. The project was divided into five tasks, outlined below alongside explanations and justifications where relevant. Figure 2-1 provides a summary of the research methodology.

Figure 2-1: Research Methodology



Task 1: Literature Review

A Rapid Evidence Assessment (REA) was carried out to capture and summarise data and views previously expressed on heat pump technology in the UK and by wider stakeholders. This included identifying lessons learned from historical rapid technological growth and the adoption of new technologies, and identifying assessments of the current and potential growth in the UK and international heat pump markets.

In total, 135 sources were identified and analysed (see Appendix A – 3: REA Sources, for the full list of sources); 80 were industry/market grey literature, 32 were grey government literature, 15 were news articles and 8 were peer-reviewed academic literature.

Task 2: Supply Chain Mapping

The initial supply chain mapping exercise (Task 2) was conducted to develop a picture of Tier 1 and Tier 2 suppliers involved in the UK heat pump manufacturing industry. Detailed supply chain mapping was carried out for domestic ASHPs (split and monobloc), GSHPs, WSHPs, commercial heat pumps[25] and a high-level market overview was produced for key manufacturers of gas boilers, refrigeration units, and air conditioning/ventilation units.

A variety of approaches were used to understand the Tier 1 heat pump and boiler markets in the UK for domestic and non-domestic applications, in terms of active participants and market share. Data gathered during the REA were used alongside further research on suppliers to the UK, including information on the size of organisations, the number of products that they have placed on the UK market and their origins. The sources used for this analysis are detailed in the Appendix - 'Data sources for Task 2: Supply Chain

[25] Commercial heat pumps include units installed in a non-domestic setting, defined as those with a nominal heating capacity greater than 50kW.

Mapping. The location of manufacture was ascertained through contacting the manufacturers or via internet searches.

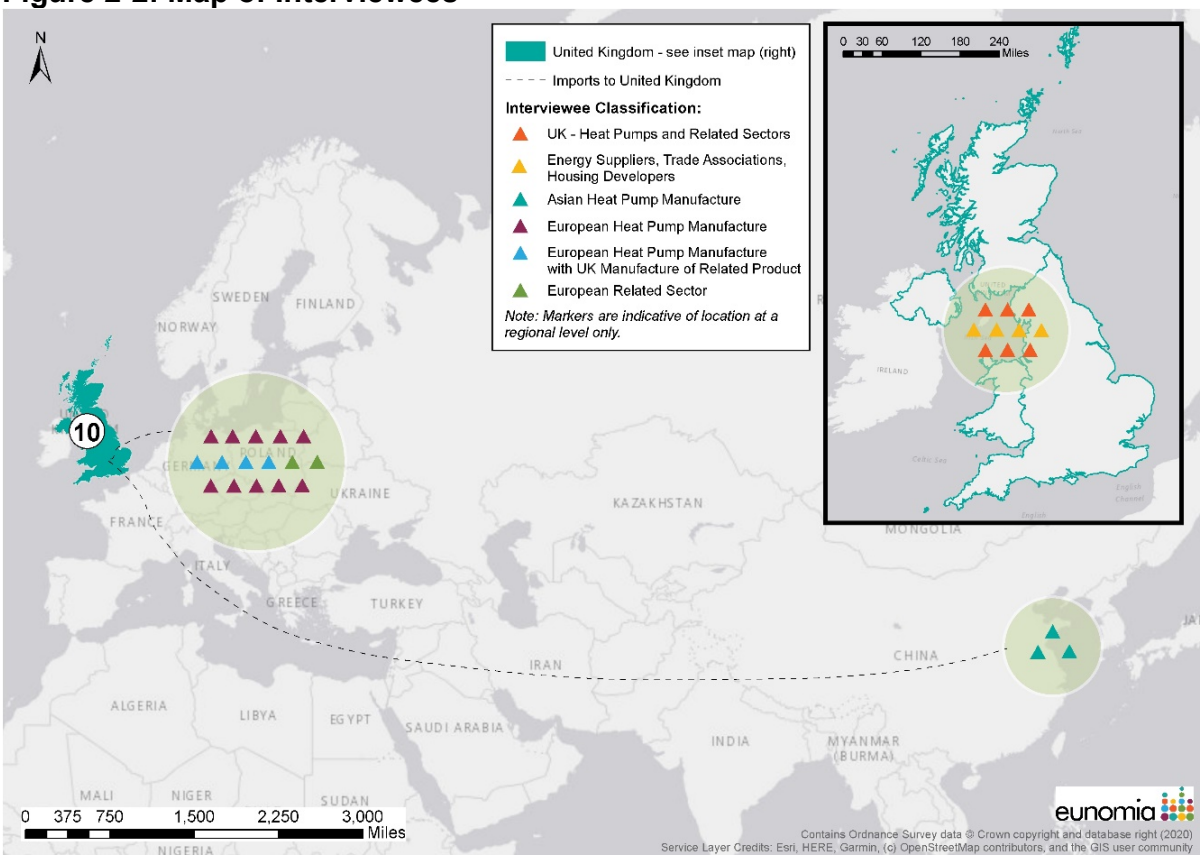
Following the completion of all manufacturer interviews (see Task 3: Manufacturer Interviews), some secondary supply chain mapping took place. This task was intended to refine the initial supply chain mapping by analysing any new insights shared by interviewees.

Task 3: Manufacturer Interviews

Semi-structured interviews were conducted with 30 individuals from UK and international heat pump and boiler manufacturers, heat pump component manufacturers, heat pump suppliers, energy suppliers and trade associations. Interviewees were identified through the supply chain mapping exercise and relevant trade associations, including the Heat Pump Association, the Ground Source Heat Pump Association, and the European Heat Pump Association. These interviews were used to gain in-depth insights into the risks and opportunities for the UK heat pump manufacturing supply chain, gather information to support the growth rate scenarios, understand barriers to growth, and determine which government support will enable this growth. A flexible topic guide that could be tailored to specifically reflect each organisation's context was used to guide interviews (see Appendix A – 2: Methodology).

Figure 2-2 shows the geographical spread of interviewees, with heat pump manufacturers mapped according to their primary manufacturing location and other organisations according to the location of their headquarters. The organisations interviewed represent just a sample of the supply chain and not all manufacturers of heat pumps for the UK market were interviewed.

Figure 2-2: Map of Interviewees



Task 4: Growth Rate Analysis

This task aimed to forecast the overall market size for heat pumps and the relative market share of key manufacturers. Data obtained from the 2020 BSRIA report was used to calculate the approximate number of installations for ASHP and GSHPs for individual manufacturers, based upon their given percentage of 2019 UK market share.[26] [27] The Microgeneration Certification Scheme (MCS) database was then used to identify manufacturers that weren't explicitly stated in the BSRIA report.

Secondly, using illustrative scenarios provided by BEIS for low, medium, high, and hybrid heat pump deployment, the Compound Annual Growth Rate (CAGR) of the sector was calculated.[28] These illustrative scenarios were designed to guide discussion with manufacturers to assess their feasibility in terms of manufacture and to assess possible UK heat pump production. For each scenario, the yearly forecasts were split into domestic and non-domestic production based upon ratios provided by BEIS.[29] Although the BEIS scenarios only run up to 2035, forecast growth rates in the analysis were continued out to 2037 to cover the Carbon Budget Six period (no growth from 2035 to 2037 was assumed; deployment targets will be completed by 2035). Additionally, CAGRs for hybrid heat pump installations between 2020 and 2025 were estimated.[30]

Finally, using the heat pump industry CAGR and the market share data, individual manufacturer reports detailing the forecast growth rates in the different scenarios were created. These were used to inform follow-up discussions with manufacturers, in which the aim was to validate figures derived in this task. The proportion of manufacturing that will take place in the UK across the different scenarios (low, medium, high), was modelled based on assumptions gathered from manufacturer interviews. For manufacturers that stated they would consider moving to the UK, this included the number of units they would need to sell annually in the UK to move production to the UK. Combined with manufacturer's market shares and market growth rates, the year in which a manufacturer would relocate production to the UK was predicted.

Task 5: Validation of Results

Having acquired multiple perspectives during Tasks 2-4, a workshop was held with manufacturers and other key stakeholders to provide some validation of the results and gain input from key stakeholders that were not interviewed. During a two-hour live webinar 21 individuals from 19 industry organisations[31] were presented with key high level insights gained from the research and asked to indicate if they agreed with the findings and

[26] It was decided that for the purposes of the model, where the BSRIA data indicated a market share of <1, a share of 0.9% was used. For any market shares that were provided as a range, the median was used and subsequently, all numbers were proportionally adjusted to total 100%.

[27] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/

[28] The following formula was used to calculate the CAGR: $\left(\frac{End\ Value}{Start\ Value}\right)^{\left(\frac{1}{Years}\right)} - 1$

[29] BEIS: Illustrative scenarios are based on domestic installations, which means that they make up 93.33% of overall installations given the 28:2 split between domestic/non-domestic buildings.

[30] As a percentage increase from zero is undefined, numbers for this period have been estimated by using the medium scenario CAGR and applying it in reverse.

[31] Earth Save Products, the Ground Source Heat Pump Association (GSHPA), Star Renewable Energy, LG, Klima-Therm, Daikin, Twenty-One Engineering, Solid Energy, Worcester Bosch, GI Energy, Ecoforest, Enertech (CTC), Baxi, GEA, European Heat Pump Association (EHPA), Pico Energy, the Heat Pump Association (HPA), Vaillant and Honeywell.

comment on each via a live Mentimeter session. The results of this can be found in A – 4: Validation Workshop Results. The webinar was recorded,[32] allowing those who were unable to attend live to view the recording at a later date and feedback directly to the researchers. An additional 6 participants viewed the webinar, however no additional responses were received. Any changes to the findings as a result of the validation workshop were incorporated into the growth rate model and are detailed in this report.

Limitations of the Research

There are limitations associated with the market and manufacturing data available online and in the academic and grey literature. Some data were not specific to the UK during the year in question, meaning assumptions had to be made when extrapolating for use in this research. Additionally, some market share data lacked completeness: not all manufacturers known to be active in the UK are included in the data, and since the data were collected the market volume has changed. The data do not capture all heat pump activity; there may also be double-counting of heat pump installations (e.g. where installers/distributors have been listed alongside manufacturers providing the same product), however the authors judged that instances where this may have occurred are not significant enough in proportional terms to impact on the findings of this report.

Hydronic heat pumps are the primary focus of this research. However, in many global market reports they are not separated as a subsection in global or regional data, which often includes air output heat pumps (primarily ATA) and room air conditioners (RACs). Both UK and international manufacturers identified that there are more types of heat pump systems prevalent outside the UK for ASHPs. There is, for example, greater penetration of ATA heat pumps that provide both heating and cooling in Asia and Europe. This poses some limitations on the ability to use international data for analysing the hydronic heat pump market. To avoid possible confusion, the types of heat pump included in the source data in the market analysis sections are explicitly identified for ASHPs and GSHPs, where they can be disaggregated.

The manufacturers of supply chain components specific to the heat pump industry were difficult to ascertain in some instances, the main reasons being the lack of literature on this topic, commercial sensitivities around heat pump manufacturing, and the component manufacturers themselves choosing not to disclose this information. As such, data on these market shares have been provided on a high-level basis and are less granular than the data on heat pump manufacturers.

The interviews and workshop undertaken were not intended to be representative of all heat pump manufacturers in the UK market, as the focus was on larger suppliers with a greater UK market share. The results presented in this research are likely to represent the views of larger organisations that can meet the current and future demand of the heat pump sector (with that judgement being made based on current market shares). To partially account for this imbalance, interviewees were asked to give their views on the role of UK SMEs in the future heat pump supply chain, and three manufacturers with small UK market shares were interviewed.

Instances of optimism bias arose during the interviews, particularly when asking Tier 1 manufacturers to estimate their market share going forward or to state their strengths or weaknesses relative to other manufacturers. Where this bias was identified this was

[32] Participants were told at the beginning of the workshop that the meeting would be recorded, and given the opportunity to leave if they did not consent.

factored into the assumptions in the growth rate model following the HM Treasury Green Book guidelines.[33] Furthermore, it should be acknowledged that the growth rate modelling of UK manufacture is based on manufacturers who are keen to demonstrate that they would manufacture in the UK, which may include some hard to identify biases.

The study over-represents suppliers and manufacturers of domestic heat pumps rather than non-domestic, due to their dominance in current installations and the data available on these markets. However, the report does include discussion of market shares which account for both domestic and non-domestic heat pumps, and the yearly forecasts formed as part of the Growth Rate Analysis are split into domestic and non-domestic production. Non-domestic heat pumps are accounted for in several aspects of the study, and interviews with non-domestic heat pump manufacturers and suppliers took place. Their insights have been considered as part of this research, albeit with less emphasis than domestic applications.

Finally, there are limitations associated with the emergence of the COVID-19 pandemic. The study began before the impact that the pandemic would have on manufacturing and trade in the UK and worldwide became clear, and it was therefore not a focus of the research questions or the interview topic guide. In later interviews, some manufacturers did mention that they anticipate the COVID-19 pandemic to have a detrimental impact on heat pump supply and demand in the short term. Some further thoughts are provided on this in the section: Impact of COVID-19 on Expected Growth.

[33] Department for Business, Energy & Industrial Strategy (2018) The Green Book: Central Government Guidance on Appraisal and Evaluation, accessed 2 June 2020, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

3) Heat Pump Market Analysis

Section Aim: It is necessary to understand the current heating market in the UK and to identify the key manufacturers of heat pumps serving this market. It is also necessary to understand what the heat pump market looks like outside of the UK, and how both markets have evolved and will continue to evolve in the future. This will enable opportunities and risks to be identified for: growing the UK heat pump sector; increasing domestic production capacity; and the potential to export from the UK. The key findings from the literature review, supply chain mapping, and manufacturer interviews are detailed in this section.

International Heat Pump Market

The heat pump industry was first developed in the 1960s and 70s and is now well established, operating around the globe. There is a diverse range of manufacturers operating on all continents, but manufacturers originating in Asia Pacific dominate the global market. This diverse group of manufacturers includes both those specialising primarily in heat pumps and those with a broader range of expertise, for example, in manufacturing consumer electronics, boilers, and renewable products.

Heat pumps represent a small but growing share of the global heating market, accounting for approximately 3% in 2018.[34] Global annual heat pump sales are expected to roughly double between 2019 and 2030 from 11.4 million to 20.8 million units.[35] [36] This is primarily due to growing efforts to reduce carbon emissions from heating, growing demand for increased energy efficiency to reduce energy bills, and increasingly strong heat pump distribution channels.[37]

By Product

The global market is dominated by ATA, used for both heating and cooling, which constitutes the majority of heat pump sales in Asia, North America and Europe.

ATA room air conditioners (RACs) are not included in the data in this section, although these are sometimes referred to as ATA heat pumps and constitute a large proportion of the global market, particularly in China. Around 40 to 50 million RAC units were sold in China in 2017, an order of magnitude higher than the 2.8 million heat pump sales reported in this section. [38] Additionally, the Chinese Heat Pump Alliance cites the value of the Chinese heat pump market as 185 billion Chinese yuan (roughly £20 billion) in 2017, whereas the value of the 2.8 million heat pumps in this section is roughly £7.3 billion in

[34] International Energy Agency (2019) Heat Pump Tracking Report, accessed 28 April 2020, https://www.iea.org/reports/heat-pumps
[35] Global Market Insights (2020) Global Heat Pump Market, 2020-2026, 2020, https://www.gminsights.com/industry-analysis/heat-pump-market
[36] The 2030 figures for heat pump sales have been calculated using the CAGR values provided in the GMI report. However, the policy assumptions that underpin these growth rates have not been specified.
[37] Ibid.
[38] Zhao, H., Gao, Y., and Song, Z. (2017) Strategic outlook of Heat pump development in China, p.5

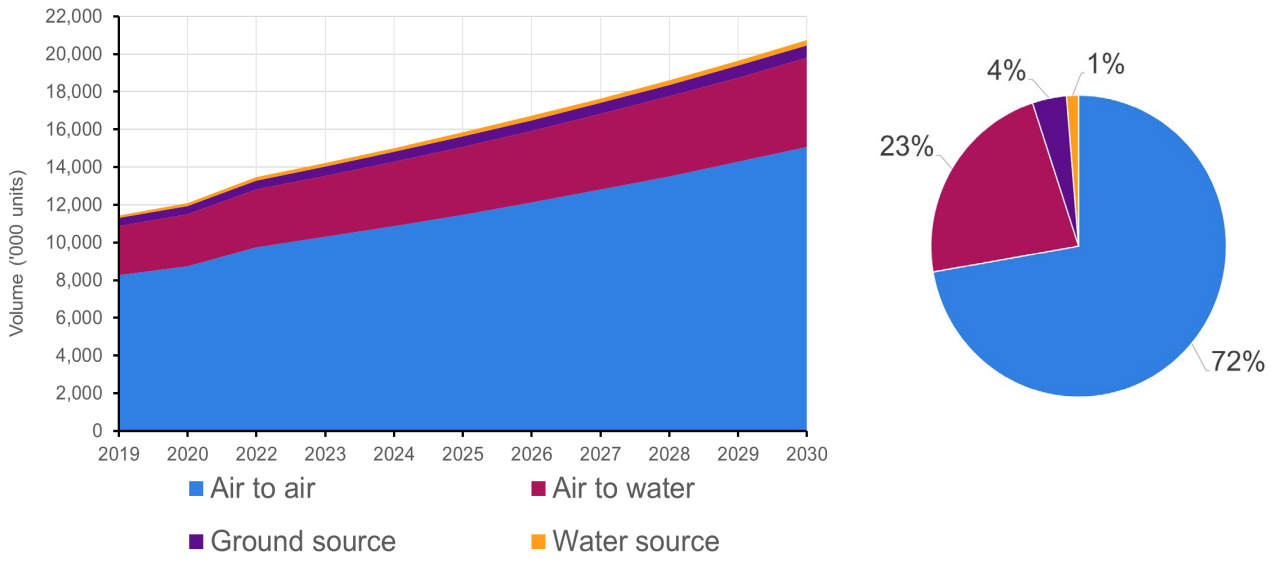
2017. This demonstrates some of the differences in heat pump definitions being used in market reporting.[39]

Figure 3-1 shows the volume of heat pump sales broken down by product type and their respective market shares. The international heat pump market is dominated by ASHPs, which accounted for 95% of the total market in 2019, followed by ground source (4%) and water source (1%). This is primarily because ASHPs require neither a substantial land area nor a water source, making them easier and cheaper to install. Of the ASHPs, ATA accounted for 72% of the total market and ATW accounted for 23%.

As shown in Figure 3-1 sales of all product types are expected to increase in the coming decade, with the assumption that there will be no substantial changes in the market shares of air, ground and water source heat pumps.

In terms of hydronic systems, globally in 2019 there were just over 3 million ATW heat pumps sold, and 0.6 million GTW and WTW combined. In comparison, in the UK in 2019, there were only 30,000 ATW sales and 3,000 GTW and WTW sales. As such, the UK holds roughly 1% of the global ATW market and 0.5% of the global GTW and WTW market.[40] The UK market is described in further detail in the 'UK Heat Pump Market' section of this report.

Figure 3-1: Predicted global volume of heat pump sales by product from 2019-2030 (left chart) and market share by volume for product types in 2019 (right chart)



Regional Analysis

Global sales data has been further broken down into five main geographical regions. The regional values for ASHPs have not been disaggregated into ATW and ATA.[41] Therefore, the following figures include ATA heat pumps, which constitute the majority of heat pump sales in Asia, North America and Europe.

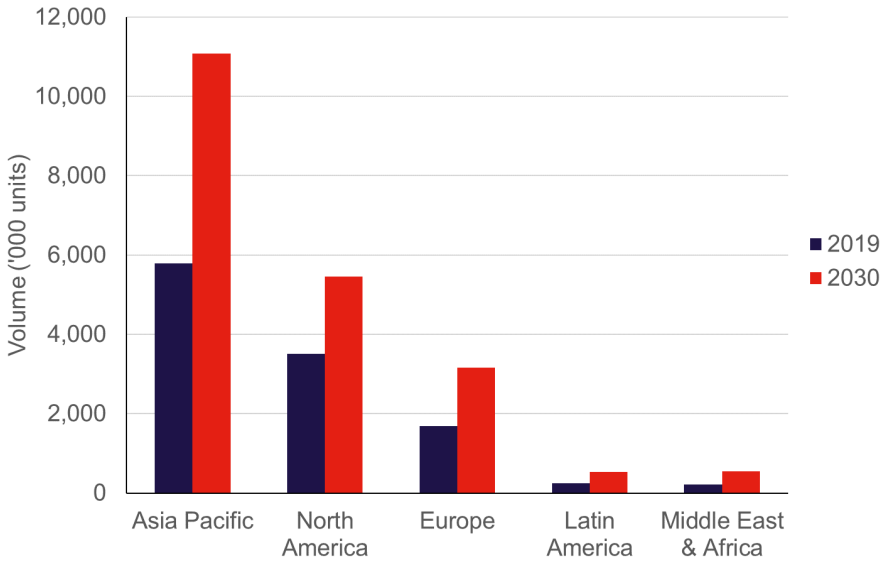
[39] China Heat Pump Alliance (2018) China Heat Pump Annual Conference & 7th International Air-source Heat Pump Development Forum, accessed 23 April 2020 https://heatpumpingtechnologies.org/news/1/53843

[40] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/

[41] Unable to disaggregate because the proportions of ATAs and ATWs across regions is unknown.

Figure 3-2 shows that the global heat pump market is dominated by Asia Pacific, which accounted for 51% of the market by volume in 2019. China alone accounted for 28%, making it the country with the largest heat pump market worldwide.[42] North America accounted for 31%, followed by Europe with 15%. Latin America, and the Middle East and Africa, only accounted for 2% each. The International Energy Agency (IEA) estimates that in 2017 nearly 80% of new household heat pump installations (including ATA) were in China, Japan, or the United States.[43]

Figure 3-2: Volume of heat pumps sales by region for 2019 and 2030[44]



China's dominance in this market is largely driven by efforts to reduce air pollution by moving away from coal as a primary fuel source for domestic heating.[45] In 2013, China introduced its Air Pollution Prevention and Control Action Plan, which provides subsidies of up to 85% to reduce upfront heat pump installation and equipment costs.[46] [47] As a result, ASHP installations for space heating in Beijing experienced a 28 fold increase from 2015 to 2016,[48] with the majority being installations of reversible ATA heat pump units that can provide both heating and cooling.[49]

In comparison with ATA, the Chinese ATW heat pump market is relatively small – of the same order of magnitude as the European ATW market.[50] Nevertheless, the Chinese

[42] Global Market Insights (2020) Global Heat Pump Market, 2020-2026, 2020, https://www.gminsights.com/industry-analysis/heat-pump-market
[43] International Energy Agency (2019) Heat Pump Tracking Report, accessed 28 April 2020, https://www.iea.org/reports/tracking-buildings/heat-pumps
[44] Global Market Insights (2020) Global Heat Pump Market, 2020-2026, 2020, https://www.gminsights.com/industry-analysis/heat-pump-market
[45] Zhao, H., Gao, Y., and Song, Z. (2017) Strategic outlook of Heat pump development in China, paper given at 12th IEA Heat Pump Conference, 2017, https://hpc2017.org/wp-content/uploads/2017/05/O.2.1.1-Strategic-outlook-of-Heat-pump-development-in-China.pdf
[46] International Energy Agency (2019) Heat Pump Tracking Report, accessed 28 April 2020, https://www.iea.org/reports/tracking-buildings/heat-pumps
[47] Zhao, C.H. (2017) China air source heat pump market development, paper given at IEA Heat Pump Conference, 17 May 2017, https://heatpumpingtechnologies.org/archive/hpc2017/wp-content/uploads/2017/06/o211.pdf
[48] Ibid
[49] International Energy Agency (2019) Heat Pump Tracking Report, accessed 28 April 2020, https://www.iea.org/reports/tracking-buildings/heat-pumps
[50] China Heat Pump Alliance (2018) China Heat Pump Annual Conference & 7th International Air-source Heat Pump Development Forum, accessed 23 April 2020, https://heatpumpingtechnologies.org/news/1/53843

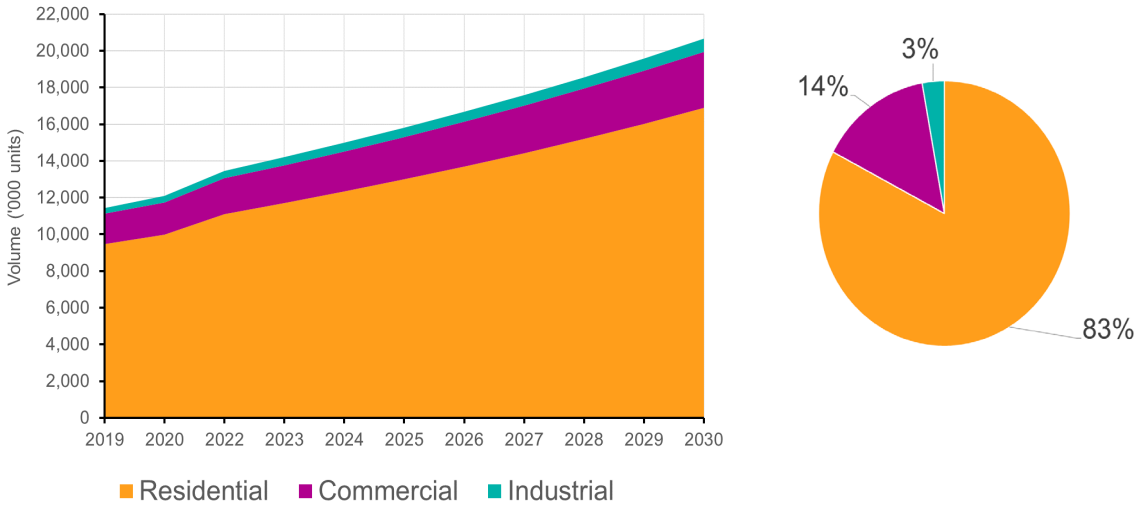
ATW market share is still significant in global terms. For example, the dramatic reduction in infrastructure spending in China during 2017 and 2018 may explain the ~33% decrease in global hydronic heat pump sales over the same time period, from 4.5 million to 3 million.[51] [52] [53]

Japan, another dominant market and exporter in Asia, used subsidies alongside targeted research and development (R&D) to boost heat pump sales in the hot water market in the 2000s. In 2001, Corona Corporation released a new and more efficient ASHP model called 'EcoCute', designed specifically to heat water. The Japanese Government incorporated the EcoCute into its CO2 reduction program under the Kyoto Protocol, introducing subsidies to help overcome installation cost barriers. In 2010, EcoCutes in residential use were subsidised by up to 40,000 Yen (~ £294), while EcoCutes in commercial use could benefit from subsidies up to 830,000 Yen (~ £6,090), depending on heating capacity.[54] By 2012, 3.5 million units had been installed and sales were around 550,000 units a year.[55]

By Application

Figure 3-3 shows that the international heat pump market is dominated by the residential sector, which accounted for 83% of the market in 2019, followed by the commercial (14%) and industrial (3%, for space heating requirements only) sectors. It is expected that this market breakdown will remain relatively constant over the coming decade, with only a small decrease of 1% in the market share for domestic heat pumps.[56]

Figure 3-3: Predicted global volume of heat pump sales by application between 2019-2030 (left chart) and market share by application in 2019 (right chart)



[51] Building Services Research and Information Association (BSRIA) (2019) World Heat Pump Market Study 2019, accessed 30 March 2020, https://www.bsria.com/uk/news/article/world-heat-pump-market-study-2019/
[52] Building Services Research and Information Association (BSRIA) (2018) World Heat Pump Study 2018 - fast growth, 2018, https://www.bsria.com/uk/news/article/bsria-world-heat-pump-study-2018-fast-growth/
[53] Financial Times (2019) China's regions hit by infrastructure spending downturn
[54] R744 (2010) Subsidies for Eco Cute in 2010, accessed July 2020, available at http://r744.eu/articles/1148/subsidies_for_eco_cute_in_2010_br
[55] Federation of European Heating, Ventilation and Air Conditioning Associations, and European Heating, Ventilation and Air Conditioning Associations (2012) Inside view into the Japanese heat pump market, The REHVA European HVAC Journal, Vol.49, No.5
[56] Ibid

Expected Growth

Heat pump sales are expected to increase in every region of the world in the coming decade.[57] The largest increases in absolute sales are expected in Asia Pacific (5.3 million increase), followed by North America (2.0 million) and Europe (1.5 million). However, the Compound Annual Growth Rate (CAGR) for North America (4.0%) is lower than that for Asia Pacific (6.1%) and Europe (5.9%). Consequently, the North American global market share is expected to decrease by 4.4%, while the Asian Pacific and European market shares are expected to increase by 2.8% and 0.5% respectively.

The growth in the Asian market is driven by China, where a large proportion of space and water heating is still provided by coal (50% in 2017), and where the economy and the construction of new dwellings is growing rapidly.[58] By contrast, in North America the economy is much more mature, the rate of construction is lower, and there is currently less focus on improving air quality and reducing GHG emissions. In Europe, growth is also being driven by regulatory regimes to promote low carbon heating, although air quality is currently a less immediate driver than in China.[59] The European market is discussed in more depth in the following section.

European Heat Pump Market

Heat pumps are a well-established technology in some European countries, with a total of 1.3 million heat pumps sold in 2018 and an estimated installed stock of 11.8 million (including hydronic and ATA heat pumps).[60] [61] However, deployment rates vary hugely between countries. The largest heat pump markets in 2018 were France (275,000 sales), Italy (200,000 sales), and Spain (120,000 sales). When expressed on a per household basis, Scandinavian countries have the most heat pump sales, with Norway reaching 46 sales per thousand households in 2018.

Despite similar population sizes, heat pump sales in the UK amount to less than one-tenth of the sales in France, with only 1 sale per thousand households in 2018. [62] [63] Nevertheless, in terms of hydronic (ATW and GTW) heat pumps, the UK has the fifth largest market in Europe after France (~150,000 sales in 2018), Germany (~100,000 sales), the Netherlands (~35,000 sales) and Sweden (~30,000 sales).[64] The ATW markets

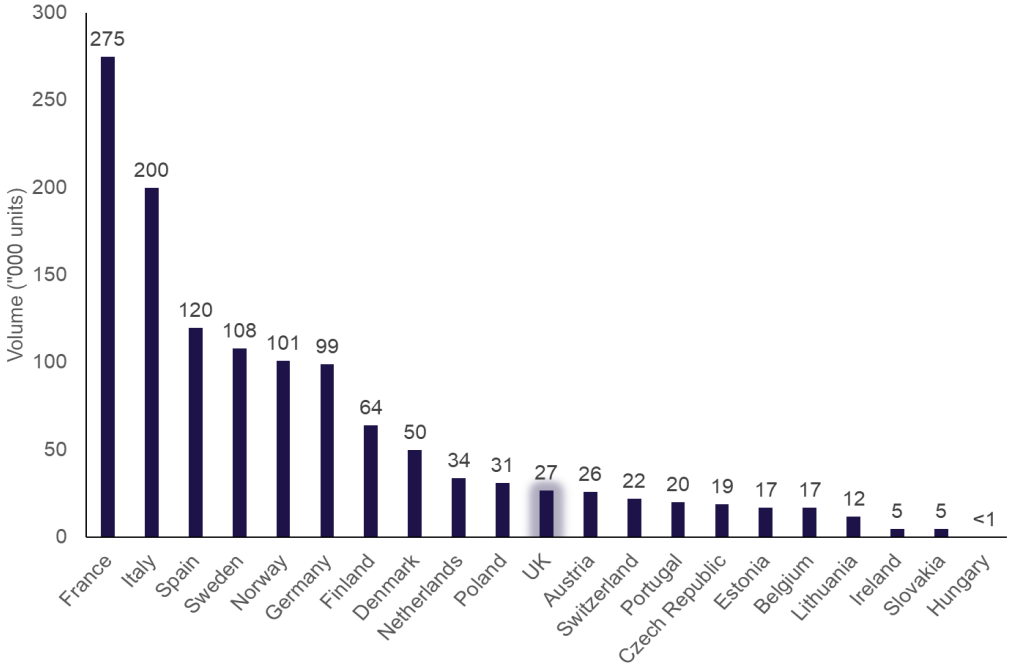
[57] Global Market Insights (2020) Global Heat Pump Market, 2020-2026, 2020, https://www.gminsights.com/industry-analysis/heat-pump-market
[58] Benazeraf, D. (2017) Heating Chinese cities while enhancing air quality, accessed 23 May 2020, https://www.iea.org/commentaries/heating-chinese-cities-while-enhancing-air-quality
[59] Global Market Insights (2020) Global Heat Pump Market, 2020-2026, 2020, https://www.gminsights.com/industry-analysis/heat-pump-market
[60] European Heat Pump Association (2019) EHPA Market Report and Statistics Outlook, 2019, https://www.ehpa.org/fileadmin/red/09._Events/2019_Events/Market_and_Statistic_Webinar_2019/20190624_-_EHPA_Webinar_outlook_2019_-_Thomas_Nowak.pdf
[61] All data in this section includes ATA heat pumps, separate data for hydronic heat pumps was not available.
[62] Worldometer (2020) Population by Country, accessed 23 May 2020, https://www.worldometers.info/world-population/population-by-country/
[63] European Heat Pump Association (2019) EHPA Market Report and Statistics Outlook, 2019, https://www.ehpa.org/fileadmin/red/09._Events/2019_Events/Market_and_Statistic_Webinar_2019/20190624_-_EHPA_Webinar_outlook_2019_-_Thomas_Nowak.pdf
[64] The EHPA does not provide the raw data for heat pump sales per country broken down by type, but they do provide a graph of these proportions. Of the six heat pump categories displayed in the graph, the following three have been included in our estimates for the hydronic market: H-ground/water; H-air/water; and Sanitary hot water. 'Exhaust air' heat pumps can be ATA or ATW, but EHPA clarified that in this graph

are extremely small in Italy (<5,000 sales), Spain (<5,000 sales), Norway (~10,000 sales) and Finland (~15,000 sales) because the majority of sales are ATA.[65]

Europe has experienced five years of double-digit growth in heat pump sales, growing by 14.4% in 2019, with 1.45 million units being sold across Europe.[66] Manufacturer interviews suggest that most of the heat pumps sold in Europe are also manufactured there, with approximately 100 heat pump manufacturing sites across the continent.[67]

The European heat pump market is summarised in Figure 3-4 and Figure 3-5. The product types included within the total are reversible ATA, reversible other, sanitary hot water (unit comprising of an ASHP, an electric auxiliary heater and a storage tank), exhaust air (extracts heat from the exhaust air of a building and transfers the heat inside for space heating and/ or hot water), GTW (for space heating), and ATW (for space heating).

Figure 3-4: Volume of heat pump sales in 2018 for each European country in total[68]



only ATA units have been included in this category. EHPA also noted that the "reversible other" category may include some hydronic heat pumps. However, given that they do not have a sales breakdown for the specific types of heat pump in this category, sales of "reversible other" have been excluded from our estimates for the hydronic market.

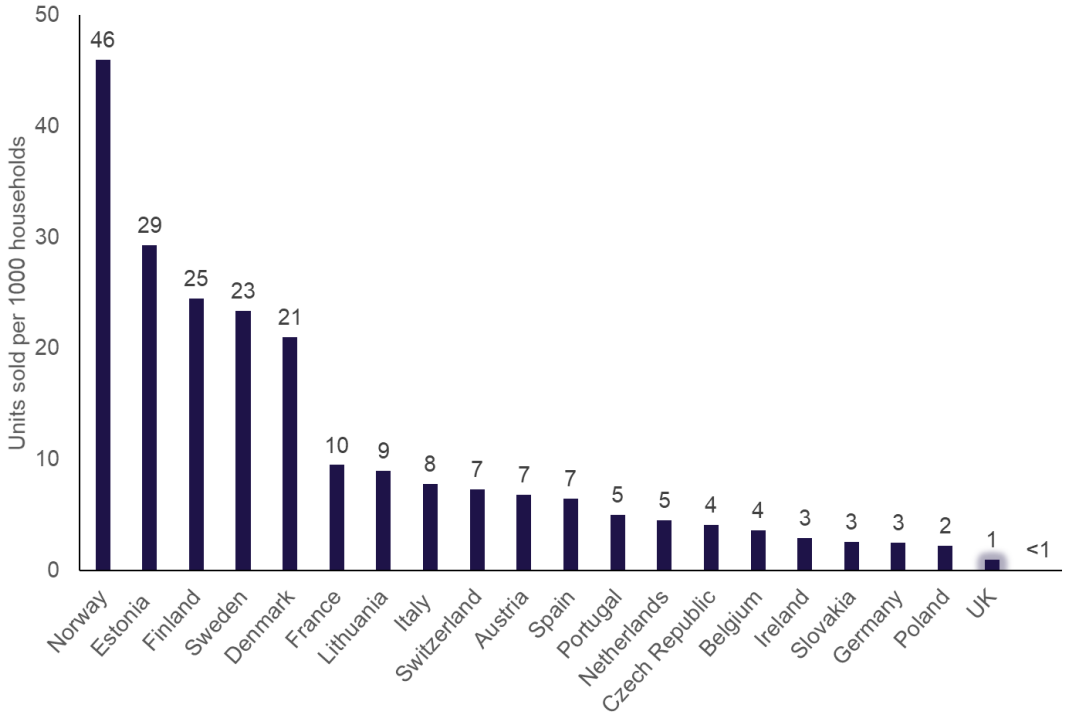
[65] European Heat Pump Association (2019) EHPA Market Report and Statistics Outlook, 2019, https://www.ehpa.org/fileadmin/red/09._Events/2019_Events/Market_and_Statistic_Webinar_2019/20190624_-_EHPA_Webinar_outlook_2019_-_Thomas_Nowak.pdf

[66] Ibid

[67] Heat Pump Association (2020) The Essence of Heat Pump Series - European Heat Pump Market Insights, 20 May 2020

[68] Ibid

Figure 3-5: Volume of heat pump sales in 2018 for each European country per 1000 households[69]



National Differences

Key features that have determined the extent of national heat pump markets in Europe include climate, connection to a low-cost gas grid, housing stock quality, and supportive policies. Of all the countries that outperform the UK in terms of heat pump deployment, the Netherlands is perhaps considered to be the most relevant. This is because it has a similar climate and a large domestic supply of natural gas. Italy and Spain are arguably the least relevant due to their warm climates and strong requirement for cooling. Whilst it is important to acknowledge the success of the Scandinavian countries, France and Germany, they are operating in quite different circumstances, with either dissimilar climates and/or less dominant gas grids. Table 3-1 outlines some of the key policies in place to promote low carbon heating in Scandinavia, France, Germany, and the Netherlands, along with the main source of residential heating to allow for comparison to the UK to be made.

[69] European Heat Pump Association (2019) EHPA Market Report and Statistics Outlook, 2019, https://www.ehpa.org/fileadmin/red/09._Events/2019_Events/Market_and_Statistic_Webinar_2019/20190624_-_EHPA_Webinar_outlook_2019_-_Thomas_Nowak.pdf

Table 3-1: Policies to promote heat pump deployment in different European countries and Main Residential Heating Source.

Country	HP sales per 1000 households [70]	Main residential heating source	Policies to promote low carbon heating
Norway	46	70-80% electric heating (not including heat pumps).[71] [72]	In 2000, banned oil boilers from new builds.[73] In 2020, banned oil boilers in existing buildings (the first country in the world to do this).[74]
Finland	25	54% district heating (19% coal, 19% biomass and 13% natural gas).[75]	Carbon tax on fossil fuels for heating (€35 per tCO2e in 2013).[76] 2012 National Building Code (SRMK) outlines stringent energy performance standards that account for the carbon intensity of the building's heat supply.[77] 45-60% of the labour costs for household renovations for renewable energy installations are tax-deductible.[78] Subsidy of up to 20% of the investment for replacing oil and electric-heating systems with renewable heating systems.[79]

[70] European Heat Pump Association (2019) EHPA Market Report and Statistics Outlook, 2019, https://www.ehpa.org/fileadmin/red/09._Events/2019_Events/Market_and_Statistic_Webinar_2019/20190624_-_EHPA_Webinar_outlook_2019_-_Thomas_Nowak.pdf
[71] Euroheat (2019) District Energy in Norway, accessed July 2020, available at https://www.euroheat.org/knowledge-hub/district-energy-norway/#:~:text=The%20national%20heat%20market%20is,12%25%20of%20the%20heat%20market.&text=In%20the%20services%20sector%2C%20use,for%20heating%20is%20about%2050%25.
[72] Energifakta Norge (2019) Energy use by sector, accessed July 2020, available at https://energifaktanorge.no/en/norsk-energibruk/energibruken-i-ulike-sektorer/
[73] Yale Center for Business and the Environment (2016) Renewable Thermal Heating: Lessons from Scandinavia, 2016, https://cbey.yale.edu/our-stories/renewable-thermal-heating-lessons-from-scandinavia
[74] Foresight Climate & Energy (2020) Polish coal boiler phase-out: an inspiration for clean heat, 2020, https://foresightdk.com/polish-coal-boiler-phase-out-an-inspiration-for-clean-heat/
[75] Energia (2018) District heating in Finland 2018, accessed July 2020, available at https://energia.fi/files/4092/District_heating_in_Finland_2018.pdf
[76] World Bank (2014) Putting a Price on Carbon with a Tax, accessed July 2020, available at https://www.worldbank.org/content/dam/Worldbank/document/SDN/background-note_carbon-tax.pdf
[77] Hannon, M.J. (2015) Raising the temperature of the UK heat pump market: Learning lessons from Finland, Energy Policy, Vol.85, pp.369–375
[78] Ibid
[79] Ibid

Country	HP sales per 1000 households [70]	Main residential heating source	Policies to promote low carbon heating
Sweden	23	55% district heating (90% renewable sources and recycled heat).[80] [81]	Carbon tax on the supply, import and production of fossil fuels for heating (€110 per tCO2e in 2020). [82] Income tax deduction on heat pump installation works in households.[83]
Denmark	21	65% district heating (23% natural gas, 14% coal). [84]	In 2013, banned the installation of oil and gas boilers in new buildings.[85] In 2016, banned the installation of new oil-fired boilers in existing buildings in areas where district heating or natural gas is available.[86]
France	10	41% electric heating, including heat pumps [87] (38% connected to the gas grid). [88] [89]	The 2005 'White Certificates' scheme requires energy suppliers to help consumers reduce total energy consumption, usually financially. Tax credits, grants, or green loans with 0% interest, for domestic heat pump installation (eligibility and magnitude for each dependent on

[80] Werner, S. (2017) District heating and cooling in Sweden, Energy, Vol.126, pp.419–429
[81] Euroheat (2017) Swedish district heating: Reducing the nation's CO2 emissions, accessed July 2020, available at https://www.euroheat.org/news/swedish-district-heating-reducing-nations-co2-emissions
[82] Government Offices of Sweden (2020) Sweden's Carbon Tax, accessed July 2020, available at https://www.government.se/government-policy/taxes-and-tariffs
[83] RES Legal (2013) Renewable energy policy database and support – National profile: Sweden, accessed July 2020, available at http://www.res-legal.eu/no_cache/archive/?cid=289&did=473&sechash=62f7a964
[84] Foresight Climate & Energy (2019) The Path to emissions-free district heating in Denmark, accessed July 2020, available at https://foresightdk.com/the-path-to-emissions-free-district-heating-in-denmark
[85] International Energy Agency (2017) Danish Energy Agreement for 2012-2020, 2017, https://www.iea.org/policies/606-danish-energy-agreement-for-2012-2020
[86] International Energy Agency (2017) Danish Energy Agreement for 2012-2020, 2017, https://www.iea.org/policies/606-danish-energy-agreement-for-2012-2020
[87] The Connexion (2020) Electric heaters cost more than wood, accessed July 2020, available at https://www.connexionfrance.com/Practical/Property/Electric-heaters-cost-more-than-wood
[88] Commission de Régulation de l'Energie (2019) Natural gas networks, accessed 25 May 2020, https://www.cre.fr/en/Natural-gas/Natural-gas-networks/Natural-gas-networks
[89] 11 million consumers connected to the gas grid divided by 28.6 million households = 38%

Country	HP sales per 1000 households [70]	Main residential heating source	Policies to promote low carbon heating
			the household's economic situation). In 2014, introduced carbon tax which now amounts to €45 tCO2e in 2020.[90]
Netherlands	5	88% connected to the gas grid.[91]	Reduced levy on electricity.[92] Increased levy on gas.[93] Since 2008, subsidising 20-40% of the upfront cost for the heat pump unit and its installation. All new buildings must be 'Almost Energy Neutral' (having an Energy Performance Certificate of 0.4) by the end of 2020.[94]
Germany	3	50% connected to the gas grid.[95]	2009 EnEV building code for new build with high thermal envelope and air-tightness requirements.[96] 2016 Renewable Energy Heating Act requires new buildings to use renewable energy for space and water heating.[97]

[90] OECD Ecoscope (2020) Carbon tax, emissions reduction and employment: Some evidence from France, accessed July 2020, available at https://oecdecoscope.blog/2020/02/04/carbon-tax-emissions-reduction-and-employment-some-evidence-from-france
[91] The Holland Times (2018) The Netherlands to go completely gas-free in the future, accessed July 2020, available at https://www.hollandtimes.nl/articles/national/the-netherlands-to-go-completely-gas-free-in-the-future/#:~:text=Out%20of%208%20million%20Dutch,to%20alternative%20sources%20of%20energy.
[92] Delta Energy & Environment (2016) Wave of new, renewed, and extended incentives to improve heat pump prospects in Europe, accessed 19 May 2020, https://www.delta-ee.com/delta-ee-blog/wave-of-new-renewed-and-extended-incentives-to-improve-heat-pump-prospects-in-europe.html
[93] Ibid
[94] Energy Saving Trust (2020) Switching to low-carbon heat: an example from the Netherlands, accessed July 2020, available at https://energysavingtrust.org.uk/blog/switching-low-carbon-heat-example-netherlands
[95] Clean Energy Wire (2020) Heating 40 million homes – the hurdles to phasing out fossil fuels in German basements, accessed July 2020, available at https://www.cleanenergywire.org/factsheets/heating-40-million-homes-hurdles-phasing-out-fossil-fuels-german-basements
[96] Gleeson, C.P. (2016) Residential heat pump installations: the role of vocational education and training, Building Research & Information, Vol.44, No.4, pp.394–406
[97] IEA (n.d.) Germany: New regulations likely to drive heat pump market, accessed July 2020, available at https://heatpumpingtechnologies.org/germany-new-regulations-likely-drive-heat-pump-market/#:~:text=From%20January%201%2C%202016%E2%80%94construction,means%20of%20heating%20new%20buildings.

Country	HP sales per 1000 households [70]	Main residential heating source	Policies to promote low carbon heating
UK	1	84% connected to the gas grid. [98]	See the section on 'UK Policy and Commitments for Heat Pumps'

The success of the Dutch market can largely be attributed to policy mechanisms aimed at promoting heat pumps, see Table 3-1. These policies helped contribute to a doubling of ATW heat pump sales in the Netherlands between 2011 and 2018.[99]

Scandinavia has a relatively cold climate compared with much of Europe, and therefore good insulation has historically been a key priority. This means its building stock is more suitable for heat pumps. Additionally, these countries have relatively abundant low carbon electricity, limited use of natural gas for domestic heating, and a range of supportive policies, outlined in Table 3-1.[100] In Norway, annual heat pump sales increased tenfold between 2000 and 2015, due to the ban on oil boilers in new builds.[101]

The key factors that differentiate France and Germany from the UK are: newer, more energy efficient housing stocks; a smaller proportion of households connected to a gas grid; and a range of policy mechanisms to improve the uptake of heat pumps. Financial incentives in France drove the value of the French heat pump market to increase fivefold between 2014 and 2018. Strict building regulations in Germany since the 1990s have made new houses much more suitable for heat pumps.

UK Heat Pump Market

As outlined in the previous section, the UK heat pump market is less mature than that of other countries in Europe with comparable populations, economies and climates. There are few UK-based manufacturers and demand for heat pumps is relatively low. Two of the key challenges faced by the UK are older, less energy efficient housing stock and a dominant low-cost gas grid.

In 2019, 34,896 hydronic heat pumps (including hybrids) were sold in the UK at a total value of £78 million at manufacturer sales price (MSP).[102][103] By the start of 2020, there were an estimated 240,000 heat pumps installed in the UK, which have supported an estimated 2,000 full-time jobs to build, install and maintain them.[104] Whilst small when

[98] Energy Saving Trust (2019) Why outside the grid does not mean outside of help, 2019, https://energysavingtrust.org.uk/blog/why-outside-grid-does-not-mean-outside-help
[99] Statista (2019) Netherlands: sales volume of heat pumps 2011-2018, accessed 19 May 2020, https://www.statista.com/statistics/1042036/sales-volume-of-residential-and-non-residential-heat-pumps-in-the-netherlands/
[100] Greater London Authority, and Etude (2018) Low Carbon Heat: Heat Pumps in London, September 2018, https://www.london.gov.uk/sites/default/files/low_carbon_heat_-_heat_pumps_in_london_.pdf
[101] Yale Center for Business and the Environment (2016) Renewable Thermal Heating: Lessons from Scandinavia, 2016, https://cbey.yale.edu/our-stories/renewable-thermal-heating-lessons-from-scandinavia
[102] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/
[103] Using the average EUR/GBP conversion for 2019 of 0.7831 €/£ (https://www.ofx.com/en-gb/)
[104] European Heat Pump Association (2019) Heat pump country cards, accessed 23 April 2020, http://www.stats.ehpa.org/hp_sales/country_cards/

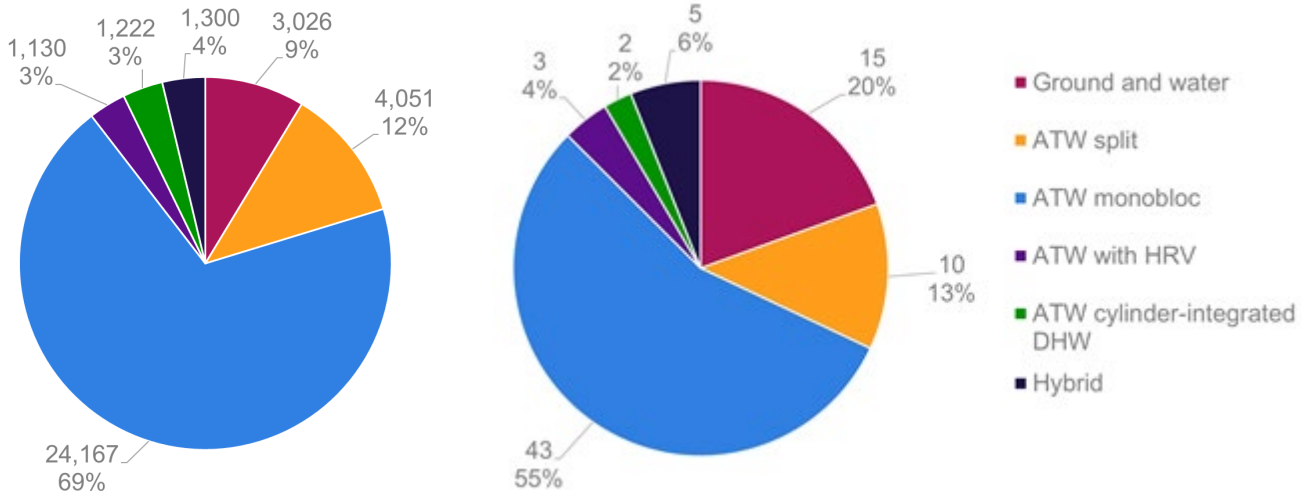
compared with other nations, the UK heat pump market is growing, with unit sales increasing by 85% in just 3 years from 2016 to 2019.[105]

The UK hydronic heat pump market is summarised below, using 2019 data from a 2020 BSRIA report (noting that ATA heat pumps are not included).[106]

By Product

Figure 3-6 shows that the UK market is dominated by ASHPs, which accounted for 87% of the market by volume in 2019. ASHPs are generally cheaper than GSHPs and WSHPs, and so only accounted for 74% of the market by value.

Figure 3-6: UK heat pump market share 2019 by product type in terms of volume of unit sales (left chart) and value in million euros at MSP (right chart)



Ground and water source heat pumps are grouped into one category, while the ASHP category is divided into four more specific heat pump types: ATW split systems; ATW monobloc systems; ATW systems combined with heat recovery and ventilation (HRV); and ATW cylinder-integrated domestic hot water (DHW) heaters. Hybrid heat pumps (heat pump with a boiler as one single integrated product) have their own category.

ATW monobloc heat pumps dominate the UK market, accounting for 69% of total heat pump sales in 2019. The main advantage of monoblocs is that their installation is simple, relatively low cost, and – unlike split systems – does not require F-gas qualified installers.

In the UK, F-gas qualified installers are relatively uncommon so their requirement can be a limiting factor. In countries where air conditioning is prevalent, they are much more common because air conditioning systems also require F-gas qualification, so a trained installer base already exists.

Although only accounting for 12% of sales in 2019, split systems can offer advantages over monoblocs. For example, in a split system the condenser fan coil can be installed up to 30 metres away from the building, whereas in a monobloc they need to be much closer. Heat pump components can produce noise levels of 40 to 50dB, so locating them further

[105] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/
[106] Ibid

away reduces the amount of noise that is heard from the building.[107] Furthermore, in a split system the fluid passing through outdoor pipes (between indoor and outdoor units) is a refrigerant and therefore does not freeze, whereas, in a monobloc system the fluid passing through outdoor pipes is water, which requires glycol (antifreeze) to prevent freezing of insulated water lines connected to an outdoor unit in cold weather. This adds further costs and can lead to inefficiencies.

While split systems were historically more efficient, the efficiency of monobloc systems has been improved and there is no longer a considerable difference between the two; however, improvements could still be made to increase the efficiency of a monobloc system further.

Heat pumps are generally installed as stand-alone units, operating as the sole heating device in a home or building.[108] However, hybrid heating systems and all-in-one hybrid heat pumps can help overcome the challenges of particularly cold winter days, where heating demand is high but heat pump efficiencies are low.[109] They are particularly prevalent in Scotland, where average temperatures (and average minimum temperatures) are lower than in England and Wales. They also provide a potential solution in buildings with insufficient space for a hot water tank. Additionally, they are promoted by some manufacturers as a potential transitional solution in the retrofit market, allowing for some of the benefits of heat pumps while retaining the flexibility of gas in extreme conditions.[110] Hybrid heat pumps account for a small but growing share of the market, with sales increasing from 900 units in 2018 to 1,300 in 2019.[111]

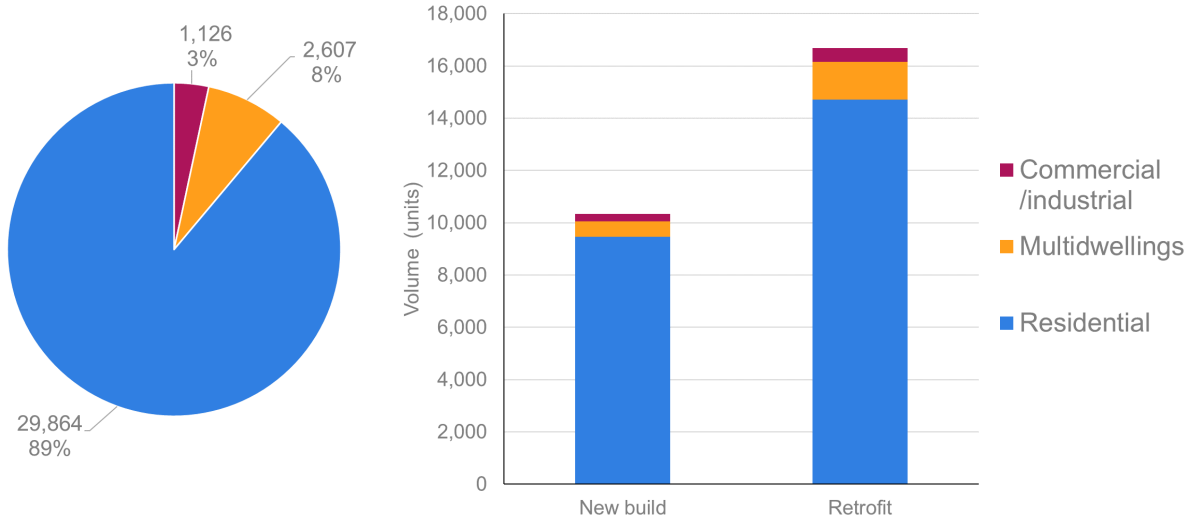
By Application

Figure **3-7** shows that 89% of the heat pump market by volume in 2019 was in the domestic sector (defined as one and two-family dwellings). In 2019, 38% of UK heat pump sales were for new buildings and 62% for retrofit (i.e. refurbishment or replacement).[112]

[107] Green Match (2019) How Much Noise Do Heat Pumps Produce?, accessed July 2020, available at https://www.greenmatch.co.uk/blog/2014/07/how-much-noise-do-heat-pumps-produce
[108] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/
[109] In this report a distinction has been made between hybrid heating systems, which have auxiliary heating such as a boiler separate from the heat pump (either in series or in parallel) and hybrid heat pumps where auxiliary heating is integrated with the unit itself.
[110] Department of Business, Energy & Industrial Strategy (2016) Evidence Gathering – Low Carbon Heating Technologies, Domestic Hybrid Heat Pumps, accessed July 2020, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/565241/Domestic_Hybrid_Heat_Pumps_-_FINAL.pdf
[111] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/
[112] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/

In comparison, in 2019 only 8% of UK boiler sales were for new build and 86% were for refurbishment or replacement.[113] Of this, over 80% of boiler sales were distress purchases for the replacement of a failed heating system.[114] [115] [116]

Figure 3-7: UK total ASHP/GSHP market share in 2019 by application (left chart) and 2018 volume of sales by application for both new builds and retrofit (right chart)



Given that there are already 26 million dwellings in the UK, and the vast majority of boiler sales are for replacement, the retrofit market represents the major growth opportunity for heat pumps in the long term. A key challenge for penetrating this market is that a failed boiler usually requires an immediate replacement, whereas heat pump installations tend to require more time, as well as ancillary changes (e.g. changing the radiators and control system) and often improved insulation. The time required to physically install an ATW heat pump may only be around 1-3 days[117] (compared with 1 day for a boiler),[118] but the time required for designing and planning the installation is often more extensive, although highly variable. Consequently, installing a heat pump tends to be much more involved than simply replacing a boiler.

Lockdown measures in the UK, as a result of the Coronavirus pandemic, have caused delays in construction in the new build market, which is seen as a key growth area for the

[113] Building Services Research and Information Association (BSRIA) (2019) Domestic Boilers (World Market for Heating Boilers 2019/R2019), 2019, https://www.bsria.com/uk/product/gDXQPB/domestic_boilers_world_market_for_heating_boilers_2019r2018_8a707622/

[114] Approximately 5.5% of boilers fail in any one year. The UK has 26 million installed boilers. Therefore, approximately 1.4 million boiler sales are for replacing a failed boiler. Total boiler sales are around 1.7 million per annum. Therefore, over 80% of boiler sales are distress purchases to replace a failed boiler.

[115] Boiler Guide (2019) Boilers on the Blink: UK Boiler Breakdown Study, 2019, https://www.boilerguide.co.uk/articles/uk-boiler-breakdown-study

[116] Building Services Research and Information Association (BSRIA) (2017) Global boiler market heats up as the UK is no longer the largest market, accessed 15 April 2020, https://www.bsria.com/uk/news/article/global-boiler-market-heats-up-as-the-uk-is-no-longer-the-largest-market/

[117] Green Match (2020) FAQs About Heat Pumps, accessed July 2020, available at https://www.greenmatch.co.uk/blog/2014/07/top-23-faqs-about-heat-pumps#:~:text=Usually%2C%20the%20process%20is%20completed,need%20to%20dig%20a%20borehole

[118] Home Servce (2020) How long does it take to fit a new boiler, accessed July 2020, available at https://www.homeserve.com/uk/living/heating-and-cooling/how-long-does-it-take-to-fit-a-new-boiler/

sector. However, stakeholders expected that sales will continue after the short/medium-term effects of the Coronavirus pandemic have passed.

Manufacturers recognised that ASHPs are currently favoured in the retrofit market, while GSHPs have a more substantial share in the new build market.

UK Policy and Commitments for Heat Pumps

Over the last decade, there has been a range of policies seeking to promote renewable heating technologies, such as heat pumps. Most significant was the introduction of the Renewable Heat Incentive (RHI), which has been followed by a number of other policies. In the March 2020 budget, the government outlined a handful of key funding commitments to support the UK's low carbon heat agenda to achieve net zero. These included an extension of the domestic RHI until 31st March 2022, and the introduction of the Clean Heat Grant Scheme and the Green Gas Levy. Most recently, in July 2020, the government announced the Green Homes Grant as a key part of its green economic recovery following COVID-19.

BEIS is planning to publish a Heat and Buildings Strategy in due course, which will set out the immediate actions that government will take for reducing emissions from buildings. These actions include the deployment of energy efficiency measures and low carbon heating as part of an ambitious programme of work required to enable key strategic decisions on how the mass transition to low-carbon heat is achieved and to set the UK on a path to decarbonising all homes and buildings.

The key policies supporting heat pump deployment in the UK (RHI, Green Homes Grant, Clean Heat Grant Scheme, and Future Homes Standard) are outlined below, as well as the government's Electrification of Heat Demonstration Project. Additional policies are outlined in Appendix A – 7: UK Policy and Commitment to Heat Pumps Continued

Renewable Heat Incentive

The domestic RHI has been extended for a further year and is now due to close to new applications on the 31st March 2022, maintaining support for heat pumps, biomass and solar thermal, ahead of the launch of the Clean Heat Grant Scheme. Recent announcements also included the introduction of a third allocation of flexible Tariff Guarantees to the Non-Domestic RHI in Great Britain on 20th July 2020. Tariff Guarantees help to provide investment certainty for larger and more cost-effective renewable heat projects. Applicants to the new allocation of Tariff Guarantees will be able to commission at any point until 31st March 2022, affording them an additional year following the scheduled closure of the Non-Domestic RHI. In addition, the government has introduced measures designed to aid projects that have been impacted by Covid-19 related delays, by increasing the deadline for commissioning new projects and accepting extension applications for projects under development that are not eligible for a Tariff Guarantee.[119]

Uncertainty surrounding the future of the RHI had been identified as a barrier to the more rapid growth of the ASHP market.[120] Furthermore, the chief cause for the decline seen in the GSHP industry is said to be uncertainty regarding the RHI and specifically the hiatus between the announcement of the policy and its delivery. Projects were delayed while potential investors waited for greater certainty regarding tariffs and eligibility. Reforms of

[119] https://www.gov.uk/government/publications/changes-to-the-renewable-heat-incentive-rhi-schemes
[120] Pathways to high penetration of heat pumps, Frontier Economics / Element Energy (report for the CCC) (2013).

the RHI in 2017 helped to remove uncertainty and led to an increase in heat pump installations in the last two years.[121]

Green Homes Grant

A £2 billion Green Homes Grant for domestic customers in England will come into effect at the end of September 2020 and run until March 2021.[122] Under the scheme, the government will fund up to two-thirds of the cost of home improvements of over 600,000 homes, via vouchers worth up to £5,000 for homeowners, including owner occupiers and social/private landlords. Households on low income can receive vouchers covering 100% of the cost of the improvements, up to a maximum of £10,000. The energy efficiency measures covered by the scheme include heat pumps (both ASHP and GSHP) and heating controls.

Beyond the RHI – Clean Heat Grant Scheme

The Clean Heat Grant scheme has been out for consultation.[123] The proposal includes up-front grant funding of up to £4,000 to install low-carbon heating technologies like heat pumps in domestic and small non-domestic buildings. This is a different funding system to the domestic RHI, which provides quarterly payments over seven years, after installation. Nevertheless, the scheme will follow on directly from the domestic RHI, thus coming into force in April 2022. It will be supported by £100m of Treasury funding for the two years of the scheme.

Future Homes Standard

Making a new home zero-carbon ready at the outset can be up to five times cheaper than retrofitting it later on.[124] The Future Homes Standard proposes that from 2025 fossil fuel heating systems in new homes will be banned. Further, in the recent Planning for the Future consultation, government announced that it intends to review the roadmap to the Future Homes Standard to ensure that implementation takes place to the shortest possible timeline.[125] New builds will incorporate world-leading energy-efficiency levels and will require low-carbon heating systems, such as heat pumps.[126] This will help provide market certainty for future heat pump demand in new builds, but it is worth recognising that the largest market for heat pumps in the UK is in retrofit.

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[121] Thornhvac (2019), Conditions ripe for UK Heat Pump market expansion, available at: https://www.thornhvac.co.uk/blog/2019/03/conditions-ripe-for-uk-heat-pump-market-expansion, accessed May 2020

[122] Department of Business, Energy & Industrial Strategy (2020), Quality assurance at heart of new £2 billion green homes grants, available at https://www.gov.uk/government/news/quality-assurance-at-heart-of-new-2-billion-green-homes-grants, accessed August 2020

[123] Department of Business, Energy & Industrial Strategy (2020), Future Support for Low Carbon Heat Consultation, available at: https://www.gov.uk/government/consultations/future-support-for-low-carbon-heat#:~:text=Consultation%20description&text=a%20Clean%20Heat%20Grant%3A%20support,green%20gas%20and%20buildings%20technologies, accessed May 2020

[124] Lord Deben, and Baroness Brown of Cambridge (2020) Letter: Future Homes Standard and proposals for tightening Part L in 2020, https://www.theccc.org.uk/publication/letter-future-homes-standard-and-proposals-for-tightening-part-l-in-2020/, accessed 30 June 2020

[125] Ministry of Housing, Communities & Local Government (2020), Open Consultation: Planning for the Future, available at: https://www.gov.uk/government/consultations/planning-for-the-future, accessed August 2020

[126] Ministry of Housing, Communities & Local Government The Future Homes Standard Consultation, accessed 2 June 2020, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/852605/Future_Homes_Standard_2019_Consultation.pdf

Electrification of Heat Demonstration Project

The Electrification of Heat Demonstration Project aims to demonstrate the feasibility of a large-scale roll-out of heat pumps in Great Britain in a representative range of British homes. The £14.6 million project will install and monitor 750 innovative heat pump systems across a range of different housing types, with the majority on the gas grid. Additionally, new products and services have been designed to overcome some of the barriers to deployment. [127]

Future Policy Focus

Despite the efforts to increase the demand for heat pumps, there are still several significant hurdles to overcome before widespread deployment of heat pumps can occur in the UK.

Commentary in the literature and from manufacturers during interviews often focuses on increasing heat pump demand, as opposed to supply-side issues. Some of the key demand issues identified include:[128]

- higher up-front costs associated with the technology than with alternatives;
- a low level of awareness, understanding and experience of the technology; and
- the competence and availability of installers to install heat pumps.

The most critical barrier to overcome is the initial capital outlay. The recent budget announcement of a new Clean Heat Grant scheme to support consumers and small businesses with the upfront cost of heat pumps is welcomed by industry and is a positive step for boosting uptake.

In Scotland, the Energy Saving Trust launched the Home Energy Scotland Loan. The scheme offers a loan of £17,500 for renewable energy systems and a maximum of £32,500 per home for a range of energy efficiency improvements. There are further schemes available such as the Warmer Homes Fund in Scotland[129] and the Arbed am Byth Scheme in Wales.[130] These schemes are helpful and could be emulated across the rest of the UK; [131] the recent announcement of the Green Homes Grant aims to provide similar support in England.

[127] UK Government (2020) Electrification of Heat Demonstration Project, accessed July 2020, available at https://www.gov.uk/guidance/electrification-of-heat-demonstration-project#project-delivery
[128] Sustainable Energy Association (2019), Installer Survey Results October 2019, available at: https://www.sustainableenergyassociation.com/resources/installer-survey-results-october-2019/, accessed June 2020
[129] Energy Saving Trust (2019), HEEPS: Warmer Homes Scotland Scheme, available at: https://energysavingtrust.org.uk/scotland/grants-loans/heeps/heeps-warmer-homes-scotland-scheme, accessed June 2020
[130] Welsh Government, Arbed Am Byth Cymru (2019), available at: https://gov.wales/atisn13378 accessed June 2020
[131] Cambridge Econometrics and Element Energy (2018), A study on Low Carbon Value Chains and Economic Growth, available at: https://www.camecon.com/wp-content/uploads/2018/12/YNYER-Low-Carbon-Value-Chains-and-Economic-Growth-Final-Report.pdf, accessed June 2020

Heat Pump Manufacturing

Key Global Heat Pump Manufacturers and Their Locations

Manufacturers have been classified into Tier 1 (heat pump manufacturers or assemblers) and Tier 2 (the component supply chain). The key Tier 1 manufacturers in the global market are shown in Table 3-2 (see also Appendix A - 9: Global and UK key Tier 1 and Tier 2 manufacturers, which includes all key players mentioned in this report). The key Tier 1 manufacturers are all headquartered in either China, Japan, the US, Germany, the Republic of Ireland or Sweden; none of them have head offices in the UK. In addition, only Mitsubishi has a manufacturing facility in the UK, predominantly serving the UK and European markets. Out of the twelve manufacturers listed in the table below, the leading heat pump market vendors are Carrier, Daikin, Mitsubishi and NIBE.[132]

Table 3-2: Key Tier 1 manufacturers in the global market and the countries in which they are headquartered and manufacture products. In this table, 'global' manufacturing location means many (i.e. 10+) manufacturing plants.[133]

Key Tier 1 Manufacturer	Country of Origin/ Head Office	Country of manufacture[134]
Carrier	USA	USA, Global
Daikin	Japan	Czech Republic, Belgium, Italy
Dimplex	The Republic of Ireland	Germany
Ingersoll Rand	The Republic of Ireland	Global
Midea	China	China
Mitsubishi Electric	Japan	Livingston (UK), Japan, Global
NIBE	Sweden	Sweden
Panasonic	Japan	Czech Republic
Stiebel Eltron	Germany	Germany, Slovakia

[132] Technavio (2016) Top 5 Vendors in the Global Heat Pump Market from 2016 to 2020, accessed June 2020, available at https://www.businesswire.com/news/home/20160929005481/en/Top-5-Vendors-Global-Heat-Pump-Market
[133] MarketsandMarkets (2018) Heat Pump Market Report | Size, Share, Growth, Forecast – 2023, 2018, https://www.marketsandmarkets.com/Market-Reports/heat-pump-market-153294991.html
[134] Country of manufacture added by Eunomia from internet searches and market intelligence gathered through interviews.

Key Tier 1 Manufacturer	Country of Origin/ Head Office	Country of manufacture[134]
Thermia	Sweden	Sweden
Vaillant	Germany	Germany
Viessmann	Germany	Germany, France, Turkey

Key UK Manufacturers

Air Source Heat Pumps

33 manufacturers have been identified as active in (i.e. having a share of) the UK heat pump market (this includes manufacturers with a market share of less than 1%).[135] Four companies manufacture ASHPs in the UK including, Mitsubishi, Global Energy Systems, Big Magic Thermodynamic Box and Star Renewables, including ATW, ATA heat pumps, industrial ammonia heat pumps and air conditioning units.[136] Furthermore, Ground heat do kit assembly of Heliotherm heat pumps. The market is dominated by three organisations, with Mitsubishi, Daikin and Samsung accounting for a combined 54% of annual sales in the UK in 2019. The rest of the market is distributed among over thirty firms.

Fifteen of the manufacturers (who account for around 40% of ASHP units sold) also sell boilers.[137] See Table 3-3 below for the market share of key UK players in both the boiler and heat pump market. Currently, only Vaillant offer a hybrid heat pump (one unit) to the UK market, however other manufacturers have hybrid products in development for the UK market.

Table 3-3: The market shares of manufacturers who make both boilers and heat pumps sold in the UK.

Manufacturer	Boiler market share	ASHP market share	GSHP market share
Worcester Bosch	~30%	1-5%	1-5%
Vaillant	~20%	1-5%	6-10%
Ideal	~16%	<1%	-

[135] We acknowledge that there may be some manufacturers who we weren't able to identify
[136] Star Renewables manufacture heat pumps in the UK, however they largely concentrate on making WSHPs for international clients; their UK ASHP, GSHP market shares are negligible.
[137] This includes Nibe, Dimplex, Enertech (CTC), Earth Save, Ecoforest, Daikin, Vaillant, Viessmann, Vokera, Worcester Bosch, Grant, Firebird, Ariston, Elco and Toshiba Carrier.

Manufacturer	Boiler market share	ASHP market share	GSHP market share
Baxi	~15%	<1%	-
Viessman	2%	1-5%	1-5%
Vokera	2%	<1%	-
Ariston	1%	1-5%	-

Ground Source Heat Pumps

17 manufacturers were identified as competing in the UK GSHP market.[138] Only one organisation (Kensa) manufactures GSHPs in the UK.[139] As with the ASHP market, the GSHP market is highly concentrated, with two firms (Kensa and NIBE) accounting for 57-65% of the market. Vaillant has an estimated 6-10% market share, another 12 firms have 1-5% market share each, and there are an unknown number of manufacturers which together make up roughly 11% of the GSHP market. Of the 17 firms identified, just three (Vaillant, Viessman and Worcester Bosch), who account for around 12% of GSHPs sold, are also active in the fossil fuel boiler market.

Location of Manufacture

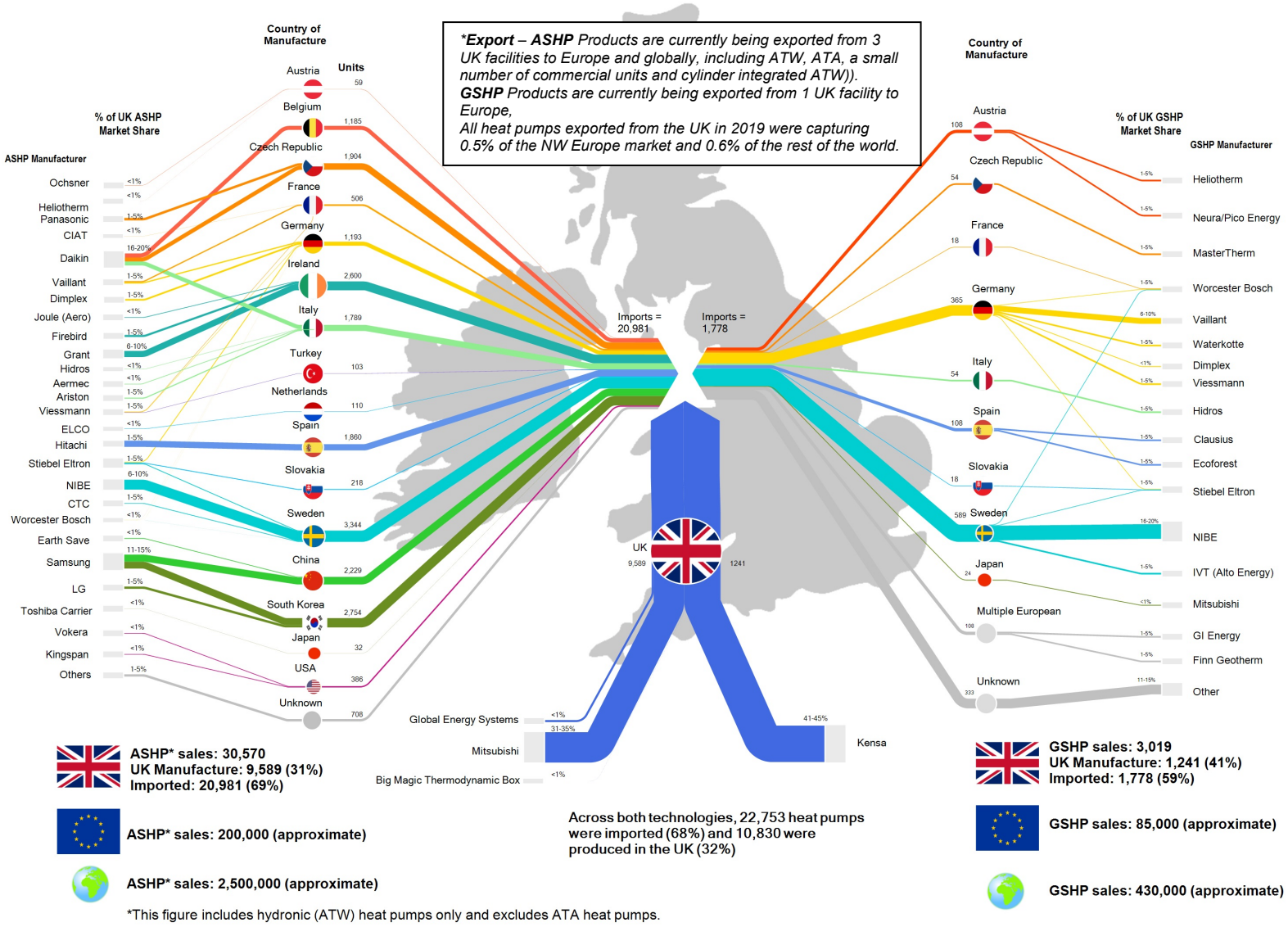
Approximately 69% of the ASHP units and 59% of the GSHP units installed in the UK are imported (68% across both ASHP and GSHP). The remainder of units installed in the UK are manufactured in the UK, approximately 31% of the ASHP units, and 41% of GSHP units (32% across both ASHP and GSHP).

The BSRIA market share data, combined with confirmed market share data from interviews, show that the largest manufacturers in each of the sectors have a market share of >30% alone. Both of these firms manufacture their products in the UK (Mitsubishi – ASHP and Kensa – GSHP). Figure 3-8 shows the market volume of the manufacturers who sell heat pumps in the UK market, as well as their country of manufacture.[140]

Furthermore, Figure 3-9 at the end of this section provides a summary of the market share and products for some of the key heat pump manufacturers in the UK.

[138] We acknowledge that there may be some manufacturers who we weren't able to identify
[139] Star Renewables manufacture heat pumps in the UK, however they largely concentrate on making WSHPs for international clients; their UK ASHP and GSHP market shares are negligible.

Figure 3-8: UK 2019 ASHP (left) – ATW and GSHP (right) – GTW Market Shares and Units Sold[141]



[141] The ASHP and GSHP parts of the diagram are not to relative scale: the GSHP market is significantly smaller.

Of the imported ASHPs, the majority (approximately 73%) come from elsewhere in Europe (LG and Samsung, Toshiba Carrier and Earth Save Products are the only companies to import from a manufacturing site in Asia, and Kingspan and Vokera from the US). The story is similar for GSHPs, where nearly all imports come from manufacturing sites elsewhere in Europe. Only one GSHP provider has been identified as importing from outside of Europe: Mitsubishi manufactures their commercial GSHP in Japan for the UK market and represents less than 1% of the market. The largest ASHP manufacturer in the UK, Mitsubishi, manufactures its Ecodan ASHP's, including both ATW and ATA models, and split and monobloc systems in Livingston, Scotland. This factory also supplies the Ecodan model to all of Europe and internationally.

The principal channels of heat pump sales described by manufacturers included selling to wholesalers and selling direct to installers. Some interviewees stated that there is little effort put towards selling directly to individual consumers, and limited attempt to sell to building contractors. There is variation in the sales channels of manufacturers, as some go initially through a distributor, who then sells the heat pump to an installer or specifier, while some market directly to large customers like house-building companies. One interviewee stated that the currently low sales volumes of heat pumps are not financially "*interesting*" to distributors, and that distributors have "*stepped back*" from the heat pump market somewhat. Another, larger, manufacturer, said it goes *"100% through the distributor channel",* but anticipates that as the market grows it will go directly to clients like social housing companies; other interviewees echoed this. One large manufacturer stated that *"brand awareness, lead generation, education is what we are about to start focusing on."*

UK Export

The UK is currently exporting heat pumps (ATA, ATW and GTW) across Europe, in particular to France, the Netherlands and the Republic of Ireland, as well as to countries further afield such as New Zealand. These exports in 2019 captured 0.5% of North-western Europe heat pump markets and 0.6% of the rest of the world.[142] These exports include, but are not limited to ASHPs manufactured in Livingstone by Mitsubishi, GSHPs from Kensa's Cornish facility and Star Renewables also exports their large commercial and industrial scale WSHPs and ASHPs globally, primarily serving district heating networks, for example to Norway.

The Energy Innovation Needs Assessment (EINA) report produced for BEIS (when the UK's 2050 emissions reductions target was 80% and the Net Zero target had not yet been implemented) found that a Gross Value Added (GVA) from exporting heat pumps and related technologies could feasibly be £500 million by 2050 (based on 210,000 heat pumps and 3,000 commercial HVAC systems), in a future where the UK captures about 10% of the EU's market.[143] Given this assessment of the value of export from UK manufactured heat pumps, there is a demonstrable ability for UK manufacturers to capture the economic benefit of exporting heat pumps. Export potential is further discussed in the later section - Potential for Growth in the UK Heat Pump Supply Chain.

[142] BEIS and Vivid Economics (2019) Energy Innovation Needs Assessment: Heating & Cooling, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/845657/energy-innovation-needs-assessment-heating-cooling.pdf, accessed June 2020
[143] Ibid.

Figure 3-9: Summary of the market share and products for key heat pump manufacturers in the UK market

Mitsubishi Electric

UK heat pump manufacturing (ASHP only)

ASHPs, GSHPs, and WSHPs

Mitsubishi has been in the heating/cooling market for decades (notably as one of the world's largest air conditioning manufacturers) and has a 31-35% share of the UK ASHP market in 2019. It is headquartered in Japan but migrated manufacture of its air to water (Ecodan) range to Livingstone in Scotland in 2009. Ecodan is its principal heat pump product line in the UK, which is available between 4-14kW. The Livingston factory distributes Ecodan not only to the UK but supplies all of Europe as well. In contrast, Mitsubishi's GSHP market share is <1% in the UK, which is a commerical offer.

Kensa

UK heat pump manufacturing

GSHPs

Kensa is a UK-based company with manufacturing facilities in Cornwall. Established in 1999, they dominate the GSHP market with a 41-45% market in 2019 being nearly twice as much as their nearest competitor. Kensa offer three product ranges, all of which are GSHPs; Kensa do not manufacture ASHPs.

Samsung

No UK heat pump manufacturing - China and South Korea

ASHPs and GSHPs

Samsung is the third biggest of the major manufacturers of ASHPs active in the UK, with a 11-15% share of the market in 2019. Ubiquitous across a range of consumer products, Samsung has long been active in the air conditioning space. Their three heat pump products have both heating and cooling functionality and are imported from Asia. Similarly, to Daikin, Samsung's share of the GSHP market is minimal compared to its share of the ASHP market, at less than 1%. Manufacturing occurs at two sites, one in South Korea and one in China. These are very large manufacturing facilities: the Korean R&D department (focusing on all technologies, not solely heat pumps) has 35,000 employees alone.

Daikin

No UK heat pump manufacturing - Czech Republic, France, and Italy

ASHPs, GSHPs. WSHPs and Hybrids

Daikin has the next largest share of the ASHP market at 16-20% in 2019. Its European headquarters are in Belgium, but manufacturing mainly takes place in the Czech Republic and France, with a small proportion in Italy. They offer 29 variants of heat pump, ranging from 3-39.2kW. Like Mitsubishi, Daikin has a long history of producing air conditioning products. Daikin's share of the UK's GSHP market is less than 1%. Daikin also have a hybrid heat pump offer, 'Altherma'.

NIBE

No UK heat pump manufacturing - Sweden

ASHPs and GSHPs

NIBE (including Enertech Group) are the other major manufacturer in the UK's GSHP market and account for a 16-20% share in 2019. NIBE's manufacturing facilities are primarily based in Sweden, with some manufacturing in Norway. NIBE has a larger product range than Kensa with five GSHP variants, and they also manufacture ASHPs, predominantly ATW (rather than ATA). However, they have a minimal market share in the UK ASHP market, as they do not promote the range in the UK at the moment; it's only available in Sweden. NIBE does provide an ATA unit that bolts on the top of the GSHP European range and provides ATA facility. It supplies primarily into the domestic market in the UK, but also into the commercial market.

Vaillant

No UK heat pump manufacturing - France and Germany

ASHPs, GSHPs, WSHPs and Hybrids

Vaillant, which is based and manufactures in Germany, is the next largest manufacturer of GSHPs in terms of UK market share (6-10% in 2019). Vaillant also has a reasonably high market share for ASHPs in the UK, estimated between 1-5% in 2019. Vaillant also have a hybrid heat pump offer, 'The aroTHERM'.

Stiebel Eltron

No UK heat pump manufacturing - Slovakia, Sweden, and Germany

ASHPs and GSHPs

Stiebel Eltron is based and manufactures in Germany; Sweden and Slovakia have a UK market share of 1-5% in 2019 in both the ASHP and GSHP markets.

Strengths and Weaknesses of Heat Pump Manufacturers Serving the UK the Market

Manufacturers outlined some of the strengths and weaknesses that they perceive with regards to their businesses within the UK market, other heat pump manufacturers, and other heat technologies. These perceived strengths and weaknesses are outlined in Table 3-4. A limited number of weaknesses were volunteered.

Table 3-4: Strengths and Weaknesses of Heat Pump Manufacturers Serving the UK the Market

Theme	Strengths	Weaknesses
Product Range	Small manufacturers can specialise their products to specific markets and their environmental conditions. For example, whilst it is easy to turn an air-conditioning unit manufactured in Asia or Spain into an ASHP, it is not necessarily best suited to a climate where there is a lot of cold weather. A more suited design would, for example, have anti-freeze cycles that are built into the heat pump because these are a necessity in Scandinavia. The equipment and the controls regime that is applied protect the product against adverse weather conditions. [Scandinavian Manufacturer] Similarly, smaller manufacturers can provide niche solutions. Strengths of one include offering: • A mix of hybrid solutions. The combination of air-water with ground source, with solar PV, wind, hydropower, or fossil fuel. • Simultaneous heating and cooling systems. • Full modulating inverter technology which better controls the compressor output to match the heat demand requirements of the building as the outdoor air temperature changes. • Sophisticated software to combine all of these different aspects into one system. [Small European Heat Pump Manufacturer]	Small manufacturers often have gaps in product ranges. It can, therefore, be difficult to compete with Asian suppliers. [Scandinavian Manufacturer] The UK market has some idiosyncrasies that are not shared by wider markets, for example F-gas registered installers are less prevalent in the UK, so monobloc sealed units, which do not require F-gas competence, are favoured. However, European manufacturers, for example, tend to produce split systems that allow the fan to be positioned further from the house, so reducing noise. In Europe, F-gas certified installers are commonplace, so this is not an issue. [Large European Manufacturer]

Theme	Strengths	Weaknesses
	Large manufacturers benefit from their scale. Long term product development has led some to supply quality, efficient products with a good coefficient of performance (although it should be noted that COP stated by manufacturers are measured under test conditions and should therefore be treated with caution). Quality is also beneficial from a warranty point of view, with some manufacturers offering up to 7 years warranty if installed by one of its qualified engineers. Large manufacturers also benefit from their size as they can offer most types of solutions, and they have the capability to supply and support at scale. [Large Asian Heat Pump Manufacturer, Large UK Boiler Manufacturer and Large European Heat Pump Manufacturer] Local manufacture allows the development of more bespoke solutions, e.g. coastal variant ASHP with higher corrosion resistance as well as products with higher capacity and higher temperature, to suit UK housing stock. [UK Manufacturer]	
Agility	Small companies can be reactive in looking for market opportunities and acting on them. Hence looking for an alternative to F-gas, and providing options with propane or carbon dioxide. [UK Heat Pump Supplier]	Development of new technologies and systems requires significant expertise and investment, which can be challenging for smaller companies. [Eunomia observation]
Innovation	Innovative and more environmentally friendly refrigerants can be deployed in the UK market. These refrigerants also have other advantages such as working at high pressures which means they can deliver higher temperatures to the heating circuit, which in turn means less upfront cost to the consumer in changing radiators and other ancillary equipment. There are also benefits associated with lower servicing and maintenance requirements. [Large Asian Heat Pump Manufacturer, Large	The majority of R&D is currently undertaken overseas, with a number of the manufacturers having large, established R&D facilities outside of the UK. This means increased R&D in the UK is likely to be limited. [Large European and Asian Manufacturers]

Theme	Strengths	Weaknesses
	International Boiler Manufacturer, and Scandinavian Manufacturer] Some manufacturers are investing heavily in hydrogen (and undertaking R&D on hydrogen boiler/ heat pump hybrids) as a potential for decarbonising the gas grid, along with heat networks, in particular, the associated plant rooms and heat interface units. [Large UK Boiler Manufacturer]	
Brand	Several manufacturers in the heating systems market recognised that they have a strong brand presence in UK domestic heating products and are widely recognised by consumers. This provides an opportunity for them to gain a larger market share in the UK heat pump market through their reputation and brand recognition. [Large Boiler Manufacturers]	
UK housing stock and heating requirements	Several manufacturers considered their understanding of the UK house, the heating and ventilation system, heat pump solutions, and how to integrate them so they work together rather than work against each other, as a key strength. [Large International Boiler Manufacturer and Small UK Company Manufacturing in China] Innovative control systems to deploy the benefits of heat pump technology while retaining existing heating systems to cope with peak load have been developed as an interim solution ideal for large and inefficient UK housing stock [UK systems developer].	Some manufacturers struggle to see much of a future for heat pumps in the retrofit sector unless there is an accompanying massive energy efficiency improvement. That market is therefore not seen as a priority at present. [Large Boiler Manufacturer]
UK installer-base relationship	Existing boiler manufacturers have the advantage that they have the contacts with the installers, and it will be boiler installers who will have to be converted to heat pump installers when the market transitions. [Large UK Boiler Manufacturer]	

Source: Based on interviews with heat pump manufacturers operating in the UK market.

Three case studies, of Kensa Group, Mitsubishi Electric, and Star Renewable Energy (UK manufacturers of GSHPs, ASHPs, and commercial-scale WHSPs and ASHPs, respectively)

have been included below. These case studies have been included to demonstrate UK manufacture across different heat pump types and different applications, to draw on the benefits brought to the UK from these facilities and products, and to outline the opportunities and challenges for these heat pump manufacturers in a UK setting.

UK Manufacturer Case Studies

Kensa Heat Pumps

Kensa Group (Kensa Heat Pumps)

Mount Wellington Mine, Truro

Ground Source Heat Pumps and associated products

Employs around 100 people at present (25 in manufacturing) with numbers set to increase depending upon the outcome of Government policy.

Kensa is privately owned by its founders and key staff. In April 2020 Legal & General Capital (LGC) took a 36% stake in the Kensa Group.

Founded in 1999, Kensa Heat Pump remains the UK's sole manufacturer of a full range of ground source heat pumps. In 2012, Kensa Contracting Limited (KCL) was established to handle larger scale installations typically involving social housing retrofit or new build projects. Kensa Heat Pumps also sells to other installers and provides industry-leading technical support to embrace new entrants to the renewables market. Kensa is the long-established UK market-leader according to BSRIA annual reports with a 41-45% market share.

Overview

>**Products Manufacturing:** It offers a wide range of outputs between 3kW (with its Shoebox model) to 75kW (Plant Room range): Shoebox, Shoebox Twin, Evo, Twin Compact and Hybrid, Commercial Plant Room. The Shoebox model is the world's smallest and quietest ground source heat pump. They aim to make their products simple to install and use. All of Kensa's commercial buildings are heated using Kensa ground source heat pumps, utilising water in a disused mine shaft below the site.

>**Jobs Roles:** Full range including R&D, business development, finance, production and project management.

>**Number of Units Producing (Installations)**: 2019 sales around 1500 units with inbound orders (for installations in 2020 and beyond) significantly exceeding this number. Around 5% of turnover is for export.

>**Sales Model**: 50% annual production sold to KCL; 50% sold to other installers (including a small element of export sales to Holland and New Zealand). Products installed into existing social houses and new dwellings for social and private sectors. Also sales to self-builders in off-gas grid locations. Offering zero cost ground arrays which are funded, owned and maintained by Kensa Utilities.

>**Supply Chain:** Compressors from Northern Ireland and France; heat exchangers from Sweden and Croatia; controls previously from Italy but switching to a UK source. Significant efforts to buy 'local' but specialist components (e.g. compressors) only available from a limited number of global sources.

>**Skilling of Workforce:** Link with Exeter College to train installers and host their own knowledge hub online.

>**R&D Activities:** Significant activity – 7 staff – but commercially confidential.

Growth of the business (opportunities): Looking to expand activities in new build residential sector and accelerate programmes at social housing properties where the removal of direct electric heating systems results in far lower running costs and carbon emissions. Expansion of their new factory to supply 30,000 GSHPs per annum, a ten-fold increase in production levels. Developing zero-cost ground arrays for new build and in early stages of developing "heat as a service" offering by combining heat storage, time-of-use tariffs and smart controls into a package that delivers superior outcomes to a gas boiler.

Manufacturing challenges/risks/barriers for the business growth: Future government policy, Covid-19 and the strength of the fossil fuel lobby.

"With significant inward investment, the company is well-positioned to grow rapidly, provided that Government is able to recognise the unique advantages of our heat pump variant. GSHPs are more efficient, more reliable and more durable. They are unobtrusive and quiet. And they can contribute far more significantly to load-shifting initiatives.The ground array should be regarded as vital national infrastructure as it will deliver heat for generations" **Simon Lomax, CEO of the Kensa Group**

Mitsubishi Electric

Mitsubishi Electric

Livingston Scotland, Japan, China and Thailand (compressors)

Air conditioning, Chillers, Ventilation, IT cooling, Heat Pumps and Controls

Mitsubishi employs 146,518 globally, and 1,300 people at their plant in Livingston Scotland

Public Limited Company

Originally founded in 1921, the company known today as Mitsubishi Electric has almost 100 years of experience in providing reliable, high quality products and support to installers, specifiers, corporate clients and general consumers all over the world. Mitsubishi believe that the need to change touches all those involved in the development and renovation of building stock, both commercial and domestic. As well as increasing the efficiency of the fabric of buildings, new technologies and new ways of thinking are needed which is why their overriding philosophy and innovative solutions position Mitsubishi as market leaders.

Overview

>**Products Manufacturing:** The Livingston site has been manufacturing air conditioning units since 1994 and began manufacturing air source heat pumps in 2009. The heat pump range produced at this site is called Ecodan. These are quiet, monobloc, air to water heat pumps that are designed specifically for UK ambient conditions, and work at temperatures down to -25°C. Ecodan monobloc systems offer a capacity range from 5 through to 84kW and have a hybrid function, for use with conventional boilers, if needed. Ecodan are also designed specifically for UK planning regulations, they are MCS certified and are the only UK-manufactured heat pumps to receive the prestigious EU Ecolabel for good environmental credentials. The Ultra Quiet Ecodan also won first place in the 2019 H&V News Awards for 'Domestic HVAC Product of the Year – Heating Units'. The Ecodan monobloc range includes models that can be used for commercial or residential applications, new build or retrofit.

>**Jobs Roles:** The Livingston site employs 1,300 people, 1,100 are in production activities, 16 in design development, and others in support services.

>**Types of units produced:** The Livingston plant commenced life with the production of ATA units and over the last 10 years has expanded into the ATW market. Originally supplying an 8.5kW unit for the UK market with the rest of the models built in Japan. As the ATW market has grown more models are now produced here ranging from 5kw to 11.2kW representing the majority of the range available in the UK. In addition, packaged type cylinders are also produced in a dedicated factory on the same site.

Growth of the business (opportunities): With the UK's binding carbon reduction targets and the electricity grid rapidly decarbonising, heat pumps offer the perfect solution to providing heat and hot water to our homes to help achieve net zero by 2050.

Manufacturing challenges/risks/barriers for the business growth: Heat pumps are an option as a well-established technology that offers immediate and substantial carbon savings compared to the heating systems being used currently. However without consumer acceptability, a large installer base and government support in terms of public knowledge and incentives, there are risks that ATW heat pumps do not become a mass market product.

>**Sales Model**: To new build housing developers, housing associations (new build and retrofit) and direct to installing contractors who supply to consumers.

>**Manufacturing process/site operations:** The Livingston site has R&D, design and manufacturing operations located together, which puts Mitsubishi in a strong position to respond to the demands of the European market.

>**Supply Chain:** Compressor and printed circuit boards come from Japan. Structural materials, such as copper pipework, evaporator coils, and aluminum panels, mainly come from Europe, particularly Poland, Croatia and Slovenia. Cylinders come from UK suppliers that build products in UK but source their components from Europe.

>**Skilling of Workforce:** Mitsubishi offers three separate one day training courses for heating engineers, plumbers and electricians, that are specific to Ecodan heat pumps and can be applied for either new build or retrofit market. The three courses are (1) design and application, (2) installation and commissioning, (3) service and fault findings. There is a fourth course (called 'applied products') and is for non-domestic Ecodan applications.

>**R&D Activities:** The majority of R&D is done at the Mitsubishi Research Institute in Tokyo, Japan. However, the Mitsubishi Electric R&D Centre Europe (MERCE) was established to create a centre of design excellence outside Japan that better caters for the European market. MERCE has two locations, one in Rennes, France and one in Livingston, UK.

"Heat pumps are the only solution that fully buys into the greening of the grid and so become more attractive from a strategic point of view as the grid becomes cleaner, moving new models of our air to water production to Livingston will ensure we are in the best position to supply the UK ATW product on the road to net zero 2050" **Donald Daw, Deputy Product Marketing Director - Europe**

Star Renewable Energy

Star Renewable Energy

12 sites across the UK. Headquarters in Glasgow.

Large ammonia Heat Pumps for cities with emerging opportunities in very high temperature heat pumps for industrial steam replacement (120°C). Core business is industrial refrigeration.

354 employees across design, manufacturing, sales and aftercare

Limited company

Star Renewable Energy (SRE) was established to recognise the growing interest in this area of Star Refrigeration's work. SRE at this stage is focussed on heatpumps although other forms of low carbon or alternative energy may be added to the unit. Heatpumps were picked because in the quest for total decarbonisation of the existing buildings there will need to be scalable techniques that are compatible with a clean air environment. Rivers and the sea offer an infinite source. The question is then around heat offtake surety, power supply and fundability. Solve these and the potential for all UK cities to be decarbonised will be realised with immense upside in employment, air quality and reduced levels of fossil fuel imports whilst offering a flexible demand for power. This will support the continued roll-out of offshore wind and auxiliary electrification, e.g. EV/H2 charging stations on shared spur with big heatpumps.

Overview


Drammen in Norway


Queens Quay Equipment

>**Products Manufacturing:** Ammonia heatpumps, typically water source and specializing in foul water e.g. rivers/sea. Although, at large sizes, the cold air dissipation is a problem which is not yet understood/evaluated. These products are for UK applications as well as for export globally.

>**Jobs Roles:** Design, manufacturing, sales and aftercare.

>**Number of Units Producing (Installations)**: 3 in 2020 (UK).

>**Sales Model**: Directly to market, installers and finance teams.

>**Supply Chain:** Most components are European. Around 50% of sales value.

>**UK Value Added:** Design.

>**Skilling of Workforce:** Large effort to upskill consultancies and large investment in "knowledge sharing" with government, universities and students.

>**R&D Activities:** Ongoing. Investment in simplifying water abstraction options.

Growth of the business (opportunities): SRE focus on clean heat to existing buildings and city areas as this is the bulk of the nation's carbon footprint. They recognise the increasing focus being placed on clean air. However, with the end of the RHI (proposed replacements will not lead to any activity in their segments) they expect the market to fail unless gas is rapidly phased down. Upward taxation on gas might help but ultimately, new markets emerge from either an uplift in consumer value (which is very hard when gas is cheap and promoted/accepted as clean) or by legislation to undermine the status quo.

Manufacturing challenges/risks/barriers for the business growth: Significant capacity once initiated, but there are funding limitations due to lack of clarity, lack of surety of heat offtake and barriers such as non-domestic rates and planning rights for district heating.

"Heatpumps offer lower carbon, lower cost and lower NOx emission heat. Now we can reach over 80ºC they aren't just for ultramodern buildings." **Senior employee, Star Renewable Energy**

"We need to deploy proven (and scalable) technologies, that have a minimal air quality impact to shift away from the unabated burning of fossil fuel." **Dave Pearson, Director, Star Renewable Energy**

Summary Findings – Heat Pump Market Analysis

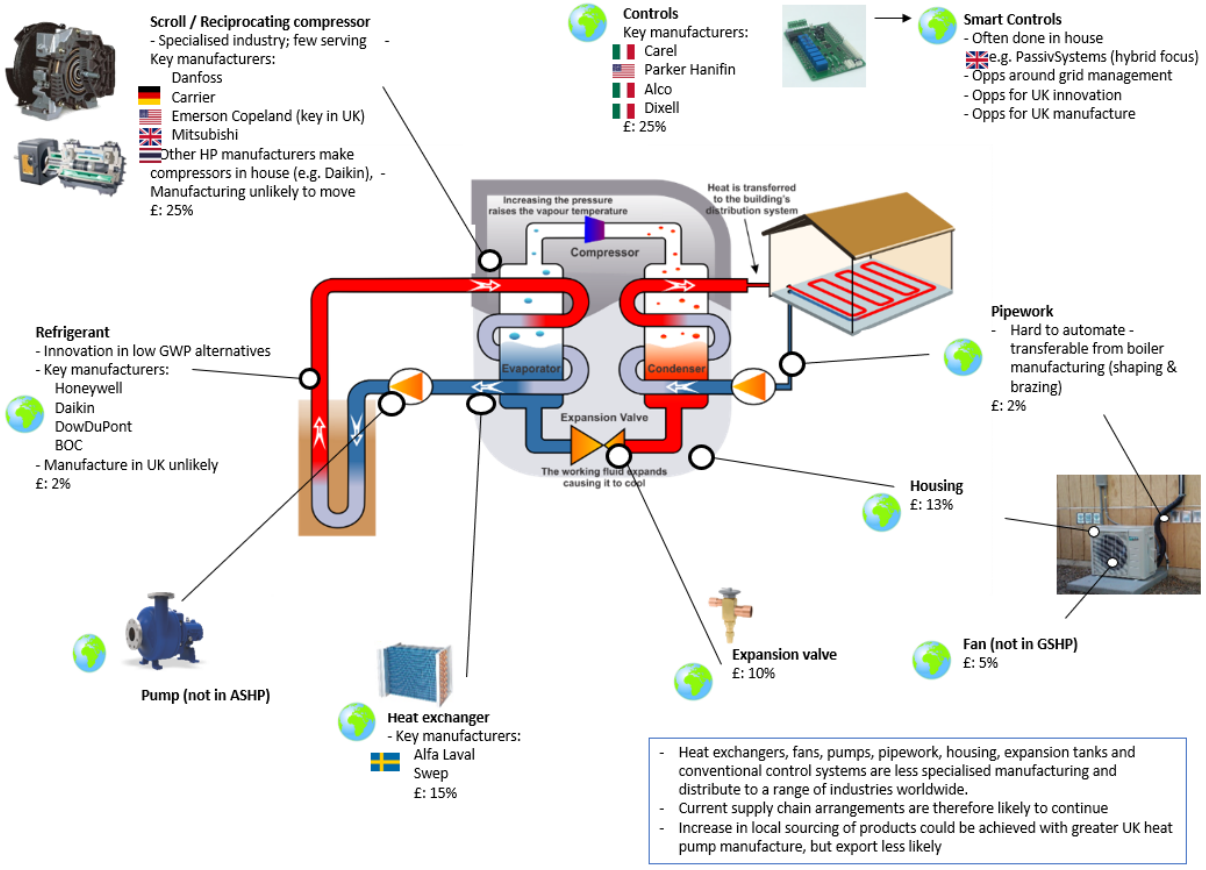
- Heat pumps currently represent a small proportion of heating systems installed in the UK. In comparison with Europe and the rest of the world, the UK accounts for ~15%, and ~1% respectively of ATW heat pump sales, and ~4% and ~1% of GTW heat pump sales.
- In 2019 nearly 35,000 hydronic heat pumps (including hybrids) were sold in the UK – a 24.3% increase on 2018, and an 85% increase since 2016. A majority of these (62%) were in retrofit applications, with the remaining 38% in new-build installations.
- Hydronic systems (ATW, GTW and WTW) dominate heat pump deployment in the UK, with limited deployment of ATA. ASHPs represent 87% of overall units, with GSHPs and WSHPs being responsible for 9% and hybrids accounting for the remaining 4%. ASHPs perform more strongly in retrofit the market, and GSHPs in the new-build market. Monobloc systems have the greatest ASHP market share at 69%, with split systems being responsible for 12%.
- One of the most comparable heat pump markets to the UK market is the Netherlands, due to the similar climate and reliance on natural gas for heating. In 2018 the number of heat pump sales were five times greater per one thousand households than the UK market. Key policy in place to support this growth included a reduced levy on electricity, an increased levy on gas, subsidised upfront heat pump unit and installation costs.
- Other comparable markets include France, Germany and Scandinavia, who have all had successful heat pump deployment when compared to the UK, however these are either operating in dissimilar climates and/or less dominate gas grids. The French scheme in particular has witnessed recent growth, with a fivefold increase in uptake between 2014 and 2018, driven by financial incentives.
- There is a wide range of manufacturers serving the UK heat pump market, comprising predominantly overseas manufacturers. UK-based manufacturers produced an estimated 31% of ASHP units and 41% of GSHPs units installed in 2019 (32% across both ASHP and GSHP). The two main UK manufacturers for these two technologies, Mitsubishi and Kensa, are located in the UK. Mitsubishi serves the UK and European ASHP market for domestic and non-domestic applications, while Kensa serves the UK GSHP market, particularly social housing providers and developers.
- Heat pumps are being exported from the UK across Europe and to New Zealand. A large proportion of these exports are ASHPs and a small proportion are GSHPs, both capturing 0.5% of North-west Europe markets and 0.6% of the rest of the world.
- The UK’s heat pump supply chain supported an estimated 2,000 full-time jobs needed to build, install and maintain heat pumps in 2019.

4) Tier 2 Component Parts Market Analysis

Section Aim: This section outlines the market for the components of heat pumps in the UK and describes some of the key manufacturers for the UK heat pump market. This is required to understand the possibility of future bottlenecks (see: Supply-side Dynamics) in heat pump manufacture, should there be a rapid increase in demand in the UK and globally. Understanding this market further enables opportunities and risks to UK manufacture to be identified. The key findings from the literature review, supply chain mapping and manufacturer interviews are detailed in this section.

The section below describes some of the key Tier 2 manufacturers identified in the UK heat pump market (see also Appendix A - 9: Global and UK key Tier 1 and Tier 2 manufacturers for a full list of manufacturers). Figure 4-1: provides an overview of the major heat pump components, where they are manufactured and the typical percentage that each component contributes to the overall cost (£) of manufacture.

Figure 4-1: A diagram of a GSHP with the major components labelled, supplemented with the component variation associated with an ASHP[144]



144 Sources: http://www.nzgeothermal.org.nz/ghanz_heatpumps.html, https://www.awcompressor.com/reciprocating-compressor.html, https://www.aliexpress.com/i/33059694545.html, https://ph.parker.com/us/en/thermostatic-expansion-valve-sporlan-type-o, https://www.pinterest.co.uk/pin/220465344237959721/

Refrigerants

All heat pumps work on the same principle: using a refrigerant at a temperature below ambient to absorb heat, then compressing it to raise the temperature above that of the medium to be heated (such as water for radiators or washing, or the air in a house).

The refrigerant used needs specific properties for this to work: it must be inert, so as not to corrode pipework and heat exchangers, and must evaporate and condense at a useful temperature and pressure, to work within the temperature range required (being colder than the heat source when compressed, and hotter than the heat sink when evaporated). Historically, refrigerants included a range of hydrofluorocarbons (HFCs) which are highly effective but also have a high global warming potential (GWP).

Manufacturers in the UK market stated the most popular refrigerant used currently is R410A (GWP 2,088) (used in approximately three-quarters of all heat pumps), followed by R134a (GWP 1,300) and then R32 (GWP 675) whose use is increasing. Several manufacturers have now also developed entire systems based around “natural” refrigerants like carbon dioxide and propane. These have a GWP of 1 and 3 respectively; carbon dioxide-based heat pump systems operate efficiently at low temperatures so are suitable for energy-efficient buildings with large heat dispersion systems (principally new-build), while R-32 and propane-based systems are capable of achieving temperatures approaching those of conventional gas boilers, so have potential for use in retrofit situations.

Refrigerant manufacture is international; some of the key players operating in the global refrigerant market are Daikin (Japan); The Chemours Company. (US); Honeywell International Inc. (US); Arkema S.A. (France); Dongyue Group Co. Ltd (China); Asahi Glass Co., Ltd. (Japan); Sinochem Group (China); Mexichem S.A.B. de C.V. (Mexico); The Linde Group (Germany); SRF Limited (India); and DowDuPont Inc. (US). UK-based sections of these businesses repackage in the UK. For example, the BOC Group operates a facility in Immingham which repackages refrigerants manufactured overseas (within the Linde Group) and imported into the UK. BOC report that the manufacture of refrigerants is “not really done anymore” in the UK. This is likely due to the fact that the market is much smaller in comparison to other regions. However, the Rhodia Chemicals UK “Briton” range of refrigerants is manufactured and distributed around the world from the UK.[145]

Mechanical Components

The main mechanical components of any heat pump are similar (see Figure 4-1:) and their function is to alter the properties of the refrigerant. The key mechanical component in any heat pump is the compressor. Heat pumps and air-conditioning systems typically use a scroll or reciprocating compressor, which have become quieter and more efficient as research and development has increased with the increase in demand for electric heating and cooling worldwide. Compressor design and manufacture is a specialised industry, so it has become dominated by a small number of global suppliers (e.g. Danfoss, Denmark; Bitzer, Germany; Emerson Copeland, Northern Ireland, UK; Mitsubishi, Thailand). Some of the larger electronics manufacturers such as Hitachi and Daikin manufacture their own compressors. Some organisations manufacture compressors in Europe, China and the US, with production facilities located to service local and regional (continental) markets. One manufacturer with a facility in Europe stated that UK does not manufacture enough

[145] Briton ® Refrigerant Gases, available at: https://www.rhodia-refrigerants.co.uk/ accessed July 2020

heat pumps or air conditioning systems for the manufacture of compressors in the UK to be viable. Emerson Copeland, Northern Ireland mainly serves the European heat pump manufacturing market, alongside Carrier and Mitsubishi.

The compressor is linked to the heat exchangers via pipework which can be complex, as designers try to fit components into smaller packages. Although the pipework itself is conventional, the process of shaping and brazing it is hard to automate, so it tends to require skilled labour. The shaping and brazing process is mostly be carried out in the same facility as heat pump manufacture; the issue being that the complex pipework often has to be made around other components.

Unlike the compressor, manufacture of the rest of the mechanical components (that are also used in other applications) such as heat exchangers, fans, pumps, housings, expansion tanks, and control systems is less specialised and distributed among a wider range of companies worldwide. As with compressor manufacturers, the heat pump market plays only a small part in their overall sales. For example, numerous fan manufacturers are serving not only the heat pump market but also others such as the air conditioning market. These organisations are outlined by the HEVAC Fan Manufacturers Association group,[146] the largest of which is most likely EBM-Papst (Germany). Housing units tend to be custom made so their design varies significantly across manufacturers. Control systems are also mostly custom-made, and the large manufacturers tend to make these themselves. Manufacturers of control systems mentioned during the manufacturer interviews include Carel (Italy), Parker Hanifin (US), Alco and Dixell (owned by -Emerson Copeland – manufactured in Italy). For pumps, Danish Manufacturer Grundfos and Wile were mentioned, but again there is a lot of variation, with a large number of suppliers available. This was also the same for heat exchangers where Alfa Laval (Sweden) and Swep (Sweden) were mentioned as some of the leading suppliers.

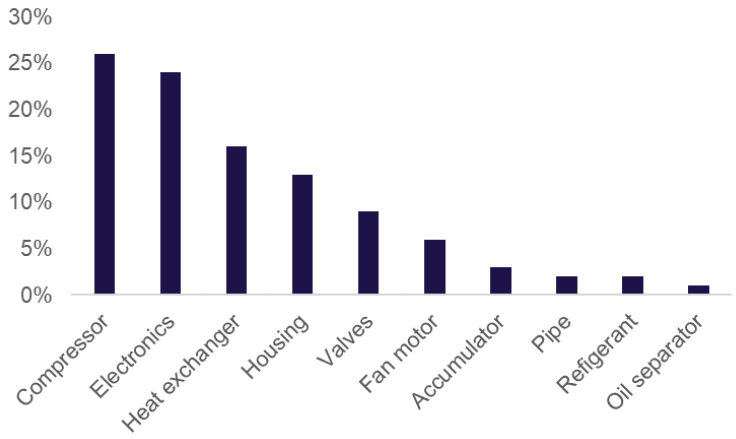
Cost Analysis

This section considers the relative value of heat pump components and provides commentary on future production costs, to ascertain where the potential value in the supply chain is and where opportunities and challenges exist around cost reductions.

Figure 4-2: shows the percentage of total heat pump value for an ASHP[147] for each component, demonstrating that two-thirds of the cost comes from three parts: the compressor, electronics, and the heat exchanger.[148]

[146] Federation of Environmental Trade Associations (2020) HVEC Fan Manufacturers Association, accessed June 2020, available at https://www.feta.co.uk/associations/hevac/specialist-groups/FMA-members
[147] Costs are for an ATA heat pump, however the manufacturer of the heat pump used in this chart confirmed costs would be virtually identical for an ATW heat pump.
[148] Clean Energy Manufacturing Analysis Center (2016) Heat Pump Supply Chains and Manufacturing Competitiveness Considerations, available at: https://www.energy.gov/sites/prod/files/2016/04/f30/30005_Mann_040716-1105.pdf, accessed June 2020

Figure 4-2: Breakdown of Component Part Costs[149]



Manufacturers were asked whether they expected to see production costs reducing, increasing, or remaining constant for heat pump manufacturers over time. As with most industries, manufacturers stated that if volumes increase, efficiencies will drive production costs down. If volumes were to go up for heat pumps, for example by three times current levels, then there is the potential to bring costs down by around 10%. However, the more expensive components are the compressor and components of the refrigeration circuit such as the heat exchanger, and expansion valves; these are already manufactured at such high volume (due to their use in other sectors) that there is not a great deal of room to bring these costs down, according to interviewees.

Some costs have been added recently, for example from the development of novel refrigerant designs specific to high-temperature heat pumps, and changing regulations, e.g. regarding F-gas management.

Supply Chain Mapping

The following section provides a summary of all the key components across the different heat pumps and gas boilers, to ascertain where similarities and differences in the supply chain are. This is summarised in Table 4-1.

Table 4-1: Key components of UK ASHPs, GSHPs, Gas Boilers and Hybrids

Key Component	ASHP – Monobloc	ASHP – Split	GSHP	Gas Boiler	Hybrids (monobloc)
Refrigerant	✓	✓	✓		✓
Refrigerant line		✓			
Compressor	✓	✓	✓		✓

[149] Clean Energy Manufacturing Analysis Center (2016) Heat Pump Supply Chains and Manufacturing Competitiveness Considerations, available at: https://www.energy.gov/sites/prod/files/2016/04/f30/30005_Mann_040716-1105.pdf, accessed June 2020

Key Component	ASHP – Monobloc	ASHP – Split	GSHP	Gas Boiler	Hybrids (monobloc)
Condenser coil	✓	✓	✓		✓
Expansion Valve	✓	✓	✓		✓
Heat Exchanger	✓	✓	✓	✓	✓
Evaporator coil	✓	✓	✓		✓
Internal Circulator		✓			
Internal Expansion tank		✓			
Control Systems	✓	✓	✓	✓	✓
Antifreeze solution	✓		✓		✓
Casing	✓	✓	✓	✓	✓
Pipework	✓	✓	✓	✓	✓
Pumps			✓	✓	
Ground Loop			✓		
Fan, fan motor	✓	✓		✓	✓
Back-up heater	✓				
Blower			✓		

Key Component	ASHP – Monobloc	ASHP – Split	GSHP	Gas Boiler	Hybrids (monobloc)
Expansion vessel				✓	
Pressure gauge				✓	
LCD				✓	
Air/ Gas collector				✓	
Flue connection				✓	
Burner				✓	
Deaerator				✓	
Accessories (e.g. Wall Brackets & Condensate Trays)	✓	✓	✓	✓	✓

Differences in Heat Pump Supply Chains

As shown in Table 4-1, the components in the different heat pump and heating system types are similar. Interviews with manufacturers suggested that the supply chains of heat pumps do not change significantly based on their application (i.e. new-build vs retrofit), nor the heat source (although additional components such as ground loops are needed for GSHPs). If a manufacturer were to switch from making hybrids to heat pumps it would be relatively straightforward, as a hybrid includes a heat pump. However, if they were to switch from heat pumps to gas boiler hybrids, they would have to procure all the components for the gas boiler and integrated control systems. As most boiler manufacturers also manufacture heat pumps, it is therefore more likely that boiler manufacturers would manufacturer hybrid heat pumps.

The supply chains for hybrids, ASHPs and GSHPs are very similar, other than the additional elements (gas, oil or LPG boilers) and the controls to support the integration. There are also many similarities in the supply chain for boilers and heat pumps, namely for shared components like heat exchangers, control systems, casing, pipework, pumps, fans and fan motors. However, some parts are specific to each: boilers do not use the compressors and refrigerants seen in heat pumps. UK boiler manufacturing facilities have established supply chains in place which could assist in domestic hybrid manufacture.

Compressors used in heat pumps are the same across all heat pumps and a limited number of manufacturers of compressors are used in the UK's heat pump Tier 2 supply chain. New refrigerants which allow higher temperatures and have lower GWPs, such as R32 (developed and now licensed by Daikin) and propane, have led to the redesign of compressors specific to the operating pressures of these refrigerants.

The approach to manufacturing can vary from the smaller scale (small batch production of individual units) production to the much more industrialised, depending on the size of the manufacturing business and the degree to which manufacturing processes are integrated within a single business. Some manufacturers will have more in-house supply chains than others, especially Asian suppliers who source directly through their air conditioning supply chain.

Regional Analysis

This section considers the variations in the heat pump supply chain by geographical region. Component manufacturers for heat pumps are located across the globe, with mature industries in Europe and Asia. There is also a tendency for particular factories to specialise in specific products, manufacturing them for markets around the world. According to feedback from several manufacturers, the location appears to be influenced by two key factors:

(1) the concentration of specialist expertise in hubs, often based around the original location of companies that have grown to dominate the market; and

(2) a requirement to locate in a particular region, either to get closer to important markets or to operate inside barriers presented by legislation, licensing requirements and exchange rates.

UK

The manufacturer interviews identified that the majority of heat pump components (the Tier 2 supply chain) used in UK heat pump manufacturing (Tier 1) are currently imported, with a significant proportion from outside Europe. One cited reason for this was that there are currently not enough heat pumps manufactured in the UK to support a localised supply chain. However, interviewees also opined that if UK-based heat pump manufacturing increased, establishing component manufacturing in the UK would be achievable. This effect is already documented among those manufacturers which do have an established presence in the UK, where the proportion of components sourced locally has increased significantly with growing demand, as local businesses develop capacity.

It is worth noting that the need for a UK based Tier 2 supply chain isn't necessarily a limiting factor to a strong UK based Tier 1 manufacturing sector. As an example, the UK has an established boiler industry, but a less evident skilled Tier 2 component supply chain, as most boiler components are manufactured outside the UK and then assembled in the UK. So logically it follows that the UK could similarly have a large HP manufacturing sector with a limited Tier 2 local supply chain.

Examples given in interviews of UK-manufactured heat pumps and descriptions of their supply chains include:

- 50% of the value of their physical heat pump product manufactured in the UK came from the UK (not including raw materials). This was the highest percentage reported by heat pump manufacturers in interviews.

- Another manufacturer of industrial-scale systems reported that they manufactured the frame, pipework and vessels themselves, but imported components such as programmable logic controllers, compressors and heat exchangers.

- For a typical non-domestic unit, most components are European—around 50% of sales value.

- One respondent bought compressors from Northern Ireland and France, heat exchangers from Sweden and Croatia, and controls from Italy (but switching to a UK source). They were making significant efforts to “buy local” but specialist components (e.g. compressors) are only available from a limited number of global sources. The proportion of components sourced locally has been shown to increase significantly with time (e.g. from 5% to 50% in the case of one major manufacturer) reflecting the ability of local businesses to adapt where long-term demand is secure.

Heat exchangers, expansion valves, refrigerant, and evaporators and condensers are primarily sourced from outside of the UK. Less specialised components, such as pipework, fans, casing and metal works and heat pump accessories have a supply chain in the UK. One European manufacturer used to manufacture control systems in Milton Keynes, however, they moved to Germany purely due to cost efficiencies.

Because of the small scale of UK manufacturing (with notable exceptions), the production of components tends to be on a smaller scale, where European and Asian manufacturers have the volume required to justify investment in automation and other efficiency technologies. Respondents suggested that this divergence has become so entrenched that it would be effectively impossible to establish large-scale manufacturing in the UK for specialised Tier 2 components such as heat exchangers and expansion valves, as the markets for components are all international, and have been developing in the absence of the UK for so long, the barrier to entry would now be prohibitive.

Europe

European—especially Scandinavian—heat pump manufacturers have developed a mature ecosystem and associated supply chains. Many European manufacturers have sales operations in the UK but have reported that they would supply at least the initial growth through imports. The level of sales increase for switching to UK manufacture varies depends on the specific circumstances of manufacturers (e.g. existing assets in the UK, market share, and production capacity).

As heat pump sales increase, many manufacturers operating in the UK market have suggested that they could relocate heat pump assembly to the UK, but the supply chains for components would likely remain, as they would be servicing both the UK and other operations. The same principle applies to component manufacturers: at the moment, the UK heat pump market is not large enough to influence their investment plans. However, in time, growth may be sufficient to encourage inward investment or even the development of new businesses based in the UK to service demand.

Asia

Asian manufacturers tend to have high-volume local markets, including high demand for air conditioning, so supply chain volumes are much higher—particularly where there are commonalities in components. These manufacturers tend to purchase in bulk, or to be more vertically integrated than European and UK competitors. However, while it is possible to use the same components (e.g. compressors) for heat pumps that heat and

cool (a requirement of warmer countries in Asia), performance is significantly improved in a unit that is specifically designed to do only one, as you have a narrower range of internal and external heat ranges, so can refine your circuit design. The very large volume manufacturing output of Asian producers is not an overwhelming advantage at the higher performance and quality end of the market.

Summary Findings - Tier 2 Component Parts Market Analysis

- Generally, there are few highly specialised components of heat pumps so component manufacturers also serve several other markets; heat pumps account for a small share of their sales. Because of this, global supply chain patterns are unlikely to change significantly due to a changing UK heat pump manufacturing landscape.
- Most components of the heat pumps installed in the UK come from globalised supply chains, with the notable exception of Emerson Copeland, who produces compressors in Northern Ireland.
- The components accounting for significant portions of the total value of a heat pump are the compressor (~25%), the electronic controls (~25%), the heat exchanger (~15%), housing (~13%), valves (~10%), fan (~5%), pipework (~2%) and refrigerant (~2%).
- The compressor manufacturing industry is a specialised industry and concentrated amongst a handful of large firms.
- Manufacturing of heat exchangers, fans, pumps, housing, expansion tanks and conventional control systems are less specialised and a vast number of companies distribute to a range of industries worldwide.
- Refrigerant manufacture is international, with a number of key players based in US and Asia, but there are also some European manufacturers. UK-based sections of key manufacturers repackage refrigerants in the UK, however there is limited UK refrigerant manufacture.
- There is some effort to ‘buy Local’ from UK heat pump manufacturers for less specialised components, such as housing, pipework, fans and controls.
- There is a mature ecosystem of Tier 2 suppliers in Europe that serves many markets which are similar to the heat pump market including the HVAC sector. Similarly, in Asia there is a high volume of both Tier 1 air conditioning and heat pump manufacturers and Tier 2 suppliers of their components.
- Beyond the notable exception of Emerson Copeland, it is unlikely that UK component part manufacturers will export a significant proportion of their output given the competitive landscape.

5) Synergies with Related Sectors

Section Aim: The UK heat pump manufacturing sector has the potential to capitalise on similarities with other, related sectors. Of particular interest is the manufacture and use of similar components and labour skills. Therefore, it is necessary to understand which industries have synergies and who the key stakeholders are in this sector. The following sections outline the key synergies of heat pump manufacturing with air conditioning, refrigeration, and boiler manufacturing. Further details see Appendix A – 8: Synergies with related sectors – market description and key players. The key findings from the literature review, supply chain mapping, and manufacturer interviews are detailed in this section.

Synergies with Air Conditioning and Refrigeration Manufacturing

The UK has three air conditioning manufacturers – Airedale and Marstair, West Yorkshire and Mitsubishi A/C, Livingston.[150] Air conditioners operate the same refrigeration cycle as heat pumps in reverse. Interviewees stated that the manufacturing processes for air conditioning, commercial refrigeration units and heat pumps are extremely similar because the technology used is largely the same. Cooling is also becoming more of a requirement in certain locations in the UK. This may act as an additional driver for heat pump systems that can provide both heating and cooling.

The monobloc ASHP (the main type of ATW heat pump installed in the UK) is very similar to an air conditioning unit—the chassis, the evaporator, compressor and printed circuit boards are all very similar. Several interviewees noted that whilst a compressor will perform in both heat pump and air conditioning applications, a compressor specifically designed for the preferred operating temperature range of the heat pump will be a more efficient solution. The key difference is the plate heat exchanger technology.

This presents an opportunity to air conditioning manufacturers that are not currently manufacturing heat pumps. In the UK, whilst Mitsubishi and Marstair do have a heat pump offering (Mitsubishi manufacture their Ecodan range and Marstair manufacture a reversible heat pump condensing unit as part of their air conditioning range), Airedale sell Mitsubishi heat pumps but do not manufacture their own.

Commercial-scale refrigeration systems technology can be readily adapted to commercial-scale heat pumps, suitable for a commercial building, city-block or district heating applications. Star Renewables is an example of a UK success story: the company developed out of Star Refrigeration, which designed and installed industrial refrigeration systems. It now supplies commercial-scale ground and water-source heat pumps supplying heat to district heating systems and large buildings.

[150] This is the same facility in which Mitsubishi manufacture their Ecodan heat pumps.

Synergies with Boiler Manufacturing

Boilers and heat pumps are technologically different but are manufactured from similar raw materials (see Table 4-1). Hydronic heat pump systems have comparable plumbing systems, and both heat space and water. After air conditioning manufacturers, traditional boiler companies hold the next largest UK heat pump market share amongst companies that also make other technologies (e.g. Baxi, Worcester Bosch, Vaillant, and Ideal). These companies have the benefit of knowing the UK heating market and have established raw material supply chains.

A number of interviewees highlighted the potential of hybrid systems as a good way of transitioning to lower carbon solutions. One advantage of a type of hybrid system, referred to by the industry as a "bivalent system", is in retrofit applications where the existing boiler and heat distribution system (e.g. radiators) can be left in place, this includes a heat pump being installed in parallel, with a control system to balance which heat source is used. This approach also allows energy efficiency improvements to be made incrementally after the heat pump has been installed, so that some benefits of having a heat pump can be realised immediately, and others achieved later.

The UK boiler and radiator manufacturing workforce is around 6,000 people. [151] The interviewees highlighted the extensive boiler manufacturing capacity in the UK, notably the Midlands cluster (e.g. Vaillant in Derbyshire and Worcester Bosch in Derbyshire and Worcestershire). This has led to the development of a skilled and knowledgeable workforce and a strong manufacturing base which could transition to the heat pump manufacturing industry.

The UK's boiler manufacturing sector is supported by a strong engineering base, design consultants, and a network of installers that would be ideally placed to develop and deliver heat pump projects, given the right installation training and upskilling is undertaken (specifiers and installers, in particular, need upskilling in aspects such as heat loss calculations, hydraulic balancing and system sizing).

Synergies with Other Sectors

The heat pump industry has some similarities with the automotive industry in terms of basic components and the assembly line manufacture. Furthermore, the skills involved in the machining of aluminium complex casting, in which the UK has particular expertise, could be transferred from this industry to heat pump manufacture.

A heat-pump cabin heater has been adopted for heating an electric vehicle (EV), using less power than conventional models.[152] It greatly improves power consumption when the heater is being used. The Nissan LEAF, manufactured in Sunderland, is the first mass-produced vehicle in the world to employ a heat-pump cabin heater—similarities could be drawn here. Through an interview it was found that one large international car manufacture had a domestic heating product in development some years ago, however,

[151] IBISWorld (2020), Radiator & Boiler Manufacturing in the UK - Market Research Report, Jan 2020, available at: https://www.ibisworld.com/united-kingdom/market-research-reports/radiator-boiler-manufacturing-industry/

[152] Nissan Global (n.d.) World's first EV power-saving cabin heater, available at https://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/heat_pump_cabin_heater.html#:~:text=World's%20first%20EV%20power%2Dsaving%20cabin%20heater&text=Nissan%20LEAF%20is%20the%20first,a%20heat%2Dpump%20cabin%20heater., accessed May 2020

all such development has now ceased and they no longer manufacture this type of product. Furthermore, they have no future plans to return to this area.

In terms of the Tier 2 supply chain, the ancillary industries like programmable logic controllers and control systems, enclosures, brazing and pipework, amongst others, will be well placed to benefit from an expansion in heat pump manufacture. As with other components, these supply chains already exist overseas meaning UK businesses will have to compete with incumbents. Furthermore, as a result of the rapid expansion of heat pumps in the UK, positive impacts could be recognised in the below industries[153]:

- Energy efficiency technologies – Heat pumps generally operate at lower delivery temperatures than conventional fossil fuel boiler systems, so they will require the parallel deployment of energy efficiency technologies such as insulation, draught-stripping, etc.
- Radiators – As heat pumps operate at lower temperatures, there will be increased demand for higher capacity (e.g. larger or fan-assisted) radiators, under-floor heating systems, etc.
- Hot water cylinders and thermal stores – There is an increase in the requirement for cylinders that store hot water, where gas combi-boilers are being replaced (advanced cylinder designs with high insulation, internal baffling, etc.). Furthermore, phase change thermal stores, for example, Sunamp's super-compact heat battery technology.[154]
- Electricity metering – Gas meters will no longer be required (for heating purposes), but electricity meters alongside smart control will become more sophisticated (see smart meters). These smart controls will contribute to wider system benefits such as grid balancing.
- Plumbing and heating supplies – The increase in activity required to change existing fossil-fuel heating systems to low-carbon systems will likely result in higher demand for general plumbing supplies.
- Solar thermal - Solar thermal systems can provide good synergy with heat pump installations and they will likely see a boost through any increase in low-carbon heating, but they are not specifically advantaged by the deployment of heat pumps.
- Water heaters – The impact of heat pump deployment on the direct electric water heater market is complex. Phasing out combi boilers may increase sales, whereas an increase in the prevalence of hot water cylinders may reduce them.

It is worth noting that although there are synergies between a heat pump and refrigerant manufacturers, it is unlikely that refrigerant manufacturers would move into heat pump manufacture because the interaction with the customer does not match the business models of these organisations.

[153] A Transformation to Sustainable Heating in the UK: risks and opportunities, UK Energy Research Centre (2018)
[154] Sunamp (2020), accessed July 2020, available at https://www.sunamp.com/

Related Sectors – Market and Key Manufacturers

An overview of the market and key players in the above sectors can be found in Appendix A – 7. Table 5-1 provides a summary of some of the key players in the above sectors, outlining which of these have heat pump offerings (including hybrid heat pumps) and which currently do not.

Table 5-1: Key Players in Related Sectors with Heat Pump Products[155]

Air conditioners	Heat Pump	Boiler	Heat Pump
Daikin	✓	Worcester Bosch	✓
York	✓	Ideal	✓
Carrier	✓	Vaillant	✓
Trane	✓	Baxi	✓
Mitsubishi	✓	Vokera	✓
Hitachi	✓	Ariston	✓
Gree	✓	Alpha	✓
Whirlpool	X	Ferolli	✓
LG	✓	Biasi	X
Fujitsu	✓	Viessmann	✓
Goodman	✓	ATAG	✓
Marstair[156]	✓	Intergas[157]	✓
Airedale[158]	X	Vokera	✓

[155] *Eunomia undertook internet searches to ascertain if these organisations manufactured heat pumps, as well as drawing on information gathered from manufacturer interviews.*

[156] Part of their air conditioning range, these slimline reversible heat pump condensing units are suitable for bespoke applications, such as air handling units. Available at https://www.marstair.com/products/mhpue/
[157] Hybrid system with a Daikin heat pump
[158] Sells Mitsubishi heat pumps

Summary Findings - Synergies with Other Related Sectors

- Perhaps the biggest opportunity for synergy is with the existing UK heating manufacturing sector. The UK's boiler manufacturing sector is supported by a strong engineering base, design consultants, and a network of installers that would be ideally placed to develop and deliver heat pump projects, given the right installation training and upskilling is undertaken. A lot of these synergies are already being realised but can be further capitalised on for UK manufacturers.
- Heat pumps operate a refrigerant cycle in reverse, meaning that there are many similar components and manufacturing techniques between a heat pump and air conditioning manufacturing units; they are often manufactured in the same facility.
- The synergy with air conditioning units is particularly true of monobloc systems, as they are very similar, presenting an opportunity to air conditioning manufacturers that are not currently manufacturing heat pumps. The UK has three air conditioning manufacturers, Airedale (who also sell Mitsubishi heat pumps but do not manufacturer their own), Marstair (who also manufacture a reversible heat pump condensing unit as part of their air conditioning range) and Mitsubishi A/C (who also manufacture heat pumps)..
- Commercial-scale refrigeration systems technology can be readily adapted to commercial-scale heat pumps, suitable for a commercial building, city-block or district heating application. This opportunity for switching to heat pump manufacture has been demonstrated by Star Refrigeration, who have developed Star Renewables to manufacture commercial scale ground and WSHPs in the UK.
- There are also positive impacts to be realised across a number of ancillary industries such as energy efficiency technologies, hot water cylinders, electricity metering to name a few.
- There may be opportunities for UK manufacturers of similar products (e.g. air conditioning and ventilation) to diversify into heat pump manufacture. Heat pump manufacturers emphasised that heat pump technology is well established and the manufacturing techniques are not especially challenging (although the interface and control systems maybe more so). However, the market is arguably saturated with incumbents who have established track records over many decades.

6) Potential for Growth in the UK Heat Pump Supply Chain

Section Aims: The section focuses on the anticipated growth rate of the UK heat pump supply chain. It provides commentary and analysis to show the role that domestic supply can play in meeting demand and the split between imported and UK-manufactured goods, as well as the potential for export from UK manufacturers. The growth rate model used was built on findings from the literature review and supply chain mapping, as well as illustrative scenarios provided by BEIS; assumptions built-in were based on information gathered from interviews with manufacturers. This section also considers the impact that the UK's future trading arrangements with EU and non-EU countries may have on the heat pump manufacturing supply chain, and how this could affect the availability of skilled labour. The key findings from the section were gathered through the literature review and manufacturer interviews.

Growth in the UK Market

Although it is small, the UK heat pump market is growing. The 2020 BSRIA report estimates it will see a CAGR of 17.5% from 2019 to 2024, which would put the 2024 sales figure at over 75,000 units.[159] Looking forward, it is expected that most sector growth will predominately support new builds (in the short-medium term).

When asked whether the CCC target of reaching over 1 million heat pumps per year by 2030 is feasible (requiring a 40% CAGR), most interviewees responded that, from a manufacturing capacity point of view, it would indeed be feasible. A range of estimates for annual growth potential in supply was given by manufacturers, from 40% to 300% per annum. Conversely, most manufacturers did not think that the CCC target scenario is likely to materialise in practice. Most manufacturers stated that they do not anticipate consumer demand to reach such high levels by 2030 given the dominance of gas boilers in the UK heating market caused by historically poor energy efficiency of UK housing stock, and relatively high price of electricity when compared to gas (per unit of heat produced). Further barriers to consumer demand were identified as high capital cost of heat pumps and the highly disruptive nature of heat pump installation, particularly when ancillary equipment is needed.

Heat Pump Deployment Scenarios

Growth predictions are dependent upon government policy. It is not yet clear how policies may change over the next ten years. BEIS and Eunomia developed illustrative policy scenarios designed to indicate expected heat pump demand. These were used to guide discussion with manufacturers to assess possible heat pump production and to deduce, for example, minimum demand required to locate manufacturing in the UK.

[159] Building Services Research and Information Association (BSRIA) (2020) Heat pumps market analysis 2020 - United Kingdom, 2020, https://www.bsria.com/uk/

A total of three illustrative scenarios are examined in the research. Each scenario has a target demand for heat pump sales for 5-year intervals:

- **A high growth rate scenario** represents a rapid deployment of heat pumps between 2020 and 2035. This scenario will result in almost all existing gas and oil boiler replacements being heat pumps from 2035 onwards. Figures for this scenario show a 10-fold increase in sales from 2020 to 2025, a 3.3-fold increase from 2025 to 2030 and a 1.6-fold increase from 2030 to 2035.
- **A medium growth rate scenario** represents a modest growth in the annual deployment of heat pumps between 2020 and 2035. This scenario represents approximately two-thirds of gas and oil boiler replacements being heat pumps from 2035 onwards. Figures for this scenario show a 10-fold increase in sales from 2020 to 2025, a 2.3-fold increase from 2025 to 2030 and a 1.4-fold increase from 2030 to 2035.
- **A low growth rate scenario** represents very modest growth in the annual deployment of heat pumps to 2025, at which point the market is forecast to become an almost steady state. Figures for this scenario show an 8.3-fold increase in sales from 2020 to 2025, a 1.2-fold increase from 2025 to 2030 and no increase from 2030 to 2035.

Although the figures for the illustrative scenarios provided by BEIS only go to 2035, the growth rate analysis continues to 2037 to ensure consistency with the 6th carbon budget. Between 2035 and 2037, annual demand is assumed to be the same for each scenario. Further modelling assumptions are included in Appendix A - 10: Growth Rate Analysis - Model assumptions. Figure 6-1 shows the total number of heat pumps sold each year under each scenario. In all three scenarios, the five years from 2020 to 2025 have the highest CAGR, as also evident in Table 6-1.

Figure 6-1: The three illustrative total annual UK heat pump sales scenarios

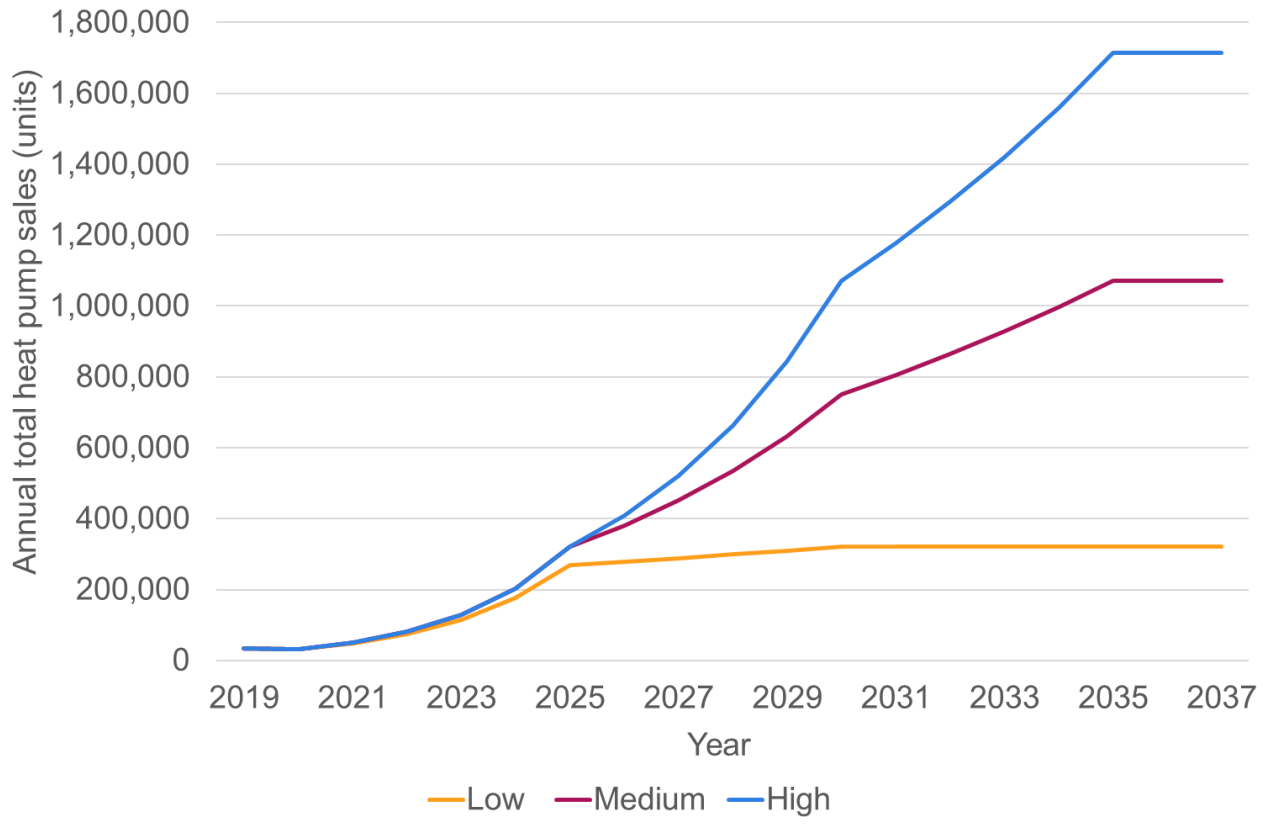


Table 6-1 Compound Annual Growth Rate for Each Illustrative Scenario

Scenario	2020 – 2025	2025 – 2030	2030 - 2035
Low	52.8%	3.7%	0%
Medium	58.5%	18.5%	7.4%
High	58.5%	27.2%	9.9%

When asked which of the growth scenarios was most reflective of their view on developments regarding growth in demand, the majority of interviewees reported that given the significant barriers to consumer demand, the Low scenario is most likely from 2020 until 2025. Looking further to the future, manufacturers identified the Medium scenario as most likely from 2025 onwards. However, this perception was not universal, and some believed that heat pump sales will not surpass the Low scenario, in particular with regard to ASHPs. Still, several manufacturers believed the High scenario to reflect future heat pump sales in the UK.

Using the data associated with the current deployment of heat pumps and the interviews conducted with manufacturers, growth in the UK manufacturing supply chain has been forecast based on these different demand scenarios.

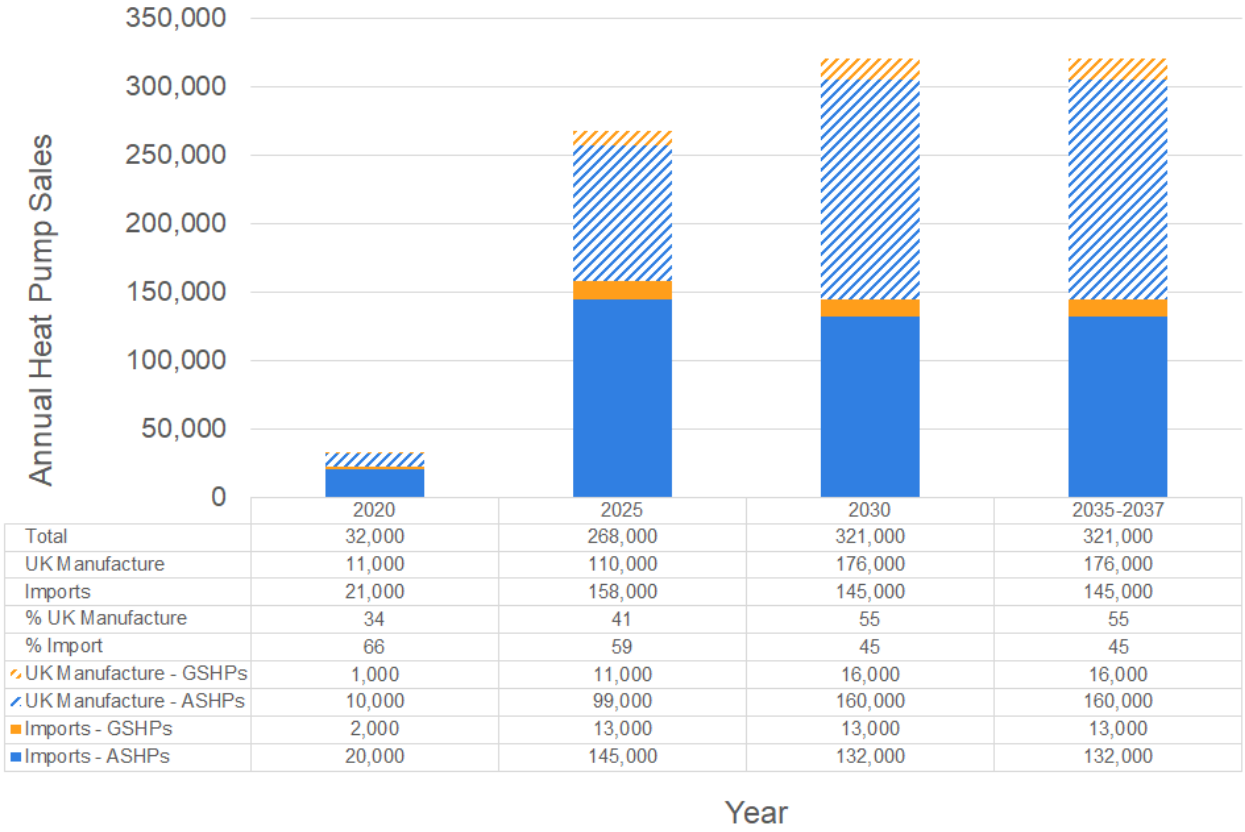
Whilst the most realistic perception from interviewees of future market development focused on the Low and Medium scenario, there was high confidence that all of the growth scenarios could be met from existing global manufacturing facilities. This could be achieved through increasing shift patterns and introducing new production/assembly lines. Therefore, it has been assumed that all manufacturers will be able to meet demand in all scenarios, based on information provided in the interviews. However, there were a few caveats associated with niche market segments (e.g. very large compressors associated with large commercial heat pumps may be difficult to source).

The growth rate analysis that follows predicts the annual sales of heat pumps by:

- Heat pump type;
- Manufacturer; and
- Domestic and non-domestic market growth.

Figure 6-2, Figure 6-3, and Figure 6-4 show the annual heat pump sales (numbers rounded to the nearest thousand) under the three illustrative growth scenarios – Low, Medium and High – and analysis of the split between the potential for domestic manufacture and import, as well as the type of heat pump. The following sections explain in more detail the assumptions behind the different scenarios and the modelled location of production.

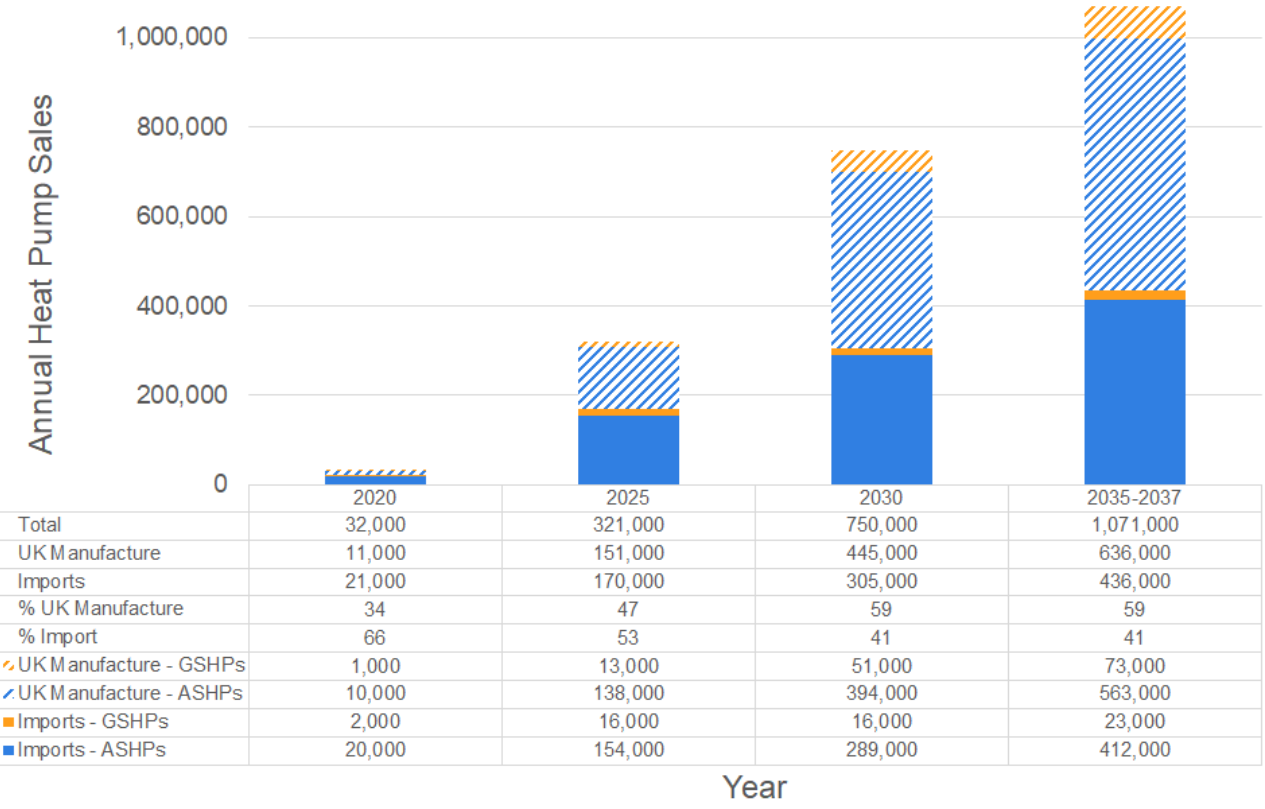
Figure 6-2: UK Heat Pump Manufacture vs Import - Low Growth Scenario



	2020	2025	2030	2035-2037
Total	32,000	268,000	321,000	321,000
UK Manufacture	11,000	110,000	176,000	176,000
Imports	21,000	158,000	145,000	145,000
% UK Manufacture	34	41	55	55
% Import	66	59	45	45
UK Manufacture - GSHPs	1,000	11,000	16,000	16,000
UK Manufacture - ASHPs	10,000	99,000	160,000	160,000
Imports - GSHPs	2,000	13,000	13,000	13,000
Imports - ASHPs	20,000	145,000	132,000	132,000

Note: Individual Figures have been rounded to the nearest thousand, and therefore may not add up to the totals provided.

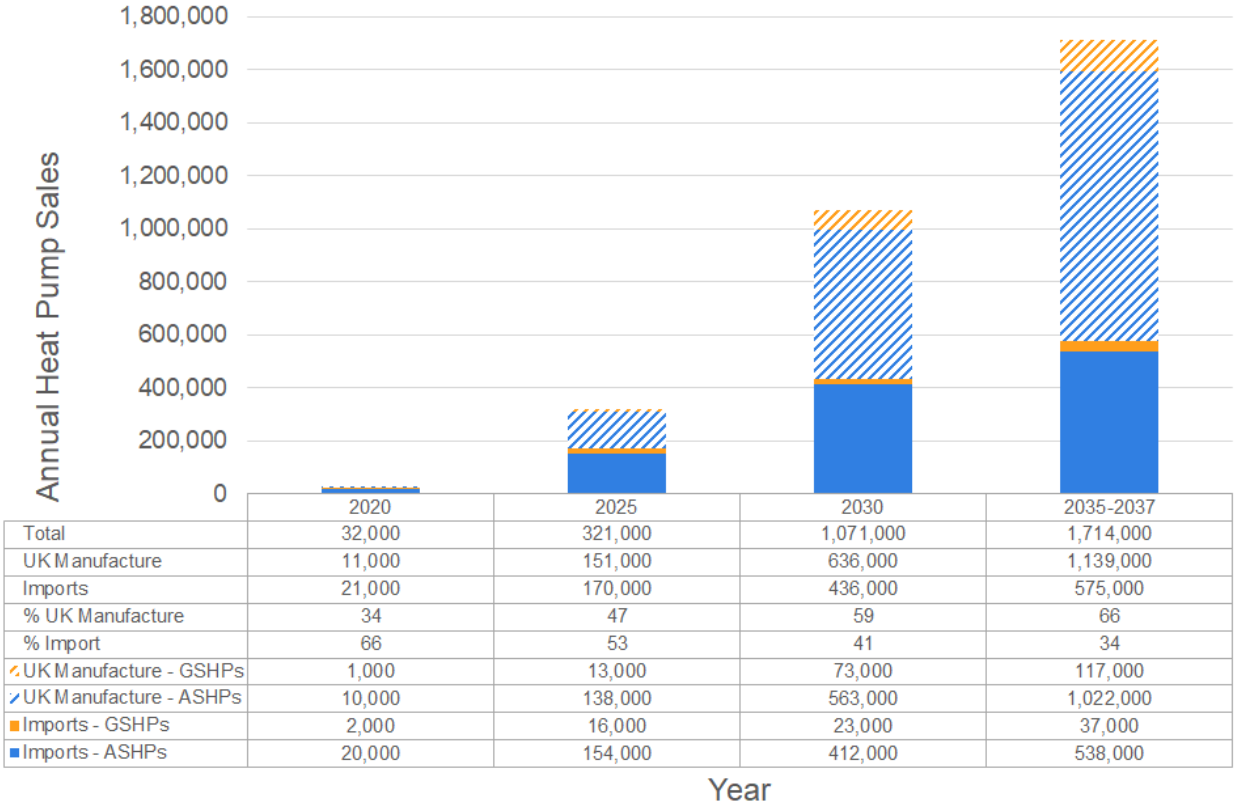
Figure 6-3: UK Heat Pump Manufacture vs Import – Medium Growth Scenario



	2020	2025	2030	2035-2037
Total	32,000	321,000	750,000	1,071,000
UK Manufacture	11,000	151,000	445,000	636,000
Imports	21,000	170,000	305,000	436,000
% UK Manufacture	34	47	59	59
% Import	66	53	41	41
UK Manufacture - GSHPs	1,000	13,000	51,000	73,000
UK Manufacture - ASHPs	10,000	138,000	394,000	563,000
Imports - GSHPs	2,000	16,000	16,000	23,000
Imports - ASHPs	20,000	154,000	289,000	412,000

Note: Individual Figures have been rounded to the nearest thousand, and therefore may not add up to the totals provided.

Figure 6-4: UK Heat Pump Manufacture vs Import – High Growth Scenario



	2020	2025	2030	2035-2037
Total	32,000	321,000	1,071,000	1,714,000
UK Manufacture	11,000	151,000	636,000	1,139,000
Imports	21,000	170,000	436,000	575,000
% UK Manufacture	34	47	59	66
% Import	66	53	41	34
UK Manufacture - GSHPs	1,000	13,000	73,000	117,000
UK Manufacture - ASHPs	10,000	138,000	563,000	1,022,000
Imports - GSHPs	2,000	16,000	23,000	37,000
Imports - ASHPs	20,000	154,000	412,000	538,000

Note: Individual Figures have been rounded to the nearest thousand, and therefore may not add up to the totals provided.

Growth Rate by Product

Total annual heat pump sales were disaggregated into product type using data provided by BSRIA and confirmed by BEIS. This shows that approximately 90% of heat pump sales are ASHPs and 10% GSHPs. It has been assumed that this proportional split remains constant throughout the forecasted period. Some manufacturers suggested that the current GSHP market share may in fact be lower than this, but some also suggested that the GSHP market share may increase in the coming decade, which may compensate for the difference.

Growth Rate by Application

The annual number of UK sales in Figure 6-1 is based on domestic installations, recognising the relatively low number of non-domestic buildings (~2 million non-domestic buildings compared with ~28 million domestic properties) and that the majority (85%) of heat pump sales in the UK are for domestic use, while only 15% are for non-domestic use. This market share is not expected to change in the coming decade. In terms of market growth, the majority of heat pump demand is therefore expected to continue to be in domestic applications; however, the non-domestic application of heat pumps in the UK and Europe is also growing.

Impact of COVID-19 on Expected Growth

The outlook for the industry before COVID-19 was encouraging. However, as with most supply chains, current growth has been inhibited by the slowdown in economic activity. Analysis by Delta-EE suggests that post-crisis UK heat pump sales in 2020 will be down

10% when compared with 2019 and down 16% compared with pre-COVID-19 forecasts for 2020.[160]

COVID-19-related supply implications have been identified by some manufacturers; however, this study – and in particular its growth rate analysis – do not include related assumptions, due to the long-term nature of the projections being made.

There are also demand-side economic effects of COVID-19, such as lower consumer confidence and reduced incomes. These could lead to lower rates of home renovation, or a tendency to purchase lower-cost heating options.

Supply-side Dynamics

Much of the research associated with the future deployment of heat pumps explores the likely demand for heat pumps under different emissions reduction policy scenarios. A relatively small proportion of this evidence focuses on the manufacturing capacity or the supply-side dynamics associated with scaling up deployment.

During the interviews conducted, manufacturers were asked to comment on whether the UK could achieve the level of heat pump installations recommended by the CCC:[161] an annual installation rate of 1,149,000 heat pumps by 2030. Manufacturers reported that the supply chain is largely unconstrained and can grow to meet demand. From a supply point of view, manufacturers were very confident that they could increase supply into the UK market, through both import and domestic manufacture, by a minimum of 25-30% year on year for the next 15 years. This increase is in line with achieving the CCC's recommended levels of heat pump deployment—the High growth scenario discussed above.

Reasons for this confidence include:

- Heat pumps and similar technologies have been manufactured at scale outside of the UK for many years and are a mature technology.
- Large heat pump manufacturers are serving the market with global operational footprints, able to source and manufacture where marketplace conditions dictate.
- The supply chain will grow as quickly as it needs to with few limitations (providing it is cost-effective to do so).
- Manufacturers of other technologies such as air conditioning units, split-systems, and boilers could switch to heat pumps.
- Other countries have been able to meet increased levels of demand with no production limitations from the supply chain. This has also been the case when rapid growth has been witnessed across several countries. Manufacturers forecast potential markets for growth so they can direct investment into their facilities, in order to cope with the increased demand across several countries at the same time. This highlights the importance of accurate forecasting of the market to meet potential rapid growth.

[160] European Heat Pump Association (2020) The Essence of Heat Pump Series - European Heat Pump Market Insights, 20 May 2020
[161] Committee on Climate Change (2019) Net Zero Technical Report, May 2019, https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-Technical-report-CCC.pdf

Limitations, Barriers and Bottlenecks to Meeting UK Heat Pump Growth

While there was an overwhelming consensus from manufacturers that there are no substantial supply-side barriers to meeting UK demand under high growth rate scenarios, some potential supply-side barriers were identified.

Workforce Skills

Skilling of international workforces and the UK workforce did not appear to be a concern for manufacturers, other than for dealing with refrigerant gas in the production process, where there is a current skills gap in the UK. The sector is supported by a current skilled workforce, and a similarly skilled workforce exists in other industries (boiler, HVAC, and chiller manufacturers) that has transferable skills. Skilling new employees in the manufacture and assembly of heat pumps is easily achievable. However, some manufacturers echoed concerns regarding uncertainty around the UK's exit from the EU and the availability of workforce for UK manufacturing facilities, in particular eastern European labour currently utilised during peak seasonal demand.

Component Parts

Overall, there was not a major concern amongst interviewees over future resource availability for the manufacturing of components. The material inputs to boiler manufacturing are generally similar to those necessary for heat pumps, and there are deemed to be sufficient levels of such materials. There are, however, some concerns over the future availability of certain metals like copper,[162] which is used in heat exchanger components. However, the final demand for copper from fluid-based applications (like pipes and heat pumps) makes up only a small share of total demand[163] so an increase in demand for heat pumps is unlikely to significantly increase the resource pressure.

One slight concern was raised around the ability of compressor manufacturers to scale up production volumes given the small number of manufacturers. However, if the UK and European markets were to grow rapidly, large compressor manufacturers have the advantage of gaining support from other plants around the world (e.g. the US and Asia). Furthermore, if a market prevails then countries such as China may look to produce compressors for heat pump applications.

Heat pump manufacturers are constantly having to evolve in terms of the refrigerants being used and these are often limited in supply. This issue with refrigerants is causing additional costs in the manufacturing chain because it is not simple to find substitute refrigerants that operate similarly and keep heat pumps working efficiently. Many manufacturers mentioned transitioning their ranges, for example from R-410A to R32 refrigerant.

Future Manufacturer Market Share

Market shares are expected to change in the next five years due to a variety of factors, as they have done over the last decade. These include (but are not limited to) the design of

[162] Northey, S., Mohr, S., Mudd, G.M., Weng, Z., and Giurco, D. (2014) Modelling future copper ore grade decline based on a detailed assessment of copper resources and mining, Resources, Conservation and Recycling, Vol.83, pp.190–201

[163] Manfredi, S., Nuss, P., Passarini, F., Ciacci, L., European Commission, and Joint Research Centre (2018) Material flow analysis of aluminium, copper, and iron in the EU-28, 2018

future policy for heat pumps which may promote one heat pump technology type over another, innovation, UK trade policy, availability of finance, and changes in the labour market.

Forecasts for market share changes are based on interviews with manufacturers as well as data on the current market share. Based on the interviews with manufacturers, three key changes that could influence changes in market share have been identified:

- Boiler manufacturers transitioning to heat pump manufacturing;
- New companies entering the market; and
- Larger companies purchasing smaller ones.

There are currently at least 33 ASHP manufacturers supplying heat pumps to the UK. The market is dominated by three air conditioning/electronics companies: Mitsubishi, Daikin and Samsung, which together account for roughly 55% of sales. Approximately 32% of ASHP manufacturing is located in the UK, almost entirely through Mitsubishi.

There are currently at least 17 GSHP manufacturers, dominated by two heat pump companies: Kensa and NIBE, which together account for roughly 60% of sales. Approximately 41% of GSHP manufacturing is located in the UK, exclusively through Kensa. Traditional boiler companies have relatively low market shares for both ASHPs and GSHPs.

There is difficulty associated with estimating future market share; however, there are some clear dynamics that were gathered from interviews on how market shares are expected to change in the next five years. These dynamics have been included as assumptions for modelling the location of manufacture, the results of which are discussed in the next section. These include:

- The most substantial change in the next five years is expected to be an increase in UK heat pump market share for traditional boiler companies, due to the proposed ban on new builds connecting to the gas grid in 2025. These companies are expected to transition some of their boiler manufacturing to heat pumps (possibly as well as hydrogen-based heating). This growth is reinforced by strong brand presence, marketing power, consumer trust and established relationships with housing developers, wholesalers, and installers in the UK. Based on feedback from interviewees, this growth is expected to take place around 2025.
- The large air conditioning and electronics manufacturers that currently dominate the ASHP market are expected to maintain a large market share over the next few years, despite increased competition from boiler manufacturers and new entrants. This is due to safeguarded distribution channels, their introduction of new and improved products, customer loyalty, and competitive prices.
- New entrants to the UK heat pump market are also expected. These may be companies with manufacturing expertise in a related industry such as air conditioning, refrigeration, or as previously mentioned, boilers. There may also be entrants with a well-established European heat pump market presence, but currently little or no UK market share, or companies with UK manufacturing facilities in a related industry, and with large shares in the European market. There is also speculation around the potential for large consumer technology companies such as Dyson (HVAC products) and Tesla (hints of HVAC offering) to enter the UK heat pump market. As this is unconfirmed and based on anecdotal evidence, such

disruptive entrants have not been included in this analysis, but should be kept in mind. If either were to enter the UK heat pump market in the future, however, their product would be expected to be imported in line with their current manufacturing strategies.

- There may be some market consolidation as larger organisations purchase smaller ones. The impact that this could have on manufacturing locations has not been modelled, as the purchase of an organisation does not necessarily mean that the manufacturing facility will close as a result (and this has not been the case previously). However, it is expected that some of the smaller players (i.e. those with <1% market share) may be purchased by the organisations with larger market shares. In fact, this trend is already being seen in the UK market. For example, in 2016 NIBE purchased the British-owned Enertech Group (CTC), and this year has purchased the German based company Waterkotte.[164] [165]

- The development of new products has been considered, as well as how manufacturers' market shares may increase in the UK as a result. This includes manufacturers who are working on new product lines that are quieter and smaller and will address potential mass-market demand.

- Some established manufacturers of one type of domestic heat pump are looking to expand their product range and offer a wider range of heat pump products (a GSHP manufacturer may look to develop ASHPs, for example).

- Manufacturers did not foresee any substantial constraints to heat pump manufacturing in the future. This includes each company increasing manufacturing by up to 30% annually over the next 15 years to meet the high scenario. Thus, it is not perceived that a cap on manufacturing would influence market shares.

- No changes in market share have been modelled past 2025; the main market share changes are expected to be focused around 2025 when no new buildings can connect to the gas grid following the introduction of the Future Homes Standard.

Location of Manufacture

Irrespective of the market share between manufacturers, a key consideration is the location of the manufacturer, whether that be in the UK or elsewhere. One manufacturer stated "*the manufacturing philosophy is nearest to the point of use, so once the economic arguments are right then we'll put the factory in place,*" this was supported by views of other heat pump manufacturers interviewed. This is similar to other supply chains, such as the car manufacturing industry in the UK, in which manufacturers build where they sell'. Shipping, export, and import costs are, on average, 6-12% of the heat pump unit's cost,[166]

[164] Nibe (2016) Nibe acquires the main parts of British-owned Enertech Group, available at: https://www.nibe.eu/en-eu/about-nibe/news/press/2016-09-28-nibe-acquires-the-main-parts-of-british-owned-enertech-group, accessed June 2020

[165] Cooling Post (2020), Nibe acquires German heat pump company Waterkotte, available at: https://www.coolingpost.com/world-news/nibe-acquires-german-heat-pump-company-waterkotte/, accessed June 2020

[166] Clean Energy Manufacturing Analysis Center (2016) Heat Pump Supply Chains and Manufacturing Competitiveness Considerations, available at: https://www.energy.gov/sites/prod/files/2016/04/f30/30005_Mann_040716-1105.pdf, accessed June 2020

meaning it makes economic sense to locate manufacturing facilities close to large markets.

Toshiba Carrier, currently manufacturing and importing ASHPs from Japan, has announced its intention to open a factory in Poland to manufacture air conditioning and heat pump products. The manufacturer cited improved lead-times, reduced product cost and proximity to the European market as incentives behind the decision. A press release also stated that "Poland's quality workforce, proximity to Western European nations and attractive investment incentives are the major factors" influencing the decision.[167]

Alongside shipping costs, shipping time is also a driver for UK manufacture, as this has an effect on costs down the supply chain. The following sub-sections outline some of the key considerations for manufacturers choosing their location of manufacture.

Imports

There is currently a high reliance on imports and this is expected to continue, particularly in the ASHP market. There is a large international manufacturing capacity that can easily meet any envisaged growth in UK demand.[168] A few stakeholders felt there would be a continued high reliance on imports to serve UK demand under all scenarios. This was felt to be particularly the case for a high growth scenario in which, to meet a rapid increase in demand, it would be necessary to import from facilities geared up to provide large quantities with little investment in facility upgrades or skilling of workforces.

Furthermore, the high number of manufacturing companies supplying heat pumps to the UK means that importing is more likely to continue than it would be if the market was dominated by a handful of manufacturers. While there is a view that a large increase in demand would largely be met through import, there is also the possibility of a staged approach that seeks to bring in new domestic manufacturing capability, and this opportunity is covered in the section below.

The cost of manufacturing in the UK is viewed by some manufacturers as being too high at present. Some of the key reasons include:

- Higher labour costs than competitors;
- Higher costs of land; and
- Lack of economies of scale.

Despite this, the UK can be a competitive location for manufacture, as proven by the aerospace and automotive sectors placed here as well as current heat pump manufacture.

Some manufacturers stated they would like to manufacture in the UK and that this would be very simple to do, especially as economies of scale can be met in a high growth scenario. A few manufacturers would also consider manufacturing in the UK under the

[167] Toshiba Carrier (2020) Toshiba Carrier to Establish New Manufacturing Subsidiary in Europe, accessed 22 June 2020, https://www.toshiba-aircon.co.uk/news/article/toshiba-carrier-to-establish-new-manufacturing-subsidiary-in-europe/

[168] Frontier Economics and Element Energy (2013) Pathways to high penetration of heat pumps, report for the CCC, available at: https://www.theccc.org.uk/wp-content/uploads/2013/12/Frontier-Economics-Element-Energy-Pathways-to-high-penetration-of-heat-pumps.pdf, accessed June 2020

Medium growth scenario. However, some confirmed that they could not afford to do it on their own and would require an incentive or subsidy to do so.

It is also worth noting that other areas of the world have a significant concentration of activity. For example, northern Italy is a centre for the manufacture of heat pumps for non-domestic applications. It would be difficult to displace this under low growth scenarios and as such, it is expected that import will continue from these regions and others for commercial-scale products.

UK Based Manufacture

As of 2019, only Mitsubishi, Global Energy Systems, Kensa, Big Magic Thermodynamic Box, Star Renewables and Ground Heat (kit assembly of Heliotherm heat pumps) manufacture in the UK. However, there is much scope for UK production volumes to increase.

A handful of manufacturers stated they are ready to increase production at current UK manufacturing facilities, with the caveat that they would need the UK government to demonstrate a long-term, stable and clear low carbon heat policy to get approval from their international headquarters. Indeed, one stakeholder stated that they were in discussions with investors on manufacturing in the UK. Another is considering the acquisition of heat pump manufacturing to support installation into their UK property portfolio. Both examples demonstrate that there is investor interest in the growth of the UK heat pump market.

Manufacturing in the UK is feasible for a large number of manufacturers and can be scaled quite quickly. For example, one existing UK-based manufacturer stated that they would be capable of doubling production capacity by doubling shifts at their current facility.

Some existing UK manufacturers have stated that they have factory space with a reserved area for heat pump manufacture. However, production has not started and they are waiting for the demand to increase before commencing operations. The level of demand needed and the lead time associated with moving manufacture are discussed further below.

There is also the opportunity for UK manufacturers of complementary products, such as air conditioning units, as these manufacturers are already making products with similar components to heat pumps. Such organisations already have an F-gas accredited workforce and, by adapting their production, they could manufacture heat pumps in the UK.

Some manufacturers stated that alongside increased demand, a decision to locate to the UK could also be influenced by product standards. If the UK market required a unique type of product, then consideration might be given to manufacturing this in a separate facility in the UK (if an existing facility could not easily be retrofitted).

Relocating Manufacturing to the UK

Some non-UK based manufacturers suggested that there may be a certain level of demand that would encourage them to consider relocating their manufacturing to the UK.

For those that stated they would consider moving, the number of units each manufacturer would need to sell annually to move production to the UK was discussed. This, combined with a manufacturer's market share and market growth rates, was used to predict the year in which a manufacturer would relocate production to the UK. This also included the time it

would take for facilities to be built and ramp up production (lead times, which are discussed further below). For example, one manufacturer stated that:

- They would consider moving their GSHP manufacture to the UK once selling 5,000 units annually.
- The growth rate projections forecast that this number would be reached in 2029 under the Low scenario, and that then it would take them 24 months to move production and get the facility up and running. Therefore, they would start manufacturing in the UK by 2031.
- Under the Medium and High scenario, they would start manufacturing in the UK by 2027.

The disparity between manufacturers are highlighted by responses to the required number of units (the 'trigger point') that would make it cost-effective to manufacture in the UK, starting at 50 for non-domestic heat pump manufacturers, 2,000 for domestic GSHPs, and ranging from 5,000 to 250,000 for domestic ASHPs.

There were several clear messages from the manufacturer interviews on the factors that will influence whether to expand or move manufacturing to the UK, as well as the trigger points for those decisions. Interviewees consistently stated that having a policy framework that creates the right conditions will be key to the expansion of UK based manufacturing. A key issue is creating a stable and significant market demand. If the UK becomes one of the biggest renewable heating markets in Europe, with sustained market volumes and realistic growth projections, then this will drive manufacturing to move to the UK.

The need for a long-term vision (e.g. a 30-year timescale) and commitment to heat pumps through clear government policy, supported by targets, legislation, and fiscal incentives was consistently highlighted in the interviews as key to business growth and investment decisions. The skills and knowledge required to expand the industry exist, but this commitment was needed to provide stability and encourage businesses to make investment decisions, whether these be about taking people on, building new factories, or acquiring new equipment. This includes seeing a commitment from the UK Government to ensure:

- A consistent Microgeneration Certification Scheme (MCS) that is not regularly changing its rules.
- Future funding support for heat pumps, to make costs comparable with alternatives for consumers, as heat pumps are not currently at a comparable cost with high carbon heating.
- Changes to building regulations to stimulate growth of low carbon heating in both new build and retrofit.
- Phasing out fossil fuel boilers. This could include some kind of boiler scrappage scheme.
- Business grants to support the expansion of UK manufacturing facilities.
- An attractive Corporation Tax regime.
- Carbon reflective pricing for all fuels.
- Upskilling of current existing installers.

- Raising public awareness of heat pumps.
- Clarity on the UK's future trading arrangements and potential tariffs.

Some manufacturers suggested that they could get new lines or sites in operation in less than 12 months following a positive decision by their board; others saw it as a longer process of a couple of years. Even at a couple of years, this could potentially provide a rapid increase in UK production capacity. Any potential UK manufacturing did, however, become more unlikely for those manufacturers that had only recently invested in large European plants.

Modelled Location of Manufacture

The proportion of manufacturing that will take place in the UK with increased demand varies amongst manufacturers, as discussed in the section above, where the number of heat pump units required to manufacturer in the UK have been provided by some manufacturers. Using these trigger points and the assumptions of market share changes outlined in the Future Manufacturer Market Share section, Figure 6-2, Figure 6-3, and Figure 6-4, show the anticipated split of UK-based manufacture and imports under the low, medium and high policy deployment scenarios at five-year intervals.

In the event that import tariffs are placed on components or finished goods, manufacturers would re-evaluate their strategy accordingly. Further discussion on the UK's future trading arrangement is provided in the section "UK's Future Trading Arrangements" below.

In the Low, Medium and High growth scenario in 2020, 67% of UK demand is met by import (approximately the same as the empirical value for 2019), as seen above in Figure 6-2, Figure 6-3, and Figure 6-4. This reduces to 59% by 2025 in the Low scenario and 53% in the Medium and High scenario, as an increasing proportion of UK demand is being met by domestic manufacture. Import is expected to be the main source of UK heat pumps for all the scenarios until 2026, when UK manufacture overtakes import figures (Low – approximately 141,00 vs 137,000, Medium – approximately 201,000 vs 180,000, and High – approximately 215,000 vs 193,000). At this point, the domestic manufacture vs. import from 2030 onwards more or less flat lines for the Low and Medium scenario. For the High scenario, UK manufacture continues to increase from 2030 onwards reaching 66% in 2035.

Table 6-2 summarises the proportion of heat pump demand met by UK manufacturing vs. imports across the three deployment scenarios for 2020, 2025, 2030 and 2035 (which is the same as 2037).

Table 6-2: Summary of UK Heat Pump Manufacture vs Import, All Scenarios

		2020 (%)	2025 (%)	2030 (%)	2035-2037 (%)
Low	Import	67	59	45	45
	UK	33	41	55	55
Medium	Import	67	53	41	41
	UK	33	47	59	59
High	Import	67	53	41	34
	UK	33	47	59	66

Export Potential

Alongside encouraging domestic production, there may be some opportunities to export heat pumps to other markets. It is understood from interviews with manufacturers that UK-manufactured ASHPs (both ATA and ATW) are exported to serve markets in Europe that are larger than the UK's, such as France. However, should the UK market also experience growth, and multiple large markets need serving, this would not be a cause for concern as shift patterns can be doubled and new assembly lines built. There is also export of GSHPs manufactured in the UK primarily to European countries such as France and Ireland, as well as internationally to New Zealand.

The most commonly mentioned countries and regions that provide markets for UK exports were: France, Netherlands, the Republic of Ireland, Germany, Spain. Eastern Europe, North America, and New Zealand.

Current manufacturers of both ATA and ATW heat pumps who are active in several European markets state that there are few differences in the heat pumps sold in different countries, and that they only require minor tweaks. France is seen as the biggest market and the opportunity for export due to government incentives. However, split refrigerant heat pumps dominate the French market over the monobloc systems which dominate the UK market.

The Republic of Ireland presents an opportunity due to its similar climatic conditions and the fact that the market is primarily consuming monobloc systems. The Netherlands, due to location, similar climatic conditions, and a growing market, also offers export opportunities.

Germany may also be a potential market. However, German building standards make the design of heat pumps slightly different and communal heating systems are more common. Portugal and Spain may also present opportunities; however, in these and other Southern European countries, ATA heat pumps dominate the domestic market, presenting less of

an opportunity in these regions. The Eastern Europe market is also seen to be an opportunity as these countries are currently experiencing growth in heat pump sales.

To sell into the US market (primarily ducted/air heating), an EU manufacturer with experience selling domestically would require retooling, and units would need additional testing to meet US efficiency standards. Historically, rather than export to the US, organisations have purchased companies with US manufacturing facilities to gain market share.

There is potential for UK manufacturers to become leaders in hydronic heat pump technology, given its relevance to the UK market and the fact that many international manufacturers are currently focussed on ATA. If UK manufacturers become competitive in this market, it would provide a substantial export opportunity. Global hydronic heat pump sales totalled just over 3 million units in 2018,[169] and are expected to continue to grow.

UK's Future Trading Arrangements

For some manufacturers who currently import directly from outside the EU, any future trade arrangements with the EU were considered to have little impact. For those manufacturing in the UK and Europe, this was more of a concern. Desk research identified a range of UK manufacturing sector-related issues and opportunities, but there is limited information in the literature specific to the heat pump sector. The interviews explored this further, with heat pump and boiler manufacturers tending to highlight the same topics as those identified at a wider UK manufacturing sector level.

Deloitte's summary of the various manufacturing challenges and opportunities concerning the UK's exiting the EU[170] are presented below, and these generally reflect the opinions of UK heat pump and boiler manufacturing sectors.

Challenges:

- Markets (reduced consumption and increased inflation means reduced revenue for manufacturers).
- Business Strategy (economic unpredictability might hinder decision-making, growth, and innovation).
- Talent (reduced UK talent pool resulting from changed border controls)
- Regulation & Legal (new regulation leading to structural reform and legal entity reconfiguration).
- Trade (increased tariff and trade complications surrounding supply chains could drive up operating costs).
- Britain's Influence (reduced role as a gateway into Europe as Britain becomes a less attractive HQ for non-EU businesses).

[169] Building Services Research and Information Association (BSRIA) (2019) World Heat Pump Market Study 2019, accessed 30 March 2020, https://www.bsria.com/uk/news/article/world-heat-pump-market-study-2019/

[170] Deloitte (2017) Impact of Brexit on the manufacturing industry - Managing through uncertainty, 2017, https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/manufacturing/deloitte-uk-brexit-impact-manufacturing.pdf

- Currency (devaluation of the pound means higher input costs and inflation).

Opportunities:

- Supply Chain (reorganisation of supply chains resulting from changes to tax/ trade regulations may lead to efficiency gains).
- Talent (reduced EU immigration opens doors to employing more talent from outside the EU).
- Merger and Acquisition (increased opportunities for UK firms to consolidate domestically or expand into the EU with local production sites).
- Currency (devaluation of the pound leads to increased export competitiveness).
- Innovation (changes to access to markets and talent may catalyse innovation).

Of the above, the following points were particularly highlighted by the manufacturers.

The UK heat pump manufacturing sector could encounter issues due to the complexities of its supply chain and a reliance on imports of key components. The movement restrictions, customs checks, and potential for tariffs on physical goods could impact manufacturers who currently rely on frictionless trade to source components and goods.

Labour also has the potential to be an issue as the UK's exit from the EU takes effect. UK boiler and heat pump manufacturers saw a risk that skilled foreign workers (both full-time and temporary seasonal workers from Europe, and in particular Eastern Europe) may be deterred from coming to or remaining in the UK, which could leave a skills gap in key areas. This concern was driven by potential restrictions on migration, including how future arrangements would impact salary attractiveness, and, if immigration is reduced, where labour could be found locally. This was considered a concern, and while less impactful for some manufacturers whose international labour made up less than 10% of its workforce, it was significant for others for whom the majority of their workforce were international workers. It was recognised that this was not a heating system sector-specific issue and reflected the same potential challenges faced by other UK sectors.

Summary Findings – Potential Growth in the UK Heat Pump Supply Chain

- The global heat pump supply chain is largely unconstrained and can grow as quickly as needed to meet an increase in UK and global demand.
- Manufacturers interviewed as part of this study stated that a 25-30% growth rate per annum sought under a High growth scenario is achievable for the UK market. Reasons cited for this confidence included that heat pumps are a mature technology, that there are existing global markets and supply chains, and that other industries can easily adapt to manufacture heat pumps.
- Monobloc ASHPs and GSHPs provide a particular opportunity to grow UK manufacture. It is not just a case of importing these heat pumps, as there is plenty of scope for UK production volumes to increase. Some manufacturers are ready to increase production at current UK manufacturing facilities, and the scaling up of UK manufacture could happen relatively quickly. Under Medium and High growth scenarios, by 2030 the UK could be meeting 65% of its demand with domestic

production. There is an opportunity to export, with some of the most attractive countries being France, the Republic of Ireland, the Netherlands, and New Zealand, with Asia and the US being harder to penetrate.

- When asked what the most realistic growth in demand for heat pumps would be in the UK, manufacturers stated that relatively low growth is likely up to 2025 (in line with the Low growth scenario), followed by an increase in line with the Medium growth scenario. Manufacturers were less optimistic with regard to the High growth scenario being achieved, given their view that there are significant barriers to consumer demand.

- As well as growing, the UK heat pump market may also change in dynamics, and although difficult to predict, there are some clear indications as to how the competitive UK market landscape might change over the next five years. These include an increased presence of UK boiler manufacturers leading into 2025, large electronics firms maintaining large market shares in the ASHP market, new entrants to the UK market and some market consolidation. These changes are dependent upon the future policy environment for heat pumps, innovations in heat pump technologies, UK trade policy, and availability of and access to finance.

- Regarding future trading arrangements, the UK's heat pump manufacturing industry could experience difficulties due to the complexities of its supply chain and a reliance on key component imports. Customs checks, tariffs, or restrictions on the movement of labour after the UK's exit from the EU could prevent difficulties; however, future impacts will not be known until the form of the UK's future trading relationship with the EU is clearer. In the event of import tariffs on components or finished goods being introduced, manufacturers would re-evaluate their strategies accordingly – it is appreciated that these challenges are not sector specific.

7) Adding Value to the UK Economy

Section Aim - Manufacturing heat pumps in the UK has the potential to add significant value to the UK economy. This section considers the value that can be added, and where along the heat pump manufacturing supply chain or related industries it could be derived. The UK has a unique need that can be filled domestically; this section evaluates where there is potential for the UK to nurture expertise and where there are opportunities for innovation and export. The key findings from the literature review and manufacturer interviews are detailed in this section.

High-Value Heat Pump Supply Chain Areas

There are four key areas of the heat pump value chain where value can be added:[171]

1. Manufacture of heat pumps
2. Technical consultancy and planning of systems
3. Installation and commissioning
4. Operation and maintenance of heat pumps

While areas 2-4 were out of scope for this study, it is worth noting that all three were highlighted by key industry stakeholders during interviews as offering opportunities to add value to the UK economy.

In particular, there was overwhelming consensus amongst interviewees concerning the number and quality of installations required to meet the net-zero aspirations. At present, most heating system installers would need to upskill to be able to install heat pumps.[172] This can only be achieved through a combination of upskilling the current heating system installers and developing the next generation of installers. The Heat Pump Association estimates that by 2035 the UK will need 44,000 heat pump-qualified installers, up from 1,800 in 2020, and has set out a roadmap for achieving this.[173] This upskilling and training of heating system installers also offers an opportunity to export expertise in installation. For example, the UK could develop training resources which can be translated into different languages to be used globally, as demonstrated by REAL alternatives online training resource for installers working with new refrigerants.[174]

[171] Cambridge Econometrics and Element Energy (2018) A study on Low Carbon Value Chains and Economic Growth, available at: https://www.camecon.com/wp-content/uploads/2018/12/YNYER-Low-Carbon-Value-Chains-and-Economic-Growth-Final-Report.pdf, accessed May 2020
[172] Sustainable Energy Association (2019), Heating installers have their say, available at: https://www.sustainableenergyassociation.com/heating-installers-have-their-say/press-release/, accessed June 2020
[173] Heat Pump Association (2019) Delivering Net Zero: A Roadmap for the Role of Heat Pumps, available at: https://www.heatpumps.org.uk/wp-content/uploads/2019/11/A-Roadmap-for-the-Role-of-Heat-Pumps.pdf, accessed June 2020
[174] Real Alternatives – Blended Learning for Alternative Refrigerants - https://www.realalternatives.eu/about-us accessed June 2020

Increasing Manufacture of Heat Pumps in the UK

As noted previously, several interviewees identified that manufacturing could be increased in the UK, should suitable conditions be present. This would primarily be focused on tier 1 heat pump manufacturing/assembly rather than tier 2 component manufacturing. The case for manufacturing in the UK will be specific to each organisation and will reflect their position in the market. For example, manufacturers who already have facilities in the UK will face a different decision to those who are considering relocating to the UK. Using the average product value for heat pumps in 2019[175] and the modelled potential number of heat pumps manufactured from UK facilities (see section on 'Modelled Location of Manufacture'), Table 7-1 provides an estimated value of UK manufactured heat pumps. Assuming that there is no change in the price of heat pumps in real terms, and that the UK has the potential to manufacture 67% of UK heat pump demand under the 'High' policy scenario in 2035; demonstrates a potential of £5.5 billion total value of products for UK manufactured heat pumps, providing income into the UK, benefitting the economy.

Table 7-1: Estimated product value of total heat pump sales in the UK 2019 and UK manufactured heat pumps, and for the UK potential estimated value for 2035 under the low, medium and high indicative market scenarios.[176]

	Low Scenario		**Medium Scenario**		**High Scenario**	
	Value (£m)	**Value (£m) – UK manu.**	**Value (£m)**	**Value (£m) – UK manu.**	**Value (£m)**	**Value (£m) – UK manu.**
	ASHP					
2019	140	50	140	50	140	50
2035	1,320	720	4,390	2,530	7,020	4,600
	GSHP					
2019	30	10	30	10	30	10
2035	230	130	750	570	1,200	910
	Total					
2019	170	60	170	60	170	60
2035	1,550	850	5,140	3,100	8,220	5,510

[175] This is based in real terms 2020 product value figures for ASHP's of £3,500-£6,500 and GSHP's of £7,000- £10,000 - provided in the report - BEIS (2020), The Cost of Installing Heating Measures in Domestic Properties, accessed October 2020, available at https://www.gov.uk/government/publications/cost-of-installing-heating-measures-in-domestic-properties

[176] All totals have been rounded to the nearest £10 million, to account for any uncertainties in the 2020 product value figures.

UK Heat Pump Manufacturing Growth Opportunities

The following sub-sections identify specific products that could add significant value if manufactured in the UK.

Ground Source Heat Pumps

There are several benefits associated with GSHPs, one being that they are typically more efficient than ASHPs. One disadvantage is the need for the additional installation and the associated cost of a ground array. The UK has the potential to capitalise on promoting this type of heat pump, offering the potential for growth both in the UK and overseas. For example, manufacturers state that the Republic of Ireland is seeing a growth in GSHP demand following its move for new homes to have no connection to the gas grid. It was estimated that heat pumps were likely the dominant heating system in new Irish homes in 2017.[177]

Water Source Heat Pumps

Large, commercial-scale UK based opportunities may also exist for WSHPs. The interviews highlighted that the Coal Authority is interested in using heat pumps for domestic heating. There are ~22,000 disused mine shafts in the UK, which are typically full of water and one quarter of UK properties sit on old coalfields.[178] This water represents a substantial source of thermal energy, which could in theory provide enough heat for all of the properties on the UK's coalfields. The water is already brought to the surface by pumps with all the associated engineering in place; introducing a heat pump alongside this could capture that energy. If the heat pumps were configured appropriately, the water in the mineshaft could also be used for the storage of excess heat. The Coal Authority recently announced its first project to use geothermally heated mine water for domestic heating. They have partnered with Durham County Council to build a new 1,500 home garden village at Seaham, County Durham directly adjacent to a disused mine. Heat derived from this mine is expected to provide heat to the entire village[179] [180]

Monobloc vs Split Systems

According to one manufacturer, there are ~50,000 F-gas qualified engineers in the UK. These cover the manufacture, installation and maintenance of stationary refrigeration, air conditioning and heat pump equipment. A rapid growth in heat pump installations could cause a potential shortfall in F-gas certified installation engineers in the UK, and impact on the type of ASHP installed. If there is a deficit of F-gas certified installation engineers in the short to medium term, it would mean that monobloc ASHP manufacturing may have greater growth potential in the UK. This is because split systems will require F-gas certified engineers to install them, whereas installation of monoblocs with its factory sealed refrigeration circuit potentially would not. However, there has been nothing to suggest that the UK could not build up this skill set.

In a traditional ownership model (i.e. the manufacturer sells the heat pump to the consumer) if a compressor was to break down in a monobloc system, an F-gas qualified

[177] Passivhouse+ 2019, accessed June 2020, https://passivehouseplus.ie/news/heating/heat-pumps-mechanical-ventilation-start-to-dominate-new-homes-market
[178] The Coal Authority (2020) Seaham Garden Village, accessed June 2020, available at https://www2.groundstability.com/seaham/
[179] The Coal Authority (2020) Seaham Garden Village, accessed June 2020, available at https://www2.groundstability.com/seaham/
[180] BBC News (2020) Homes to be heated by warm water from flooded mines, accessed June 2020, available at https://www.bbc.co.uk/news/science-environment-52963645

engineer would be required to go on-site, access the refrigerant circuit, and repair the heat pump. However, if the manufacturer ran a service exchange business model whereby the monobloc is replaced with a new unit and the one that needs the compressor repair is returned to the factory, then the engineer would not require F-gas certification, as they would not be accessing the refrigeration circuit. In this circumstance, the UK would most likely only need 10,000-15,000 more F-gas qualified engineers. Category 1 F-gas qualification is needed for refrigerant handling during the heat pump manufacture process, installation and maintenance. This qualification is offered by a number of training providers and takes 4 days and costs £910+VAT per delegate.[181]

It is worth noting that the market trends show that cooling is becoming a greater requirement in certain locations in the UK. This may act as an additional driver for increasing the number of UK F-gas certified installation engineers to meet the need for installation and maintenance of air conditioning units.

The interviews also highlighted that historically split systems are on average more efficient than monoblocs. If monoblocs are the heat pump type of choice in the UK, the development of more efficient monoblocs could be an area of UK-specific R&D.

Role of hybrid and bivalent systems in the transition away from boilers

The term “hybrid” is used in the context of heat pumps to describe several different things: (1) conventional heat pumps which may have more than one heat source (e.g. air, ground, water, thermodynamic), (2) heating systems which include both a heat pump and a gas boiler in the same housing unit. (3) “Bivalent Systems”, heat pumps that are installed in parallel to existing fossil fuel-powered systems, with a control system to balance which heat source is used, and how.

On cold days the heat pump coefficient of performance decreases, while heat demand simultaneously increases, particularly in poorly insulated houses. On such days, heat pumps may require up to four times as much power, even though their total energy consumption throughout the winter may be modest. Type (2) and (3) systems reduce carbon emissions most of the time[182] while retaining the power of existing (e.g. gas, oil) systems to supply heat for short periods of extreme load. This may be particularly useful for installation in buildings that are hard to renovate (e.g. traditional and historical buildings) where heat losses in winter may require a high-intensity heat supply, but only for a short period. A hydrogen-ready hybrid system would also be ready for mains hydrogen, should this become available.

While seen by a lot of interviewees, with only a heat pump product offering, as possibly posing a risk by ‘locking in’ dependency on fossil fuels and thus slowing the rate of decarbonisation, a number of interviewees saw hybrid heat pumps (heat pump and boiler in one single unit) and bivalent systems (heat pump and boiler working in parallel, but separate units) as a ‘bridging technology’ that allows the benefits of heat pumps to be realised sooner, particularly in retrofit programmes. One manufacturer for example stated that they will continue to have a place for some time, and that they are selling quite a large number of hybrid heat pumps, particularly in Scotland and mainly in the new build sector.

[181] PPL Training (2020) F-Gas (Category 1), City & Guilds 2079-11 (FCAT1), accessed June 2020, available at https://www.ppltraining.co.uk/training-course/mechanical-and-electrical-technical/f-gas-handling/f-gas-category-1-city-and-guilds-2079

[182] The ability of a hybrid to reduce carbon emissions is dependent on how often the heat pump component is used versus the boiler/fossil fuel powered system.

The control systems in both type (2) and (3) systems can learn the energy performance of the buildings they are installed in and can be connected to external data feeds which supply forecasts for weather, electricity and gas grid carbon intensity, smart tariff prices, etc. Whilst not specific to hybrid deployment, these smart controls allow the systems to optimise performance based on cost, environmental impact or other metrics, and allow the opportunity for such systems to be used in heat as a service (HaaS).[183] [184]

For the gas and oil boiler manufacturing sector, the uptake of hybrids and bivalent systems may slow the rate of transition to stand-alone heat pumps, allowing the manufacture of boilers, their spare parts, and the offer of maintenance services to decline at a slower rate. The UK has an extensive boiler manufacturing base, including companies that offer hybrids such as Vaillant, Worcester Bosch, and Baxi, accounting for three quarters of the UK's key wall hung condensing gas boiler manufacturers.

Labour transition from gas manufacture to heat pump manufacture

Linked with, although not specific to, the role of hybrids, all the boiler manufacturers interviewed noted that the boiler manufacturing workforce has several complementary skillsets to those manufacturing heat pumps. In 2019, it was estimated that the UK heat pump stock (approximately 240,000 units) supported 2,000 full-time jobs to build, install and maintain the heat pumps.[185] In 2020 the boiler and radiator manufacturing industry alone provided over 6,000 jobs,[186] with more than 120,000 registered gas engineers to install and maintain these boilers.[187]

While the technologies are different, many of the engineering and component assembly processes are similar (except pipe brazing and refrigerant handling which are specific processes associated with heat pumps). If there was a rapid transition (i.e. over the next couple of years) from gas boilers to heat pumps, it is reasonable to assume that the workforce would also be in a good position to transition in parallel. Repurposing a facility is likely to take less time than building the installer base, which is a key barrier identified by manufacturers and will involve developing training standards, establishing a training network and retraining installers.

Innovation, Research and Development

The UK's total expenditure on R&D was £34.8 billion in 2017, the equivalent of 1.7% of GDP, and the government has a target for total R&D investment to reach 2.4% of GDP by 2027.[188]

[183] PassivSystems (2020), Smart hybrid heat pumps provide the UK's pathway of choice to decarbonize heat, accessed June 2020, available at https://www.passivsystems.com/case-studies/smart-hybrid-heat-pumps-provide-the-uks-pathway-of-choice-to-decarbonise-heat/
[184] B-Snug (2020) All you need to know about our Smart Hybrid Heating System, accessed June 2020, available at https://www.b-snug.com/smart-hybrid-heating-system
[185] European Heat Pump Association (2019) Heat pump country cards, accessed 23 April 2020, http://www.stats.ehpa.org/hp_sales/country_cards/
[186] IBISWorld (2020) Radiator & Boiler Manufacturing in the UK - Market Research Report, 2020, https://www.ibisworld.com/default.aspx
[187] Green Match (2020) Gas Safe Register: General Information, accessed 29 June 2020, https://www.greenmatch.co.uk/blog/2015/07/gas-safe-register
[188] Chris Rhodes (2020), Commons Research Briefing – Research and Development Spending, 2020, available at: https://commonslibrary.parliament.uk/research-briefings/sn04223/, accessed June 2020

Designing heat pumps with new components and technologies (e.g. gas sorption, new compressors, and new refrigerants) can lower the capital and operating costs of heat pumps, and investment in these aspects may deliver economic advantages to the UK.[189]

ASHPs could see cost reductions of around 20% in the UK if they reach 'mass-market adoption'.[190] Up to 50% of cost reductions would come from non-equipment costs (e.g. an efficient supply chain and better-trained installers) and up to 10% from reducing unit costs through economies of scale and newer components.[191] The following areas were identified as having potential for UK based R&D and innovation.

Developing UK-optimised heat pump solutions

The UK generally has poorly insulated buildings and a maritime climate, with warmer winters and cooler summers compared to continental Europe.[192]

While implementation of improved standards for insulation and airtightness would help make the UK's building stock more closely aligned with other countries (and therefore mean imported heat pumps were also more aligned),[193] an additional option is to support the design and manufacture of heat pumps better optimised to the UK climate without the need for parallel building standards. This includes, in particular, circumstances where improvements in retrofitting insulation and improved airtightness are more challenging.

Some manufacturer interviewees suggested there is potential to develop heat pumps for the UK's niche, but higher sales volumes would be required to make the necessary product development worthwhile. This was not a universal view, however, with some suggesting that heat pumps installed across Europe (northern to southern latitudes) were equally suitable to the UK. Optimising heat pumps to a specific climate involves many factors like the size of evaporator and condenser coils, the amount and type of refrigerant, the size of capillary action, and the rate of airflow. Manufacturers who were more positive about UK-optimised heat pumps said there was scope for manufacturers moving into the UK market to trial and test these aspects. Beyond its climate, some other specific UK aspects that were discussed included:

- UK planning restricts the size of the exterior unit of a heat pump while requiring low noise; this can be hard to achieve, so may offer opportunities for UK optimised solutions.
- An installation is often required to fit in constricted space, for example, a garage (rather than basements in Europe or central service spaces in communal buildings, where open pipework, etc. are not a problem).

[189] BEIS and Vivid Economics (2019) Energy Innovation Needs Assessment: Heating & Cooling, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/845657/energy-innovation-needs-assessment-heating-cooling.pdf, accessed June 2020

[190] Ibid.

[191] Department of Energy and Climate Change, and Delta Energy and Environment (2016) Potential Cost Reductions for Air Source Heat Pumps: The Scope for a Mass Market, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/498962/150113_Delta-ee_Final_ASHP_report_DECC.pdf, accessed June 2020

[192] Ebac Ltd (2017) Heat pumps for the UK environment, available at https://www.recognitionpr.co.uk/clients/id/14381, accessed June 2020

[193] Greater London Authority (2018) Low Carbon Heat: Heat Pumps in London, available at https://www.london.gov.uk/sites/default/files/low_carbon_heat_-_heat_pumps_in_london_.pdf, accessed June 2020

- With improvements in energy efficiency, particularly of new-build housing, there is potential to develop hot-water only heat pumps, as the space heating load is so low.

Furthermore, as monobloc systems dominate the UK ASHP market, research and development into improving the efficiencies, size and appearance of these systems could be an area of focus.

It is also worth noting that the market trends show that cooling is becoming more of a requirement in some southerly areas of the UK. This needs to be taken into account when considering which heat pumps are most suited to those locations. It is generally more efficient to install a heat pump system that can both heat and cool instead of installing two separate technologies.

There may be opportunities to promote (and protect) UK heat pump manufacturers if UK-optimised design requirements are introduced, as high-volume foreign manufacturers might not consider it worth their while to produce a separate model specifically for the UK market. In this regard, there may be a role for a British Standard for heat pumps in supporting manufacture in the UK. However, it is questionable whether this would result in the optimal technological solution for the UK consumer, for example, it could lead to reduced choice and lower quality for a higher price. Therefore, any standards to support UK manufacture should be carefully considered in terms of the outcome for consumers.

Developing UK-based skills in optimising solutions for the specific climate and housing stock could also be beneficial from an export perspective, especially to those countries with similar conditions, such as France, the Republic of Ireland, and the Netherlands. The developed skills could be applied to adapting and modifying heat pumps to the specific climate and housing stock of other countries. This is then not limiting the required R&D and innovation to the UK, but opening up export potential, and providing the opportunity to add further value to the UK economy.

Smart tariffs and controls

There is a growing demand for the deployment of smart meters and internet-of-things connected devices, which, along with smart connectivity and forecasting, allow the development of advanced business models such as heat as a service (HaaS) and integration with electric vehicles. This allows companies to sell consumers a final service like heat delivery in a building or transportation, rather than the elements they are currently obliged to buy (e.g. boilers, cars, insurance, service contracts, and fuel) to achieve that service.

This offers potential for future growth in the UK design, manufacturing and support services for these systems. Software engineers would be an important part of this type of business. This market is already represented by PassivSystems for example, a UK-based business that specialises in smart energy control systems and services. Kensa is also switching its controls supplier from Italy to the UK, demonstrating that this is a potential area of growth for the UK.

Control systems are becoming not only more sophisticated but more connected, allowing installed systems to vary their output in response to occupancy and usage patterns, weather forecasting, grid carbon intensity, time-of-use tariffs, connected devices and other factors. With the ability to analyse these data-sets, smart systems can learn the energy efficiency characteristics of buildings and modulate demand accordingly to achieve optimal heat pump output. The UK is at the forefront of developments in energy technology markets, and has made some progress with key technologies such as smart

metering; this opens up the potential for differentiation of the proposed UK heat pump deployment programme through the development of novel business models. This approach is consistent with other initiatives such as the move towards a circular economy, an approach likely to be embedded in the development of the European economy.

Several further aspects of heat pumps and related technologies were identified as current areas of innovation. Whilst these were not identified as areas of specific UK R&D and innovation, they are highlighted due to their growing significance in the market and therefore future growth potential. These include:

Designing heat pumps with greater modularity

This approach is popular in circular economy business models, for example facilitating heat as a service. It involves greater standardisation of components that are simple to replace combined with smart monitoring, allowing users or non-specialist local tradespeople to swap out standard parts that can be delivered using existing logistics (and reverse logistics). Faulty components can then be returned to the factory for renovation rather than having to be fixed on-site by specialists.

Refrigerants

In a leaky installation, the conventional refrigerant in cooling circuits can make the climate impact of leaks greater than that of emissions from energy consumption. Leaks commonly occur when there is a pipe failure or leaking seal in the compressor. The high GWP of conventional refrigerants has led to pressure to develop alternatives. The interviews demonstrated that several manufacturers are developing alternative refrigerants. These include other synthetic fluorocarbons with a lower GWP (e.g. R-32) and “natural” alternatives such as propane, ammonia and carbon dioxide, which have very low or even zero GWP.

Design of large-scale heat pumps for industrial applications and heat networks

The UK is home to companies which are specialised in the design, manufacture and installation of large-scale heat pumps for industrial and agricultural applications or district heating networks, such as Star Renewables. These are typically large-scale ASHPs and WSHPs, which in industrial and agricultural applications are particularly well-suited to circumstances where both heating and cooling are required on site. This area of expertise offers growth potential both in the UK and overseas, especially as Europe is one of the world leaders in district heat networks with over 6,000 systems installed across the continent.[194] It will be important that, where they are not initially connected to a heat pump, heat networks are future-proofed to allow the retrofitting of heat pumps.

Export

Domestic opportunities in terms of manufacture, installation and maintenance of new heat pump technologies have great potential. The associated GVA and jobs will likely be

[194] D. Connolly, H. Lund, B.V. Mathiesen, S. Werner, B. Möller, U. Persson, T. Boermans, D. Trier, P.A. Østergaard, S. Nielsen, Heat roadmap Europe: combining district heating with heat savings to decarbonise the EU energy system, Energy Policy 65 (2014) 475–489. https://doi.org.1016/j.enpol.2013.10.035

replacing current activity associated with traditional heating,[195] with an increase in some activity as heat pumps are slightly more complex to produce and install, in particular relating to GSHP's. Therefore, there is a clear benefit of creating a product, service or innovation in this country that can be exported, providing this adds further value, rather than displacing the delivery of the current boiler export market.

There is great potential for domestic added value in exports from current and future UK heat pump manufacturers. Value added can be broken down into the following components: compensation of employees, gross operating surplus, mixed-income, and other taxes on production.[196]

As mentioned in previous sections, the UK is already exporting heat pump units. If investment in UK facilities to not only meet UK demand, but to export is landed, then the UK gains more added value through jobs and money spent here. Furthermore, some UK-based manufacturers of related appliances are already exporting other products like boilers and HVAC units—a business model that could be replicated by the heat pump sector. There is also much scope for the UK to create efficient, high-quality products that are recognised for these traits globally, supporting their competitiveness in an international setting.

If the UK can grow its domestic capability and market by attracting inward investment, there may be greater export opportunities later on. In the context of R&D and innovation for UK-specific heat pump products, the potential for their export must also be considered in order to maximise the potential to add value to the UK economy. The same considerations apply in related sectors, such as controls, designs with greater modularity and refrigerants as this presents additional value. There is also much scope for innovation to be fostered in the UK setting for export globally, whether it be products or skills.

Summary Findings - Adding Value to the UK Economy

- The deployment of monobloc heat pumps may add significant value to the UK economy. The short to medium term deficit in F-gas qualified engineers could benefit the deployment of monobloc systems and there is an opportunity for the UK to focus on R&D for monobloc systems.
- The UK boiler manufacturing and heat pump workforces have complementary skillsets. Transferring the boiler manufacturing workforce to making heat pumps is critical both for safeguarding UK employment and harnessing existing skills.
- UK and overseas demand for GSHPs is growing and offers export opportunities for UK-based manufacturers.
- The transition to stand-alone heat pumps via hybrid and bivalent systems could act as "bridging technology", especially in some retrofit applications (for example, where high levels of insulation are not cost-effectively achievable).

[195] Department for Business, Energy & Industrial Strategy, and Vivid Economics (2019) Energy Innovation Needs Assessment - Sub-theme report: Heating & cooling, 2019, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/845657/energy-innovation-needs-assessment-heating-cooling.pdf, accessed June 2020

[196] OECD (2016) Domestic value added in gross exports, available at: https://data.oecd.org/trade/domestic-value-added-in-gross-exports.htm, accessed June 2020

- Opportunities to boost the added value to the UK economy brought through the manufacturing of heat pumps include:
    - aiding the transition of the boiler manufacturing workforce to heat pumps;
    - investing in R&D to develop UK-specific heat pump solutions;
    - investing in R&D into new types of refrigerant,
    - greater use of smart tariffs and controls to support the wider integration of heat pumps into the smart grid, allowing installed systems to vary their output in response to occupancy and usage patterns, weather forecasting, grid carbon intensity, time-of-use tariffs, connected devices and other factors.
    - designing heat pumps with greater modularity; and
    - designing large-scale heat pumps for industrial applications and heat networks.

8) Impact of Heat Pump Growth on the Boiler Industry

Section Aim - Heat pumps will contribute to the decarbonisation of heat in the UK, and there will be a necessary transition away from fossil fuel boilers. The potential impacts on this sector are covered this section. These impacts were explored with manufacturers in interviews as well as through the literature review and supply chain mapping.

Gas Boilers

All the main UK boiler manufacturers (e.g. Vaillant, Baxi, Worcester Bosch, and Ideal) also manufacture heat pumps overseas, albeit not at the scale of their boiler production. Traditional boiler manufacturers, therefore, have the potential to transition to manufacturing in the UK and increase a heat pump offering going forward if the demand was sufficient. The number of units each manufacturer would need to sell annually to move production to the UK ranged from 5,000 to 45,000 units. The majority of interviewees stated the banning of gas boilers in new builds by 2025 in the Future Homes Standard would encourage a shift in the industry. This effect would be limited to the new-build market, however.

Boiler manufacturers highlighted that, with respect to new or different technologies, their current focus is on hydrogen-ready boilers. Hydrogen will remain a focus for the industry; this technology is preferable because it would be less disruptive to their current business model and operations.

Hybrid heat pumps will also play a role, but the conventional boiler will continue to dominate their offering. Overall, there were no real concerns raised by boiler manufacturers in the short term for the boiler industry, and it was felt that the industry would remain relatively stable—particularly while wholesale gas prices remain stable and lower than electricity per unit of heat supplied.

One heat pump manufacturer suggested that there is scope for partnerships between heat pump manufacturers and boiler manufacturers: boiler manufacturers have expertise in indoor technologies (inside domestic properties) and heat pump manufacturers have expertise in compressors and the refrigerant side of heat pumps (outdoors). Boiler manufacturers could continue to focus on heating hydraulics and heating controls with their current expertise.

The increase in heat pump sales logically translates to a decrease in boiler sales (other than hybrids). Consequently, there is a concern that there could be a downturn in the UK-based workforce required during this period, for a UK manufacturing workforce of around 6,000 people (boiler and radiator).[197] There may be a transitionary period during which demand for UK-manufactured boilers falls while the heat pumps that are replacing them are imported rather than made locally. In the short term, little change is expected except in

[197] IBISWorld (2020), Radiator & Boiler Manufacturing in the UK - Market Research Report, Jan 2020, available at: https://www.ibisworld.com/united-kingdom/market-research-reports/radiator-boiler-manufacturing-industry/

the new build market, however this is a small percentage of the market (~10%) and the overall UK gas boiler market is predominantly repair, maintenance and improvement products.

Oil/LPG Boilers

The Clean Growth Strategy committed to 'phase out installation of high carbon fossil fuel heating in buildings not connected to the gas grid, starting with new build, during the 2020s.' BEIS is seeking to develop a comprehensive policy framework to support this transition; they are currently exploring all options for this decarbonisation and will be consulting on proposals for this in due course. This means that in the 2020s heat policy is likely to target off-gas grid homes before on gas grid homes, meaning oil and LPG boiler sales will be the first to be impacted.

In terms of impact from growth in UK heat pump sales, if this is dominated by the new-build sector then the impact on oil/LPG boiler sales would be very low as oil/LPG boilers are generally not installed in new buildings. One manufacturer suggested that in a low heat pump deployment scenario, oil boiler sales would be impacted by less than 1,000 units. However, if the growth of heat pump sales in the retrofit market is also supported by policy interventions then there would be more of an impact. In this instance—and if it was left to the market and householders to decide—the same manufacturer estimated that a drop in annual oil boiler sales by around 10,000 units could be seen.

In 2020 the government announced £100 million new exchequer funding to subsidise heat pump unit costs to incentivise a transition away from fossil fuel heating. The funding will be open for two years. One large boiler manufacturer (gas, oil and LPG) that was interviewed considered this to be effectively introducing an oil boiler scrappage scheme incentivising the replacement of oil/LPG boilers with heat pumps. Manufacturers stated in interviews that they were not convinced that this will be successful as the installation costs of a heat pump after the proposed grant (£4,000) would still be around £2,000- £3,000 higher than for an oil boiler.

Generally, the view of manufacturers on the impacts of heat pump deployment on the oil/LPG boiler sector in terms of transitioning into new markets mirrored those for the gas boiler sector. It was noted that, if policies were introduced aimed at reducing the dependence on oil/LPG boilers, a two or three-year window would be needed before implementation to allow the workforce to transition to heat pump manufacturing. It was noted that heat pumps are slightly more complicated to manufacture than gas, oil and LPG boilers, particularly in comparison to oil boilers, highlighting the need for upskilling should they transition to heat pump manufacture.

As with the gas boiler industry, most of the oil boiler manufacturing companies are global businesses with established heat pump operations elsewhere, and similarly, they would simply follow market demand. Furthermore, the largest UK oil boiler suppliers have heat pump product offerings, potentially softening any transition to heat pumps. Some of the gas boiler manufacturers could start manufacturing in current UK facilities relatively quickly, as they have access to the required technologies. Some even stated they have reserved factory floor space for this, but are waiting for demand to increase.

Lessons Learned from Other Transitions to Minimise Disruption

Many comparisons were drawn by manufacturers between the Future Framework for Heat in Buildings[198] and the government's commitment to end the sale of petrol and diesel cars from 2040,[199] a policy that has provided the automotive industry with clear direction and opportunities for growth. The automotive supply chain is undergoing its own transition to low carbon alternative technologies, from traditional internal combustion engines to electric drive trains. One boiler manufacturer highlighted that they are drawing on lessons from the sector at present.

Fewer employees are required to make an electric car compared to a fossil-fuel-powered car, which has led to a structural shift in the market and means that manufacturers are facing workforce issues: fewer employees are needed to deliver the technology for the same output. However, heat pumps are slightly more complicated to manufacture than boilers, meaning that it is unlikely such a structural shift will be required in the heating manufacturing sector.

The transition from internal combustion engines to electric vehicles has meant that there is no longer constant evolution in the current technology due to its decline. The rapid change in electric vehicle technology requires short term investments to avoid production facilities making obsolete designs. Advanced Propulsion Centre UK funding, expertise and collaboration were put in place to focus on ensuring that the UK remains competitive in the research, development and production of low carbon propulsion technologies.[200]

Furthermore, the boiler industry in the UK has already undergone a rapid transition. Lessons can be taken from the sector's switch to condensing boilers, where the government set a date (the 1st of April 2005) after which non-condensing boilers could not be installed. This gave manufacturers approximately two years notice to successfully prepare, highlighting that transitionary periods between policy changes are necessary for large technological shifts.

Disruption to the fossil fuel sector can be minimised by setting clear and consistent policy in advance. For example, if there was a ban on oil-fired boilers, the sector should be given advance notice of at least two to three years. The sector can thus plan to maintain its workforce. Reskilling and upskilling grants could help future-proof the fossil fuel industry by ensuring staff are trained ahead of the transition to heat pumps, strengthening their resilience and enabling a better response to a changing product landscape. Policies that concentrate on creating more flexible, longer term investments in UK facilities could help to smooth the transition.

[198] Department of Business, Energy & Industrial Strategy (2018) A Future Framework for Heat in Buildings, accessed June 2020, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762546/Future_Framework_for_Heat_in_Buildings_Govt_Response__2_.pdf

[199] Defra (2017) UK plan for tackling roadside nitrogen dioxide concentrations: an overview, accessed June 2020, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/633269/air-quality-plan-overview.pdf

[200] Advanced Propulsion Centre UK, https://www.apcuk.co.uk/, accessed May 2020

Summary Findings - Impact of Heat Pump Growth on the Boiler Industry

- Boiler manufacturers think that in the short term their manufacturing operations will remain relatively stable, especially while wholesale gas prices remain stable and lower than electricity per unit of heat supplied.
- Several boiler manufacturers also offer heat pump products and are therefore capable of ‘following’ changing market demand.
- The Future Homes Standard is expected to initiate a shift away from boilers to lower carbon heating technologies, however this will only apply to the new build sector.
- In the retrofit market, boiler manufacturers are targeting a transition to hydrogen boilers, and in some case hybrid heat pumps.
- There is a need for a managed transition, advanced notice and intervention from the government to protect jobs and help re/up-skill existing employees. This would encourage the transition to heat pump manufacturing at UK facilities.

9) Conclusion

Combined with the decarbonisation of the electricity grid, heat pumps are very likely to play a key role in the decarbonisation of heating needed to achieve the UK's net zero carbon target by 2050.

The heat pump market in the UK, Europe and globally has been studied in order to understand how to develop an environment that is more supportive of the UK's heat pump supply chain. Globally the heat pump industry is well established, and mature supply chains are in place. The UK market for heat pumps is less mature than countries like France which have comparable populations, economies, and climates.

The heat pump market is growing across the UK, Europe and internationally and is expected to double between now and 2030 across the world. The UK is one of the largest European heating markets (due to its dominance in the gas boiler sector) and as such could become a large low carbon heating market.

Unlocking the potential of heat pumps as a low-carbon heating technology will be focused on policy to stimulate demand. If demand were to increase significantly in the short term, there would be no fundamental supply-side barriers that could hamper rapid growth in UK heat pump deployment. The well-established supply chain can grow as quickly as the market requires because, in many instances, heat pumps represent a small fraction of manufacturers' product portfolios. Shift patterns can be increased at existing facilities and new assembly lines can be established relatively quickly and easily (<12 months). New facilities will need longer lead times (~24 months). Accurate forecasting of demand across countries is key to ensuring that there is no lag time between demand and manufacture.

This research also aimed to understand the key steps needed to ensure that the UK will capitalise on this domestic and international growth, creating jobs and growing the UK's economy. The extent to which the UK can meet growing demand through domestic infrastructure has been studied, particularly in interviews with manufacturers.

The UK's attractiveness for manufacture is affected by large considerations like the cost of labour, cost of real estate, and future tariffs. Attracting manufacturers to install factories in the UK throughout the supply chain will be challenging, and stimulating demand is core to investment decisions. The UK has the potential, under a high heat pump demand scenario, to attract manufacture to meet around two-thirds of UK demand with domestic manufacture by 2035, an end-user product value of £5.5 billion. Long-term policy commitments which reduce the risks associated with investment in the UK and stimulate demand is just part of the story. It is unlikely that demand alone will be enough to stimulate investment in the UK heat pump supply chain for organisations currently not manufacturing in the UK.

According to interview responses, no two organisations that serve the UK heat pump market have the same portfolio of requirements in terms of what would make the UK manufacturing attractive.

The UK has established engineering skills to support UK manufacture and innovation, and there is already UK-based manufacturing of heat pumps taking place by the dominant market share holders for both ASHPs and GSHPs. There is much scope to scale these operations up and current facilities are poised for further investment to satisfy potential increases in demand. Export of heat pumps, from these facilities is already happening. If

the UK were able to target and land more investment in heat pump manufacturing facilities, both for export and to supply the UK market, then there is great potential of added value to the UK economy.

UK-manufactured products could easily be technologically tailored for export, however, given the established global market, gaining market share here will be difficult. This could be focused on countries experiencing large growth or that have similar climates such as France, the Republic of Ireland, and the Netherlands.

There is a good opportunity in utilising existing UK boiler manufacturing facility space and re-skilling the workforce in the UK to meet future demand for heat pumps. The boiler manufacturers with current modest market shares in the heat pump sector represent one of the biggest opportunities for UK manufacture, but also the biggest threat to the current dominant ASHP market share held by Mitsubishi (who currently manufacture in the UK), Daikin and Samsung. Most boiler manufacturers in the UK market have established and dominant European heat pump market shares which could easily be emulated in the UK—should the business environment be right and given business appetite (which there appears to be).

The manufacture of heat pump components is currently done throughout a global supply chain, with specialist manufacturers, extremely large workforces, and manufacturing clusters that are located for historical, economic, and other reasons. It is unlikely that Tier 2 suppliers would uproot these embedded facilities to move to the UK in the short or medium-term without significant incentives. However, experience thus far has demonstrated that certain parts of the supply chain may gradually grow locally around manufacturing facilities.

Several focus areas could provide added value to the UK economy, in addition to the manufacture of the heat pump product itself. This includes: the training of installers and the potential to export this expertise; capitalising on the promotion of GSHPs where efficiencies are higher, global demand is growing and the market is less saturated; specific R&D into monobloc heat pumps, which are the favourable option in the UK (alternatively the training of F-gas certified installation engineers to support greater penetration of split systems that could also be utilised for the UK’s growing cooling demands); the opportunity to develop UK-optimised heat pump solutions; innovation and manufacture of smart control systems (particularly where hybrid systems are employed) as the UK is at the forefront of developments in energy technology markets; smart controls which could open up the potential for novel business models such as “heat as a service”; developing heat pumps with greater modularity, which has the potential to facilitate “heat as a service” and follow an increasingly popular circular economy business model; developing alterative refrigerants for the sector; and finally building upon and exporting the UK’s current heat pump specialism: the design, manufacture and installation of large scale heat pumps for industrial and agricultural applications or district heating networks.

Appendix

A – 1: Research Questions

1. What are the risks and opportunities for the UK heat pump supply chain?

1.1. What does the current heating market look like in the UK for domestic and non-domestic properties?

Who are the key manufacturers of heat pumps and boilers (tier 1) and the key component suppliers (tier 2)?

What are their relative strengths and weaknesses?

What are the potential risks to the existing UK heating systems manufacturing sector as a result of a move to low-carbon heating?

Which low carbon alternatives are heating companies investing in?

1.2. What does the current heat pump market look like outside the UK?

Who are the key manufacturers (tier 1) and component suppliers (tier 2)?

Which of these manufacturers could look to the UK to expand or relocate their operations due to interests that align with the UK market?

1.3. Which other industries are likely to have synergies with the heat pump industry, in terms of similar components, similar skills requirements etc. (e.g. refrigeration, air conditioning, ventilation)?

Who are the key tier 1 and 2 stakeholders in these industries?

What are their relative strengths and weaknesses?

1.4. In each tier of the heat pump supply chain, what does the UK produce, import and export (to cover air-source heat pumps, ground/water-source heat pumps, high-temperature heat pumps, hybrid heat pumps for both domestic and non-domestic properties)?

What other aspects add value (e.g. training for installers)?

What are the key differences between the supply chains of different types of heat pump?

How do the supply chains differ if heat pumps are being manufactured for new build or retrofit?

1.5. In each tier of the supply chain for boilers and other related industries, what does the UK produce, import and export?

What other aspects add value (e.g. training for installers)?

Where are there synergies with the heat pump supply chain?

1.6. What would make the UK an attractive proposition for heat pump manufacture?

In which aspects of the heat pump manufacturing supply chain, or those of related industries, does the UK have particular expertise?

Where is there potential for the UK to grow expertise and where are these opportunities for innovation?

1.7. Which aspects of the heat pump supply chain represent the highest return on investment for the UK?

1.8. What impact could the UK's future trading arrangements with EU and non-EU countries have on the manufacturing supply chains of heat pumps?

How will this affect availability of skilled labour?

2. How fast could the UK heat pump supply chain grow?

2.1. In terms of production volumes, what would a feasible growth rate of the heat pump manufacturing supply chain be over time under a range of different heat pump demand scenarios compatible with net zero (e.g. current policy environment, hydrogen + electrification future, electrification future) and scenarios of future support for the industry (e.g. current policy environment and plausible policy interventions)?

What would be the split of imports vs domestic manufacture? What would the level of exports be?

2.2. Under different scenarios, what would happen to the gas boiler industry?

Would it continue to make gas/hydrogen boilers, focus on hybrid heat pumps, convert to heat pump manufacture?

What would happen to the oil/LPG boiler industry?

2.3. Under different scenarios, what would meeting a particular growth rate mean in terms of import/production of heat pumps and their components, skilling the workforce, number of factory buildings, organisation of the factory floor etc.?

What are the trigger points for business decisions and what are the associated lag times?

2.4. What are the opportunities and scope for the UK to secure a larger share of the international heat pump market, regardless of the scale of expected UK demand?

Which suppliers currently engage in trade, especially exports and which countries do they trade with?

3. What is the role for government in supporting a thriving UK heat pump manufacturing sector?

3.1. What aspects of the current policy environment (e.g. standards, regulations, policy commitments) in the UK are supporting or hindering growth of the heat pump supply chain?

3.2. What commitments/incentives/upskilling programs/standards/targeted investment would encourage manufacturers to grow their heat pump supply chain in the UK, as opposed to elsewhere?

3.3. In other sectors (in the UK and elsewhere) that have grown rapidly or converted operations from producing one product to another (e.g. condensing boilers) and other countries where the heat pump supply chain has grown rapidly, what policy environment enabled that to happen?

3.4. What policy levers are likely to be most successful in terms of growing a sustainable and resilient supply chain and fostering innovation in the UK manufacture of heat pumps to deliver a product that is better suited to the UK housing stock?

3.5. What is the role of the UK government in the growth of the heat pump manufacturing supply chain in the UK and the facilitation of imports for any shortfall that is not possible to meet domestically?

How can the government minimise disruption in the transition away from fossil fuel heating?

Table A- 1: Mapping of research questions

	TASKS				
#	Literature Review	Supply Chain Mapping	Manufacturer Interviews	Growth Rate Analysis	Validation of Results
1	What are the risks and opportunities for the UK heat pump supply chain?				
1.1	✔	✔	✔		✔
1.2	✔	✔	✔		✔
1.3	✔	✔	✔		✔
1.4		✔	✔		✔
1.5		✔	✔		✔
1.6	✔	✔	✔		✔
1.7	✔	✔	✔		✔
1.8	✔	✔	✔		✔
2	How fast could the UK heat pump supply chain grow?				
2.1			✔	✔	✔
2.2				✔	✔
2.3			✔	✔	✔
2.4			✔	✔	✔
3	What is the role for government in supporting a thriving UK heat pump manufacturing sector?				
3.1	✔	✔	✔	✔	✔
3.2	✔		✔	✔	✔
3.3	✔		✔		✔
3.4			✔	✔	✔
3.5			✔	✔	✔

A – 2: Methodology

In this report, all information and opinions collected through the interviews have been anonymised, such that individual manufacturers or organisations cannot be identified either directly or by proxy; all interviewees signed a written consent form allowing anonymous data to be collected. All information collected during the interviews was stored securely following the General Data Protection Regulation (GDPR). Data presented in this report have been anonymised and presented at an aggregated level to maintain confidentiality.

Interviewees were stratified using classifications with a purposeful sampling approach, as shown in Table A- 2.

Table A- 2: Manufacturer Classifications

Manufacturer Classification	Target Number of Interviews	Number Interviewed/ Scheduled
International heat pump manufacturers (manufacturing overseas)	8-10	11
International heat pumps and boiler manufacturers (manufacturing overseas)		2
UK based heat pump manufacturers (manufacturing in the UK)	6-8	3
UK based - Heat pumps and boilers (boiler manufacturing in the UK, heat pump overseas)		4
International manufacturer of related products and components	3-5	2
UK manufacturer of related products and components		3
Trade Associations	1-2	3
Energy Suppliers	0-1	1

Manufacturer Classification	Target Number of Interviews	Number Interviewed/ Scheduled
Wholesaler	0-1	0[201]
Housing developer/association	0-1	1
Total	**18-28**	**30**

Research Question Mapping

All of the research questions were mapped to each of the above research tasks. The five tasks were designed and implemented in a complementary manner to balance primary and secondary research while ensuring the effective synthesis of results. Different tasks were designed to address particular elements of the different research questions, summarised by the three key research questions in Table A- 3.

Table A- 3: Mapping of Research Questions

Tasks	Lit. Review	Supply Chain Mapping	Manu. Interviews	Growth Rate Analysis	Validation of Results
What are the risks and opportunities for the UK heat pump supply chain?	✔	✔	✔		✔
How fast could the UK heat pump supply chain grow?			✔	✔	✔
What is the role for government in supporting a thriving UK heat pump manufacturing sector?	✔	✔	✔	✔	✔

[201] Wholesalers were targeted, however recruitment was unsuccessful.

Data sources for Task 2: Supply Chain Mapping

The three main sources used in the heat pump market analysis section were:

- International market: a 2020 Global Market Insights (GMI) report, which includes air-output heat pumps (ATA, GTA and WTA) in data totals.[202]
- European market: a 2019 European Heat Pump Association (EHPA), which also includes air output heat pumps.[203]
- UK market: a 2020 Building Services Research and Information Association (BSRIA) report, which only includes hydronic (ATW, GTW and WTW) heat pumps.[204]

Two different main data sources were used to quantify manufacturers' market shares in the UK:

- The Microgeneration Certification Scheme (MCS) database of ASHP installations. This dataset provides data on the installation of small scale (<45kw) heat pumps installed in Britain. The MCS is mandatory for the domestic RHI installations and therefore likely to be one of the most comprehensive datasets for ASHPs in the domestic sector, however not all installed heat pumps (approximately one-third) claim the RHI. Non-domestic installations do not need to be accredited under the MCS.[205]
- A 2020 BSRIA report, with market share data for ASHPs and GSHPs up to 2019. This report estimates the market shares of each manufacturer.[206]

A total of 37 manufacturers of heat pumps were identified during the initial supply chain mapping exercise. These manufacturers were sorted into those that do and do not manufacture in the UK, as well as those identified as having a large share of the UK market in 2018 for either GSHPs and ASHPs.[207]

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A – 3: REA Sources

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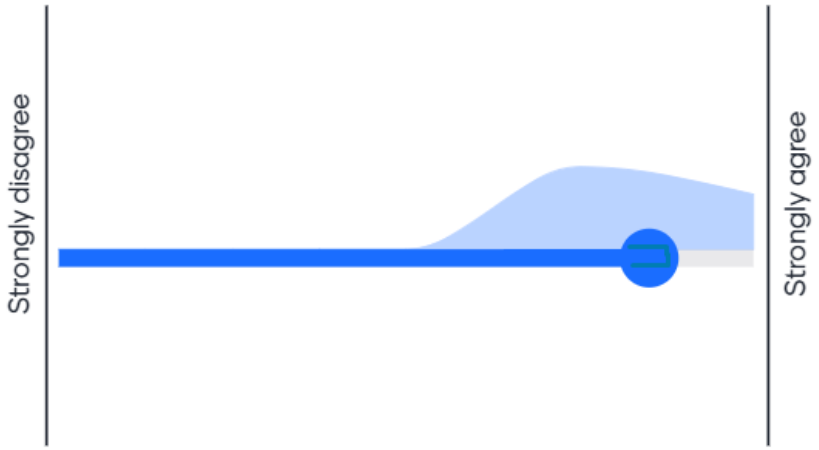
A – 4: Validation Workshop Results

21 manufacturers took part in responding to these questions, this is not intended to be representative, but was used to gain additional qualitative insight from a wider representation of the industry.

Question 1.1: Do you agree with the general findings discussed on the last three slides?

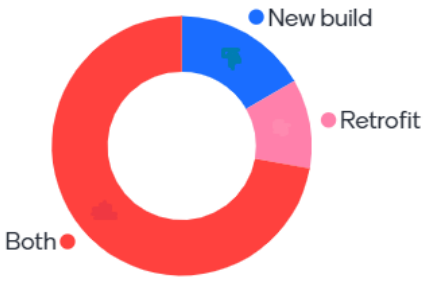


Question 1.1: Please explain why you chose that answer.

Mentimeter

The findings were very much as expected.	Agree with clear findings.	Good representation of the current situation and industry requirements
I agree with the overall findings	All matches my experiences in the sector	No surprises with the results
There was a balance of technical, social and legislative aspects. The challenge is however what drives what. For me legislation is key. We must create an imperative to decarbonise	Findings were as expected	I fully aggre with the results
It covers the current position	Not sure where the UK air-source are being manufactured, unless you include Mitsubishi assembly. I assume that the measurement was by number of boxes, rather than compressor power	General info was accurate, however, the market share data where GSHP > ASHP for new build does not seem accurate. The vast majority of HP installed are ASHP. So it does not seem practical to have this finding. Check dRHI data for guidance.

Question 1.2: Which market are you likely to focus on going forward?

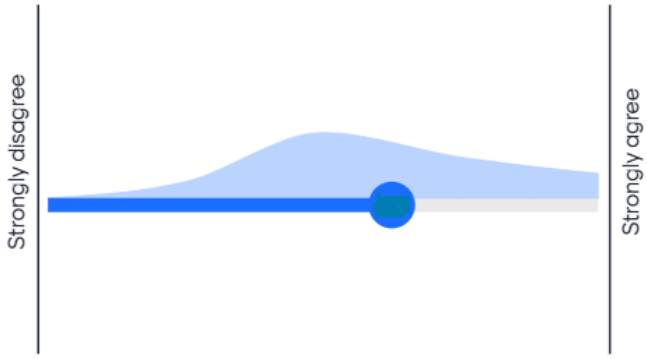


Question 1.2: What are the challenges associated with exploiting that opportunity?

Mentimeter

- Legislation and cost of gas.
- Price of gas
- Consumer attitude, experience, poor quality existing homes, significant work to upgrade
- Poor government policy. Continued subsidies for gas and oil
- The clients looking beyond a payback on the installation for retrofit (ie Heat pumps vs Boilers)
- Trying to find equipment that can be retrofitted into existing builds
- Displasing gas in the retrofit sector
- Scale: the larger the better for us. Legislation: will need more very clear stick than carrot, I think
- Changes to the building regulations will be key in stimulating the growth in new build. A range of changes will be needed for retrofit including carbon reflective fuel pricing and the upskilling of the workforce.
- Retro is not challenging but the size of the market dictates a larger potential so cannot be ignored even though the vast majority of policy is focused on new build at present
- Building Regulations Price of Gas v electric Installer Training
- We are still encouraging individual plot solutions in commerciall london which makes it harder to decarbnise the neighbouring plots. Biggest problem is lack of obligation (and gas is cheap)
- Price gas, consumers knowledge, upfrnt incentives,...
- Both are attractive markets if you can offer a range adapted for each one..
- The issue that existing properties, particularly off gas properties are rarely efficient enough for a Heatpump system to work at its best
- Building regulations and fuel cost of both electricity and gas
- Stronger incentives/legislation are required in the retrofit market to increase the numbers of low carbon heating installed. This will need to be done if we want to achieve 2050. Also awareness must increase

Question 1.3: There aren't many differences between the supply chains of different types of heat pump (e.g. ASHP/GSHP - A-W, A-A, W-W, W-A etc.)

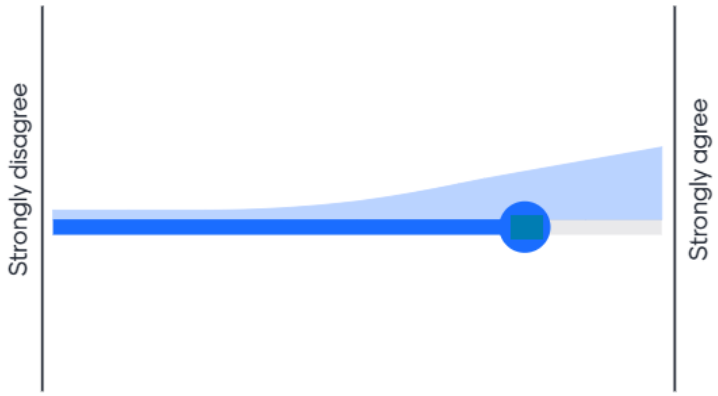


Question 1.3: Please explain why you chose that answer.

Mentimeter

- based on technical knowledge of the equipment
- The design element of GSHP is a significant differentiator.
- Very similar technology despite the heat source i.e ground or air
- Most focused manufacturers provide both types of unit.
- For Ground Water or Water - Water solutions the supply chain is more technical
- On the larger scale heat pumps then ashp becomes a little more restricted
- Similar components
- At the equipment level, the supply chains are much the same. Installation and design inputs are quite different
- Core components are similar. Supply chains are relatively mature.
- The primary heat pump components are very similar
- Ground and air are similar, water source is different because of the scale of the opportunities
- GSHP's require a wider knowledge that ASHP's, particularly geology and bore hole drilling.
- Aside from ground loop aspects the kit is the broadly the same. Where both struggle is building integration in retrofit is underskilled and understaffed.
- Non-ASHP installers more niche and involved
- Each type of heat is a different product and as such the supply chain is different. It is true that when sharing some components, there are some things in common.

Question 1.4: Given increased demand, our business would find it easy to expand or relocate manufacturing to the UK.

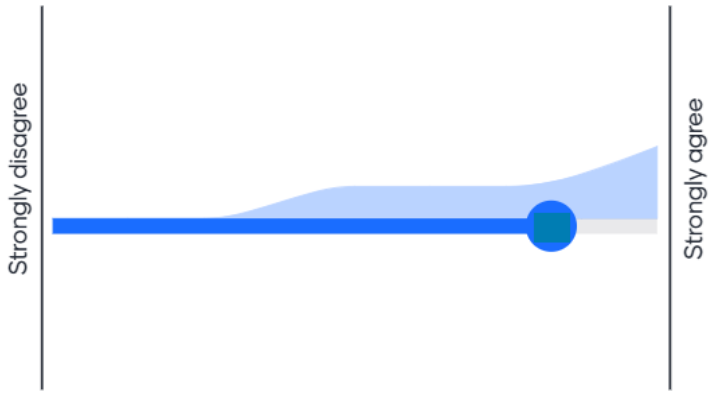


Question 1.4: Please explain your previous answer.

Mentimeter

- Demand is only part of the picture
- Demand drives supply.
- Mitsubishi Electric already manufacture in the UK and are poised for further investment to satisfy demand.
- Established engineering skills
- UK based already
- Our current volume is about 0.5% of refrigeration market activity.
- Disconnect between market projections and current demand ' policy - makes investment difficult
- With sufficient demand manufacturing will happen.
- Large manufacturing base in europe, unlikley to relocate
- With sales growth it is a more than reasonable option
- Demand drives supply. Good connection with HQs, good engineering skills in the country, ...
- We could repurpose one or more of our boiler production lines once we have a demand into the thousands of units.
- Close transport links to Europe. The UK is one of the largest European heating markets, so could become one of the largest low carbon heating markets
- Incentives to relocate manufacturing will be needed
- UK manufacture is expanding e.g. Kensa Investomet
- demand will be key to investment in the UK

Question 2.1: The heat pump supply chain can grow quickly to meet demand; production will not be a limiting factor.

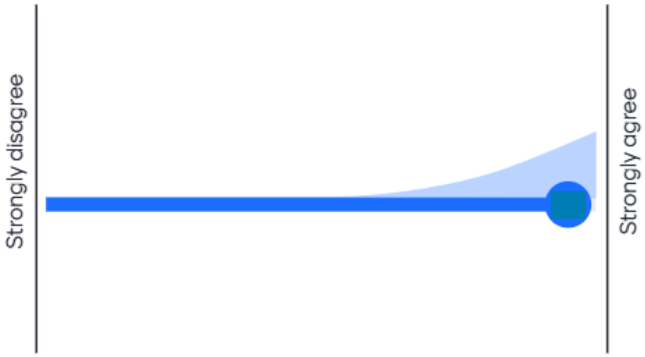


Question 2.1: Please explain why you chose that answer.

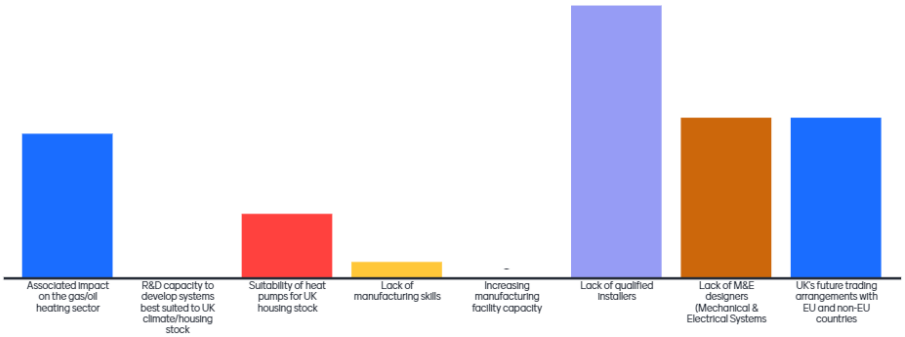
Mentimeter

- Because it's true
- Industry is well below capacity. Also disagree that Compresser or Refrigerant availability will be an issue.
- Large compressors may be in short suppy
- The Large Heat pumps are unlikely to be 'off the shelf' items so have a long lead times
- The overall manufacturing and legislative and competitive environment will be key
- Manufacturing facility is already in place in the UK.
- Existing manufacturers have capacity to handle growth
- Disagree on 12 month time frame - the build or repurpose facilities needs strong policy commitment and several year lead in
- Huge volumes of heat pumps already manufactured around the world as well as similar air con units that total into the hundreds of millions per year.
- Supply chains already exist and far larger volumes of cooling focused heat pump products are already shipped into Europe
- From the manufacturer's point of view, if demand grows, it is simply adapting your manufacturing process.
- The UK volume numbers are not a major increase when compared to global volumes
- A large proportion of boilers are manufactured I the UK and this is because the market is there
- Modular construction, so more sales more production . Capacity to grow
- The supply chain is currently there for boilers and can be repurposed for HP's including installers.
- There might be a supply chain pinch for blue paint but apart from that we are ready :p
- The manufacture and distribution will be ok given enough notice, it's consumer expectation and installer skills which will be the stumbling block.

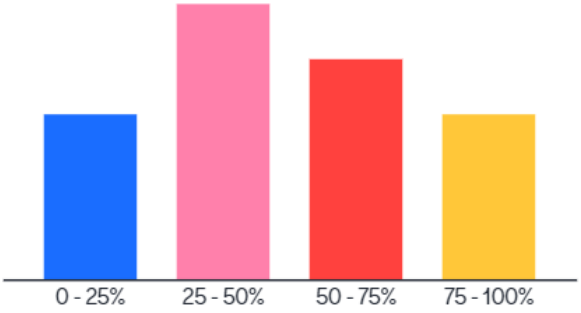
Question 2.2: I am confident that my business could increase supply in the UK market by a minimum of 25-30% annually over a 15 year period



Question 2.3: Select the top 3 risks to rapid expansion in UK heat pump demand.



Question 2.4: What proportion of your manufacturing do you think will take place in the UK with increased demand (Central Policy Scenario 2035)?



Question 2.4 What are the key barriers to achieving these percentages?

Mentimeter

- Incentives to manufacture in UK
- Competitiveness with other manufacturing centres in EU
- Clear indication of support coming from policy.
- Minimum volume to move operations, incentives, ...
- Sufficient market size to ensure investment is returned
- Market uncertainty due to policy vacuum and low cost product from overseas.
- The overall economic environment - lots would have to change to make the UK a globally significant manufacturing base
- Clear policy commitments and direction in the UK
- Clear reasons to invest
- Lack of medium to long term supportive government policy. Energy policy needs to have a thirty year vision, not the current parliamentary one of less than five years (if we are lucky).
- clear regulation enabling higher heat pump uptake inn the UK & incentives to manufacture in the UK
- EU trading restrictions - Can we easily and profitably export to Europe
- Market size, Uk policies
- Cost of manufacturing is a barrier to high %. EU labour market or alternative low cost source.
- Increase in market demand, regulation to drive growth and changes in fossil fuel tax

Mentimeter

Question 2.5: What level of demand increase would be required for it to become cost-effective to manufacture in the UK? Number of Units

We already manufacture in the UK and export to europe

Minimum of 8000 - 10,000

If we can see a clear policy and market environment a doubling of the market each year would be a driver to UK manufacture.

Air Source over 5000 Ground Source over 2000

50 - but these are large heat pumps

Needs a total market of 200,000 per year to drive investment

Not only a demand-side question. The global capacity exists to service our market in its entirety, so the overall environment would need to change too

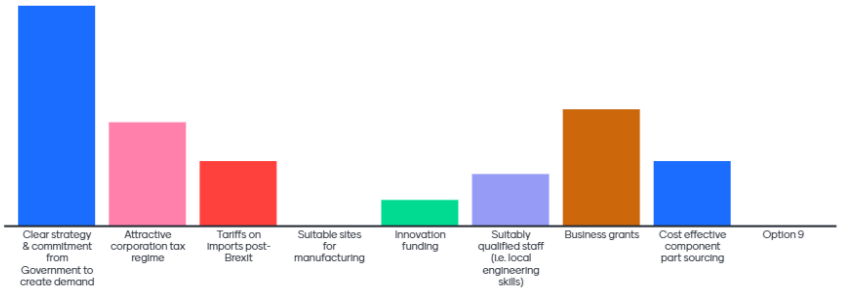
1200-1500 GSHPs per year. Over 4000 ASHPs

UK demand is not the only consideration and EU demand is also a factor.

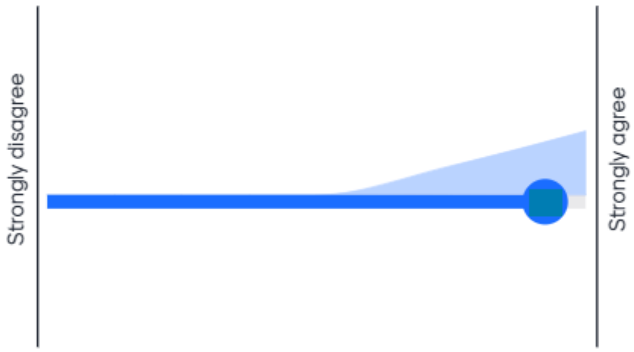
A market size of 250'000 per annum

Unlikely that production would start up in UK. Market would need to see significant size and growth similar to gas boiler market

Question 2.6: Identify the top 3 most influential factors when deciding to expand into or relocate manufacturing to the UK.



Question 3.1: There is universal appetite for consistency in the policy. Short-term/inconsistent policy support is worse than no policy support.

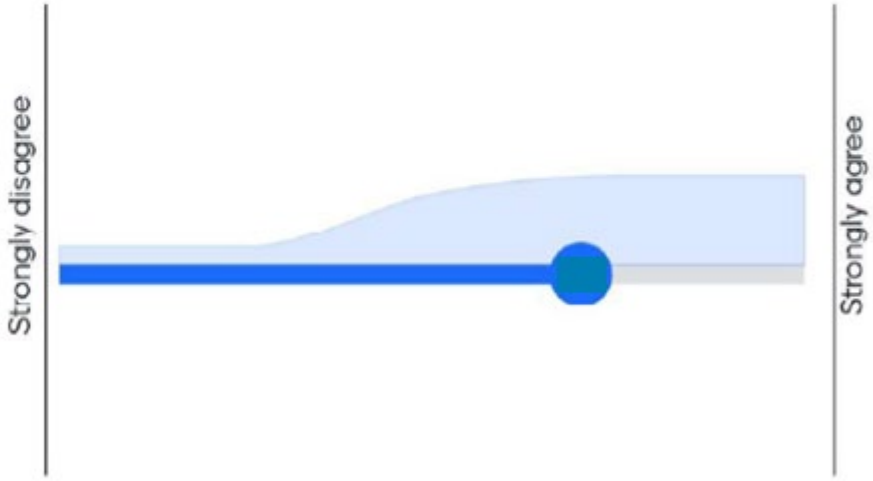


Question 3.1: Please explain why you chose that answer.

Mentimeter

- Gives some sort of direction, rather then no direction
- Damaging to business confidence
- You just have to look at the damage to the market that was done in the early days of the FITs/RHI
- Industry cannot react to constantly changing policy. Commercial heat pump system's take years in gestation
- certainty and at least consistency allows us to plan and request funding for growth
- Clear policy provides confidence for consumers, installers, suppliers and manufacturers
- Short term policy leads to inaction in supply and demand
- lead in times for strategy are long, similarly good strategy is based on the movement of the customer (predicting their strategy) and so this is in effect two cycles of at lest 3 years each.
- Long term clear policy allows confidence to plan ahead. Short term policy creates a confusing scenario that undermines this confidence
- the market would start and stop damaging confidence
- Policy must be technology agnostic - set the goal not the route
- If a product is released when it is perfect then often the market has moved on. The same is for policy and long term consistent direction with commitment is key. However, short term policy is needed to deliver change now when it is needed.
- Some of the 'here today, gone tomorrow' incentives have certainly seen manufacturers and installers lose money and confidence in the UJ renewable market.

Question 3.2: The RHI has been the principal policy driving the deployment of heat pumps in the UK.

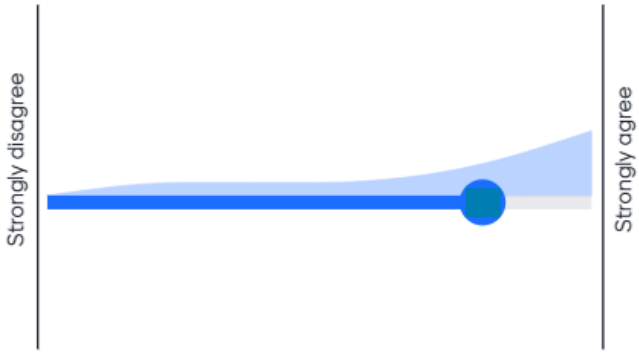


Question 3.2: Please provide commentary on why you chose your previous answer.

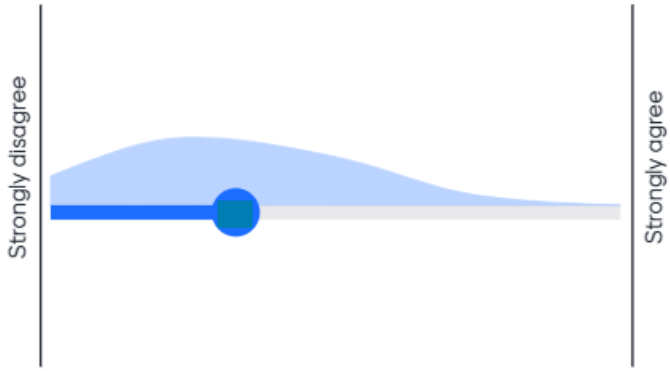
Mentimeter

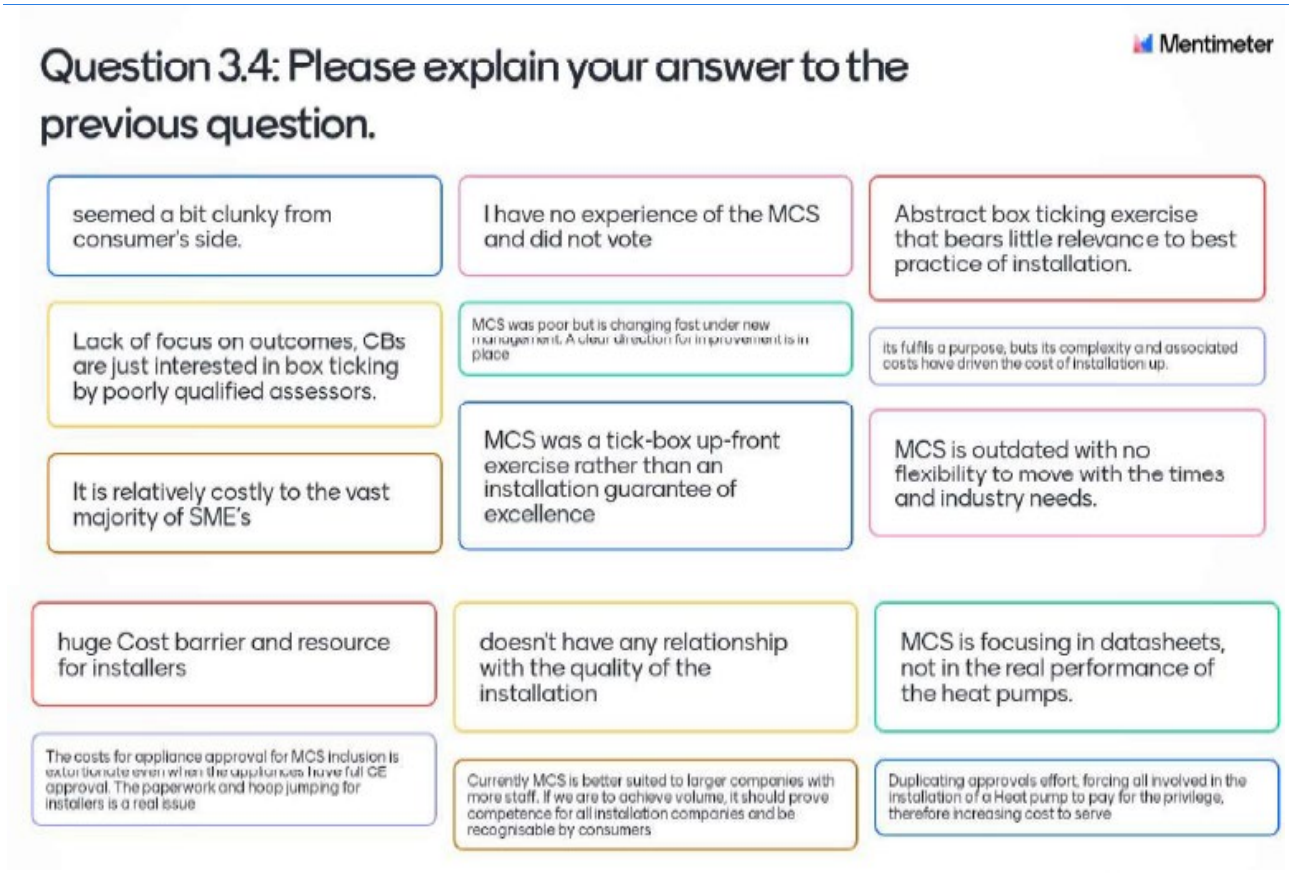
- Almost all sales are associated with grants
- There is no other policy relating to heat pumps of any real scale or quality
- Comparison always with biomass funding
- Some early adopters in new build not eligible
- Heat Pump Technology is a credible 'off gas grid' option for homeowners without the RHI. The RHI is only responsible for 40% of the total ashp market sales.
- 97% of RHI went to biomass!
- New build market equally important, although no support here.
- RHI highlighted the HP sector to a much wider audience
- On reflection it's probably SAP or the country or regions ambition to be green in newbuild and RHI in existing properties
- It is the only mechanism to overcome the subsidised and hence cheap gas. could also be argued the "gaps" in the RHI are the biggest barrier eg waste heat, lack of tariff guarantee for 10 years and lack of 3rd party ownership for 10 years
- technology should be the reason but right now RHI is
- The RHI is far from perfect and has taken a long time to get it to a point where it drives the market. The irony is that it is now in a good place and is running out of time!
- The RHI has driven sales, however the MCS scheme has limited wider acceptance
- Other drivers exist, such as fuel poverty, availability of gas and climate change. RHI reduces overall capital cost
- HP installations that are MCS (RHI) accredited are below 50% and has helped but has not driven the majority of the market uptake. This is due to mixed policy and difficulty in obtaining RHI funding.

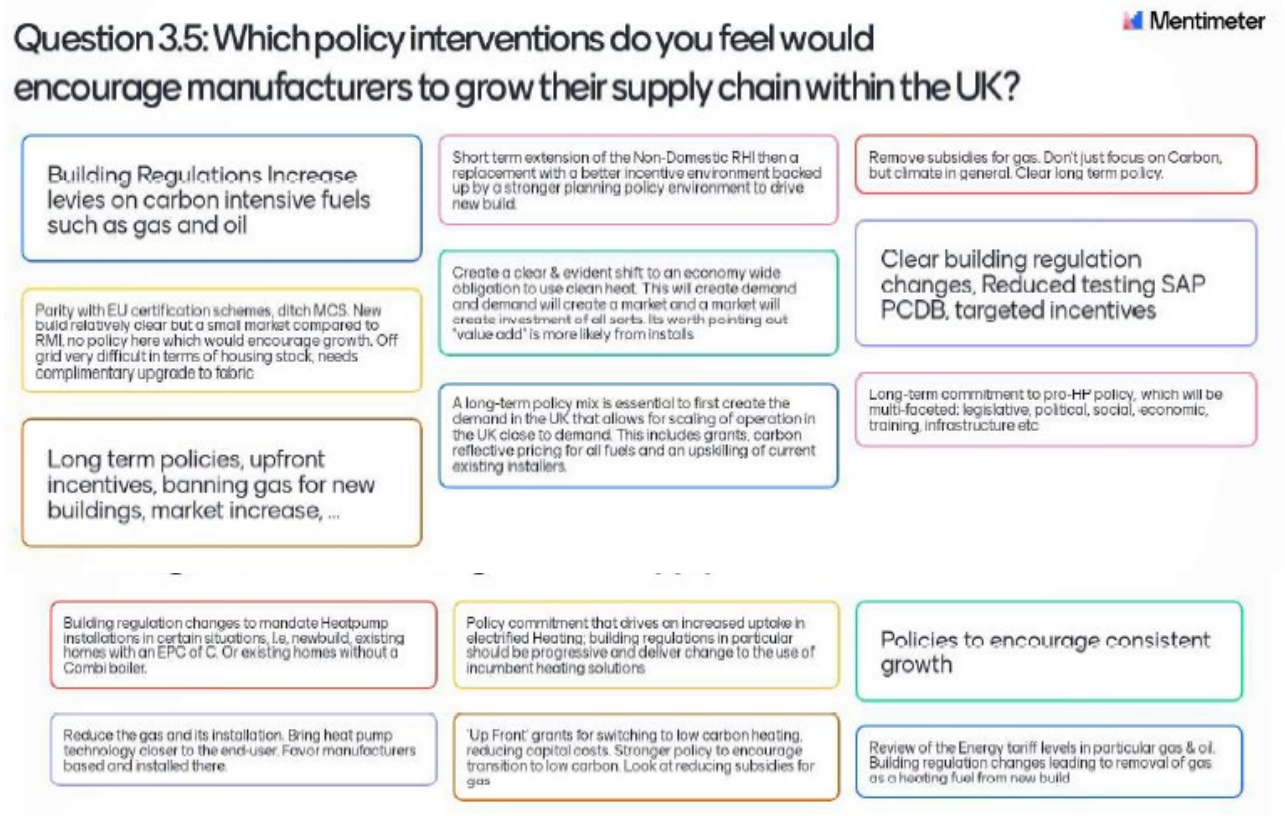
Question 3.3: While the RHI has been successful, inconsistency in implementation has hampered planning, training and investment.



Question 3.4: The MCS is fit for purpose in ensuring the operational performance quality of heat pump installations.




Mentimeter
Question 3.4: Please explain your answer to the previous question.
seemed a bit clunky from consumer's side.
I have no experience of the MCS and did not vote
Abstract box ticking exercise that bears little relevance to best practice of installation.
Lack of focus on outcomes, CBs are just interested in box ticking by poorly qualified assessors.
MCS was poor but is changing fast under new management. A clear direction for improvement is in place
its fulfils a purpose, buts its complexity and associated costs have driven the cost of installation up.
It is relatively costly to the vast majority of SME's
MCS was a tick-box up-front exercise rather than an installation guarantee of excellence
MCS is outdated with no flexibility to move with the times and industry needs.
huge Cost barrier and resource for installers
doesn't have any relationship with the quality of the installation
MCS is focusing in datasheets, not in the real performance of the heat pumps.
The costs for appliance approval for MCS inclusion is extortionate even when the appliances have full CE approval. The paperwork and hoop jumping for installers is a real issue
Currently MCS is better suited to larger companies with more staff. If we are to achieve volume, it should prove competence for all installation companies and be recognisable by consumers
Duplicating approvals effort, forcing all involved in the installation of a Heat pump to pay for the privilege, therefore increasing cost to serve


Mentimeter
Question 3.5: Which policy interventions do you feel would encourage manufacturers to grow their supply chain within the UK?
Building Regulations Increase levies on carbon intensive fuels such as gas and oil
Short term extension of the Non-Domestic RHI then a replacement with a better incentive environment backed up by a stronger planning policy environment to drive new build
Remove subsidies for gas. Don't just focus on Carbon, but climate in general. Clear long term policy.
Parity with EU certification schemes, ditch MCS. New build relatively clear but a small market compared to RMI, no policy here which would encourage growth. Off grid very difficult in terms of housing stock, needs complimentary upgrade to fabric
Create a clear & evident shift to an economy wide obligation to use clean heat. This will create demand and demand will create a market and a market will create investment of all sorts. Its worth pointing out "value add" is more likely from installs
Clear building regulation changes, Reduced testing SAP PCDB, targeted incentives
Long term policies, upfront incentives, banning gas for new buildings, market increase, ...
A long-term policy mix is essential to first create the demand in the UK that allows for scaling of operation in the UK close to demand. This includes grants, carbon reflective pricing for all fuels and an upskilling of current existing installers.
Long-term commitment to pro-HP policy, which will be multi-faceted: legislative, political, social, economic, training, infrastructure etc
Building regulation changes to mandate Heatpump installations in certain situations, i.e, newbuild, existing homes with an EPC of C. Or existing homes without a Combi boiler.
Policy commitment that drives an increased uptake in electrified Heating; building regulations in particular should be progressive and deliver change to the use of incumbent heating solutions
Policies to encourage consistent growth
Reduce the gas and its installation. Bring heat pump technology closer to the end-user. Favor manufacturers based and installed there.
'Up Front' grants for switching to low carbon heating, reducing capital costs. Stronger policy to encourage transition to low carbon. Look at reducing subsidies for gas
Review of the Energy tariff levels in particular gas & oil. Building regulation changes leading to removal of gas as a heating fuel from new build

A – 5: Calculation to extract ATW data from air source total

Outlined below is the calculation method used to extract ATW data from the air source total within the international datasets used, where this breakdown was not provided. This was undertaken to enable to more comparable analysis against the UK market.

- A 2019 BSRIA report states that 3 million hydronic (ATW, GTW, WTW) heat pumps were sold in 2018.[208]
- For the purpose of this split, it has been assumed that no ground to air (GTA) or water to air (WTA) heat pump were included, as these types of heat pump are less common, and no split is available.
- Therefore, the GMI values for total ground source sales (0.4 million units) and total water source sales (0.1 million units) are assumed to equal the GTW and WTW sales respectively.
- Consequently, an estimated 2.5 million of the 3 million hydronic sales in 2018 are estimated to be ATW units.
- The GMI reported 10.27 million total air source sales in 2018. Consequently, 24% of air source sales (2.5 million) are estimated to be ATW and 76% (7.8 million) to be ATA.
- It has been assumed that this percentage split remains the same over the coming decade.

[208] Building Services Research and Information Association (BSRIA) (2019) World Heat Pump Market Study 2019, accessed 30 March 2020, https://www.bsria.com/uk/news/article/world-heat-pump-market-study-2019/

A – 6: Interview Topic Guide

Using a flexible topic guide allowed for a general questioning structure to address the research themes while encouraging participants to discuss their views, perceptions, and attitudes in an open way and without excluding issues of importance to the study.

Table A- 4: The manufacturer interview topic guide

Background Questions			
1.1	Participant's role in the organisation?	Probe: What department do you work in? What are your responsibilities? What is your role in investment decisions?	
1.2	Nature of Business/Organisation	Probe: Briefly describe your business? Are you a subsidiary of a large organisation? What is the main product or service you provide? What sector or sub-sector are you in?	
1.3	What geographical locations do you cover?	Probe: Local, regional, national, international	
1.4	Size of organisation	Probe: How many sites are there in the UK? Are your headquarters in the UK Do you have manufacturing facilities/capabilities in the UK? What is the estimated total workforce? Any recent growth?	
2a. Current UK Market Situation – Manufacturing Heat Pumps			

Background Questions			
Your activity – manufacturing heat pumps – Show interviewee market information compiled for this organisation.			
2.1	What type of heat pumps do you manufacture?	Probe: Ground source? Air source? Water source? Geothermal Air to Water Water to Water Ait to Air Liquid to Air Hybrids?	
2.2	What is your target market for heat pumps in the UK? What is your target market for heat pumps Internationally?	Probe: Is it primarily domestic or commercial? Property types: Domestic: public, private (New build, retrofit)? Commercial: Health, etc. Probe: Do you sell directly or through distributors? What is the split?	
2.3	UK as a whole vs their company What is your current market share? How many units do you sell per year? (quote amount from supply chain mapping exercise – their market share from X source)	Probe: by application, type, rating/output)	
2.4	UK as a whole vs their company How has this changed over the last 5 years?		

Background Questions			
2.5	What is your current split between the UK and international markets? (quote amount from supply chain mapping exercise – their market share from X source)	Probe: Which countries do you sell to? Are you more popular in certain markets? Which ones? Why?	
2.6	What are your strengths and weaknesses in relation to the UK Market, other heat pump manufacturers and other heat technologies?	Probe: E.g. IP, performance, suitability to UK market, cost, any others?	
2.7	Who are your key competitors within the heat pump and heating technology sectors?	Probe: Are they based in the UK? Probe: Manufacturers, distributors, key component suppliers? Probe: What are their relative strengths and weaknesses?	
UK Heat Pump Market These next set of questions are associated with your views on the current UK heat pump market			
2.8	What is your impression of the UK market for heat pumps?	Probe: Demand and Supply Prompt: Is it particularly competitive / active Probe: Domestic vs Non-domestic Probe: Different technologies (e.g. AWHP, GWHP etc)	
2.9	Have you seen any organisations enter or exit the market in the last five years?	Probe: Views on why this have occurred Probe: 2 years, 5 years, 10 years (depending on response)	
2.10	Are there any particular features of the UK market that make it different to the international market?	Probe: Does this make it easier or harder to produce heat pumps that are suitable for export?	

Background Questions			
		Does this mean they have an advantage over international manufacturers? Probe: Heat pump standards (Ens accredited list)- UK, EU, International	
2.11	What innovations have you seen which are specifically related to the UK market?	Probe: Refrigerants used? Is there any coupling with other technologies being explored? E.g. Thermal store to monitor demand. What sort of innovations do you think are still needed? Alongside other energy efficiency measures Innovations on control systems Industrial and domestic Monitoring systems? Modular parts	
2.12	Are there any universities leading research in this area? Are you working with any?		
2.13	Are you seeing any regional differences in demand for heat pumps?	Probe: New build market	
Synergies with other heating sectors			
2.14	Beyond manufacturing of heat pumps, what other activity do you see in the low carbon heating market in the UK, that make it a compelling market for investment?	Prompt: Training for installers, EE installations, link with energy supply company (heat as a service)	
2.15	Which low carbon alternatives are heating companies investing in?	Probe: Hydrogen?	

Background Questions			
		District heating networks? Heat Exchangers? Cooling systems? Air purifying systems as a key functionality?	
2.16	Which other industries are likely to have synergies with the heat pump industry?	Probe: This could be in terms of similar components, similar skills requirements (e.g. refrigeration, air conditioning, ventilation)? Are any other industries likely to move into heat pump production?	
2b. Current UK Market Situation – Boiler Manufacturers [only ask this to relevant organisations]			
2.1	What is your view on the current outlook of the UK boiler industry? Key concerns for the industry?	Probe: Is it going to expand/contract. Are organisations looking at new products (e.g. Hydrogen compatible boilers)	
2.2	In the boiler supply chain (and other related industries), how do you view the UKs position in producing, importing and exporting?		
2.3	Are there any synergies with the heat pump supply chain and the boiler manufacturing sector?	Probe: Where should we be prioritising/ where are the most valuable synergies?	
Heat Pump Supply Chain			
3.1	Are there any aspects of the heat pump manufacturing supply chain, or those of related industries, which the UK has particular expertise in?	Probe: What are the key component manufacturers in the UK? Are there regional hotspots for key components in the supply chain? What regions offer potential for the	

Background Questions			
		development of clusters in the supply chain? Is the UK more likely to manufacture the component parts, or assemble the final heat pump (or both)	
3.2	What are the key factors in your decision to assemble, rather than manufacture in the UK? OR What are the key factors in your decision to manufacture in the UK?		
3.3	Are there any key differences between the supply chains of different types of heat pump?	Probe: Firstly, let them explain and define in their own way. Prompt: This includes hybrid, ground source, air source, domestic, non-domestic etc, size, performance etc.	
3.4	Do the supply chains differ if heat pumps are being manufactured for new build or retrofit?	Probes: Refrigerant used, temperature ranges etc.	
3.5	What role do/can UK SMEs play in the manufacturing supply chain	Prompt: If yes, what role do they play? Probe: What are the barriers they face and how are these different from those faced by large manufacturers?	
3.6	Which heat pump components are widely imported and where do they come from? Is there opportunity to build up domestic capability?	Probe: Which countries do they trade with?	
3.7	Are there any current supply side restraints/ limitations restricting growth?	Prompt: Those beyond demand limitations, could you gain greater	

Background Questions			
		market share without below limitations? No. of production lines, shift patterns, labour, skills, SC, new equipment & factories (access to funding) etc.	
Current Government Policy			
4.1	What is your view on current Government policies to encourage the decarbonisation of heating?	Prompt: General awareness of existing policy and support	
4.2	What is your view on current Government policies to encourage heat pumps specifically?	Probe: What current policies are you aware of relating to heat pumps? What aspects of the current policy environment (e.g. standards, regulations, policy commitments) in the UK are supporting or hindering growth of the heat pump supply chain?	
4.3	In light of current government policy, what is your view on how the UK heating market is going to develop over next 10-20 years?	Probe: Is policy a driver for that? Does this pose any risk to your organisation? Does this present any opportunities to your organisation? Do you anticipate expanding or relocating your operations to align with the UK market?	
4.4	Do you think the UK government should have a role in the growth of the heat pump manufacturing supply chain in the UK?	Probe: What kind of policies do you think would be most successful in terms of growing a sustainable and resilient supply chain?	
Future Outlook – Manufacturing Heat Pumps			

Background Questions			
5.1	What would make the UK an attractive proposition for heat pump manufacture going forward?		
5.2	UK as a whole vs their company Could the UK get to 1,000,000 installations per year (2030 HPA)? What would the reliance on Imports be?	Probe: Installers – UK capability to install these? And how much will these hinder rapid growth? Any other bottle-necks in the heat pump supply chain? And how much will these hinder rapid growth	
5.3	How do you expect the boiler industry to change over the next decade?	Probe: Examine this view in light of climate change targets if not explicitly raised.	
5.4	What are the trigger points for business decisions (e.g. scaling up and investment) being made and what are the associated lag times?	Probe: At what point are investment decisions made? What external factors can encourage investment? Over what timeframes do manufacture investments materialise?	
5.5	How are these business decisions made?		
5.6	Do you anticipate any opportunities for the export of low carbon heating products from the UK?		
5.7	Do you have ambitions to grow your heat pump supply chain?		
5.8	How fast could the UK heat pump supply chain grow by 2025, 2030, 2035? Units installed per year.	Probe: % of building powered by HP Number of units Power input What is the fastest it could grow? Units installed per year	

Background Questions			
		What is the slowest you think it could grow? What is your best estimate (range)? What do you think the limiting factor is?	
5.9	What would encourage manufacturers to grow their heat pump supply chain in the UK, as opposed to elsewhere?	Probe: Commitments Incentives upskilling programs standards - targeted investment	
5.10	What do you think are the key barriers (limiting factors) to growing the UK Heat Pump Manufacturing Supply Chain?	Probe: Capital, labour, competition, etc How complicated is the process of manufacturing a heat pump? How easy is it train people to do this, where would those new people come from (e.g. gas boiler manufacturers)? How expensive is it to increase production? Would you need more/larger machinery, would you need a larger facility? Where would this capital come from?	
5.11	Do you see production costs reducing, increasing or remaining constant for heat pump manufacturers over time?	Probe: What might be a realistic reduction in the unit and installation costs of a heat pumps over the next 5, 10 and 15 years?	

Background Questions			
Future Outlook – Government Policy			
6.1	What kind of policies do you think would be most successful in terms of fostering innovation in the UK manufacture of heat pumps to deliver a product that is better suited to the UK housing stock?		
6.2	What would you foresee at the best-case and worst-case scenarios in terms of EU trade for the UK heat pump manufacturing supply chain?	Probe: For example, a huge tariff on heat pumps, but not components.	
Future Policy Scenarios (Once Scenarios Developed)			
7.1	TBC – Follow up with BEIS		

A – 7: UK Policy and Commitment to Heat Pumps Continued

The delivery of renewable heat is a critical component of UK climate and energy policy. As part of global efforts to avoid the worst effects of climate change, the UK Government has ratified the Paris Agreement which sets out a global action plan to limit global warming to well below 2°C. Efforts to tackle climate change were enshrined in UK law before the agreement. The original Climate Change Act 2008 targeted an 80% reduction of carbon emissions by 2050 compared to 1990 levels.[209] Subsequently, under advice from the Committee on Climate Change, this target was amended from 80% to 100% (i.e. net-zero) by 2050.[210]

As heating and hot water for UK buildings make up around 40% of energy consumption and nearly a third of greenhouse gas emissions,[211] the decarbonisation of almost all heat in buildings is likely to be necessary to meet carbon reduction commitments. In addition to targets at both an EU and national level, there are also strategic drivers for decarbonisation such as delivering energy security and job creation.

The current reliance on natural gas is incompatible with long-term decarbonisation and key decisions will be needed in the next few years to determine how low-carbon heat for

[209] HM Government (2008), Climate Change Act 2008, available at http://www.legislation.gov.uk/ukpga/2008/27/pdfs/ukpga_20080027_en.pdf, accessed May 2020
[210] Ibid.
[211] Committee on Climate Change (2016) Next Steps for UK Heat Policy, available at https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/, accessed May 2020

properties on the gas grid, especially those outside heat-dense areas will be achieved. A range of technologies will likely be required, including heat pumps.

Clean Growth Strategy

The Government released the Clean Growth Strategy (CGS) in October 2017,[212] aiming to set out how emission reductions could be achieved. The strategy sets out a comprehensive set of policies and proposals which aims to accelerate the pace of 'clean growth', delivering increased economic growth and decreased emissions. Renewable heating and energy efficiency featured heavily within the report. Some of the highlights include:

- Support for around £3.6 billion of investment to upgrade around a million homes through the Energy Company Obligation (ECO), and extend support for home energy efficiency improvements until 2028 at the current level of ECO funding;
- All fuel poor homes to be upgraded to Energy Performance Certificate (EPC) Band C by 2030 and for as many homes as possible to be EPC Band C by 2035 where practical, cost-effective and affordable;
- Develop a long-term trajectory to upgrade as many privately rented homes as possible to EPC Band C by 2030 where practical, cost-effective and affordable;
- Phasing out the installation of high carbon fossil fuel heating in new and existing homes currently off the gas grid during the 2020s, starting with new homes;
- Invest in low carbon heating by reforming the RHI, spending £4.5 billion to support innovative low carbon heat technologies in homes and businesses between 2016 and 2021; and
- Invest around £184 million of public funds to develop new energy efficiency and heating technologies to enable lower-cost low carbon homes.

Future Framework for Heat in Buildings

In March 2018, the Government sought to build upon the CGS by publishing a call for evidence to seek views on how industry, government, and consumers could work together to phase out the installation of high carbon fossil fuels from rural homes and businesses off the gas grid during the 2020s.[213] The Government sought to understand what these stakeholder groups can do to reduce the barriers to the installation of clean heating, reducing reliance on subsidy, while preparing the ground for future policy approaches that could include regulation. In its response to the call for evidence, the government highlighted one of the strongest overriding messages from the responses was the need for a clear, long-term framework set by the government, ideally through regulations, that would enable the industry to play its part. Further consultation is currently taking place and

[212] Government of the United Kingdom, and Department for Business, Energy & Industrial Strategy (2018) The Clean Growth Strategy: Leading the Way to a Low Carbon Future, April 2018, https://www.gov.uk/government/publications/clean-growth-strategy, accessed May 2020

[213] Department for Business, Energy & Industrial Strategy (2018) Future framework for heat in buildings: call for evidence, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/691546/Future_framework_for_heat_in_buildings_call_for_evidence.pdf, accessed May 2020

is targeted specifically at improving the energy performance of non-domestic, private-rented buildings.[214]

Heat Networks

£96 million for the final year of the Heat Networks Investment Project, which ends in March 2022, has been announced by government. After this, a further £270 million will be invested by government in a new Green Heat Networks Fund, which aims to support and incentivise the use of low carbon heat sources in heat networks. This could support the use of large-scale heat pumps for heat networks for both domestic and non-domestic consumers.

[214] Department for Business, Energy & Industrial Strategy The non-domestic private rented sector minimum energy efficiency standards: the future trajectory to 2030, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/839362/future-trajectory-non-dom-prs-regulations-consultation.pdf

A – 8: Synergies with related sectors – market description and key players

Global and UK Heating, Ventilation and Air Conditioning systems (HVAC) Market

The global HVAC market is expected to grow substantially in the coming decade. In 2019 the HVAC market size was valued at £102.7 billion and it is projected to register a CAGR of 6.1% from 2020 to 2027.[215] This is largely due to:

- increasing urbanisation;
- emergence of energy-efficient HVAC systems;
- government incentives and rebate programs promoting the usage of energy efficient HVAC units
- growing spending in the construction sector;
- increasing disposable incomes in major economies; and
- rising global temperatures and unpredictable climate conditions. [216]

In terms of geographical regions, the HVAC market is currently dominated by Asia-Pacific regions, particularly China, Japan and India, which all have considerable growth potential. However, the market is wide and also spans North America, Europe, Middle-East and Africa. In terms of application domestic units (houses, small non-domestic use e.g. restaurants) has the largest share of the market at 40%, followed by non-domestic and industrial.

The UK HVAC market, however, was expected to contract by 4.1% between 2018 and 2020.[217] This was in part due to the UK exiting the EU, which was expected to impact the construction sector substantially: a key driver of demand. HVAC demand in the UK is currently dominated by the development of tall office buildings. Nevertheless, the HVAC market was expected to recover in 2020 (before the COVID 19 pandemic), partly due to a recovery in the construction sector and partly due to the development of more energy-efficient systems, which align with more energy-efficient building regulations.

Key Global HVAC Manufacturers

Table A- 5 provides a list of the largest manufacturers in the HVAC market, such as Daikin and Midea who enjoy large market shares, as well as US manufacturer Carrier. Airedale and Marstair manufacture their products in West Yorkshire, UK. Almost all packaged air conditioners are imported from Asian and European, with only a small handful of chiller

[215] Grand View Research (2020) HVAC Systems Market Size, Share & Trends Analysis Report By Product (Heating, Ventilation, Cooling), By End Use (Residential, Commercial, Industrial), By Region, And Segment Forecasts, 2020 - 2027, February 2020, https://www.grandviewresearch.com/industry-analysis/hvac-equipment-industry

[216] Grand View Research (2020) HVAC Systems Market Size, Share & Trends Analysis Report By Product (Heating, Ventilation, Cooling), By End Use (Residential, Commercial, Industrial), By Region, And Segment Forecasts, 2020 - 2027, February 2020, https://www.grandviewresearch.com/industry-analysis/hvac-equipment-industry

[217] Hallidays (2019) Sector Report – Heat, Ventilation & Air Conditioning Industry, 2019, https://www.hallidays.co.uk/views-and-insight/sector-report/heating-ventilation-and-air-conditioning-hvac-industry

manufacturers existing in the UK. However, over 50% of fan coil and airside products are manufactured in the UK.[218]

Some of the key heat pump manufacturers in the UK market are all traditional Asian air conditioning companies: Daikin, Mitsubishi, Panasonic, LG, Samsung. All of which already have supply chains in place for components needed to manufacture heat pumps.

Table A- 5: Significant global manufacturers of HVAC

Name	Country of Origin/ Head Office	Country of manufacture
Airedale	UK	Leeds (UK), South Africa, USA
Blue Star	India	India
Carrier	US	USA, global
Daikin	Japan	Global
Electrolux	Sweden	Italy, Poland and Hungary
Friedrich	US	Mexico
Fujitsu	Japan	Japan, China, Thailand
Haier	China	Global
Hitachi	Japan	Global
LG	South Korea	Global
Marstair	UK	West Yorkshire (UK)
Mitsubishi	Japan	Livingston (UK), global
Samsung	South Korea	Asia
Sanyo	Japan	Asia

[218] BSRIA (2016), BSRIA says: post Brexit vote - HVAC & smart energy falls by £95 million, available at: https://www.bsria.com/uk/news/article/bsria-says-post-brexit-vote-hvac-smart-energy-falls-by-pound95-million/, accessed June 2020

Name	Country of Origin/ Head Office	Country of manufacture
Toshiba	Japan	Japan, Thailand
Videocon	India	India
Voltas	India	India
York	US	USA, global

Key Global Air Conditioning Players

The key players in the global air conditioning industry are Daikin, York International Corporation, Carrier, Trane, Mitsubishi, Hitachi, Gree, Airwell Group, Lennox, GEA Group, Midea, Whirlpool Home Cooling and Heating, LG Electronics, Fujitsu, Goodman Manufacturing Company, Nortek Global HVAC LLC, Rheem Manufacturing Company.[219] There is substantial overlap between these and key players in the HVAC sector, given that HVAC includes air conditioning.

UK Boiler Market

All data is sourced from the BSRIA 2020 UK Domestic Boiler Report unless otherwise stated.[220] The 2018 values are the most up to date measured values at the time of the report; the 2019 values are estimates given in the report.

The UK heating stock is dominated by gas central heating systems (85%), followed by electric storage heating (5%), oil central heating (4%), and heat networks (2%).[221] The majority of boilers are used for domestic heating, with a small proportion for non-domestic heating (<10%).

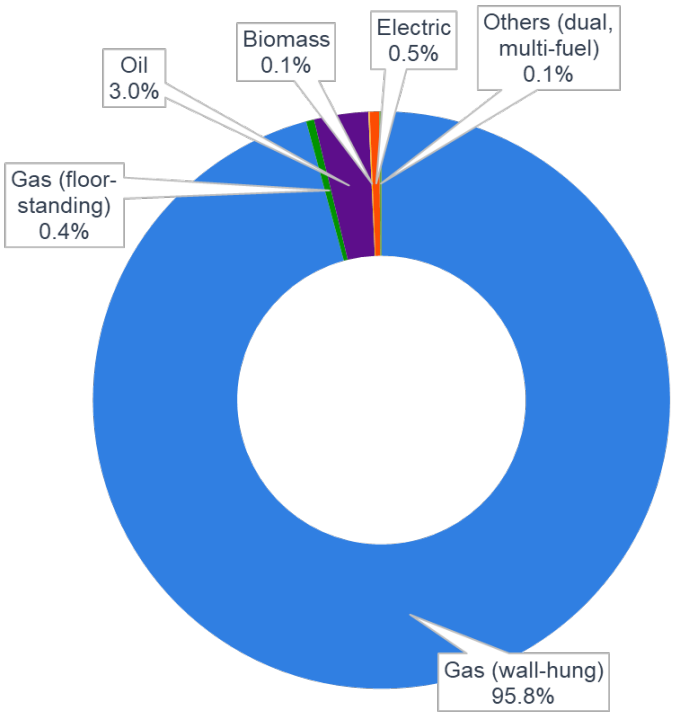
Figure A- 1 shows the proportion of different types of boiler in the UK in 2018 (estimated). Wall-hanging (WH) gas condensing boilers have a clear majority of the market share at 96% of all the 1,750,000 boilers sold in 2019. In contrast, floor standing (FS) gas boilers (condensing) have less than 1% of market share. Oil condensing boilers make up most of the remaining market, while biomass and other types of boiler (electric, dual, multi-fuel) account for the final 1%. Across all types of boiler, condensing boilers are more popular than non-condensing.

[219] MarketWatch (2020), Global Central Air-conditioning Market 2020 Industry Size, Segments, Share, Key Players and Growth Factor Analysis by 2026, available at https://www.marketwatch.com/press-release/global-central-air-conditioning-market-2020-industry-size-segments-share-key-players-and-growth-factor-analysis-by-2026-2020-05-07, accessed June 2020

[220] Building Services Research and Information Association (BSRIA) (2020) Domestic boilers market analysis - United Kingdom, April 2020, https://www.bsria.com/uk/market-intelligence/market-reports/heating/domestic_boilers/

[221] Department for Business, Energy & Industrial Strategy (2018) Clean Growth - Transforming Heating: Overview of Current Evidence, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf

Figure A- 1: Domestic boiler market by type, % volume, 2019e



Key UK Boiler Manufacturers

Figure A- 2 shows the boiler manufacturers with the largest proportion of the UK market share. The majority of production occurs in the UK and is dominated by the manufacturers Worcester Bosch, Ideal, Vaillant and Baxi. The remainder of production is dominated by Italian manufacturers (Vokera, Ariston, Alpha, Ferroli and Biasi), followed by the Netherlands and Germany.[222]

For wall-hung condensing gas boilers, Worcester Bosch is the market leader, selling through their main supplier British Gas, followed by Ideal, Vaillant and then Baxi. For the oil boiler market, there are five main players in the UK. In order of market share, these are Worcester Bosch, Grant UK, Firebird, Warmflow and HRM. As with the gas condensing units, Worcester Bosch dominates this market.[223] There are fewer manufacturers of oil boilers operating in the UK than of heat pump or gas boilers.

[222] Department for Business, Energy & Industrial Strategy (2018) Clean Growth - Transforming Heating: Overview of Current Evidence, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf
[223] Ibid

Figure A- 2: 2018 Wall Hung Condensing Gas Boiler Market Supply Chain – Key Manufacturers' Market Shares and Main Country of Manufacture[224]

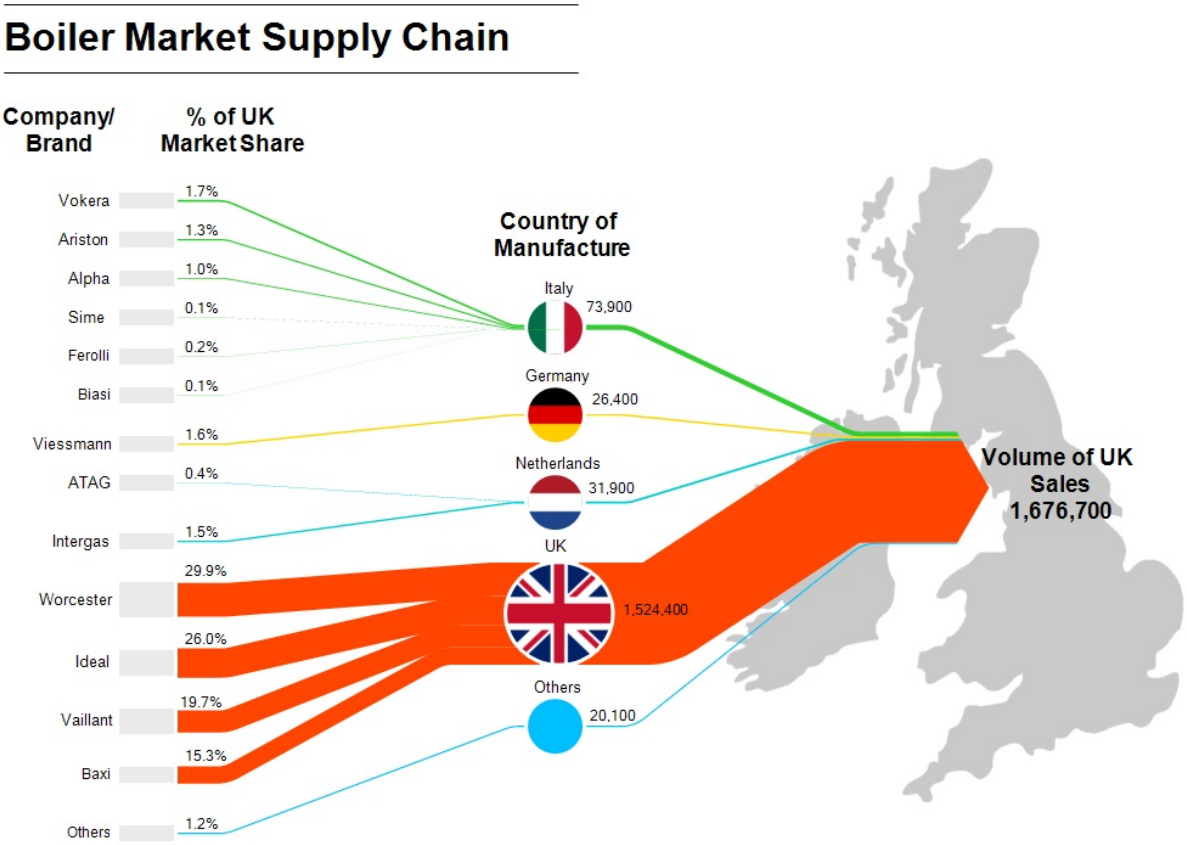
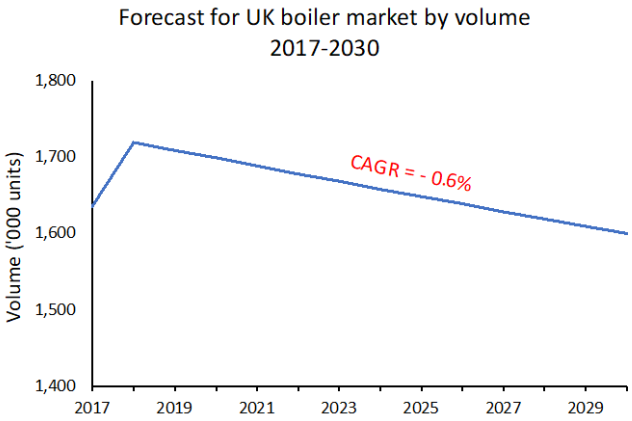


Figure A- 3 shows that, despite a steep increase from 2017-2018, UK boiler unit sales are expected to gradually decrease from 2018 to 2030 by 0.6% per annum.

Figure A- 3: Forecast for the UK boiler market (by volume of unit sales) from 2017-2030 (values for 2019 to 2030 are estimates)[225]

[224] It is understood that Worcester Bosch Manufacture 60% of boilers in the UK, 15% in Germany, 15% in Turkey, and 10% in Portugal. Baxi manufacture 93% in the UK, and 7% in Italy, with plans to transition the remaining 7% to the UK over the next 12 months. Furthermore, it is understood that Ideal and Vaillant manufacture 100% in the UK.

[225] Building Services Research and Information Association (BSRIA) (2019) Domestic Boilers (World Market for Heating Boilers 2019/R2019), 2019, https://www.bsria.com/uk/product/gDXQPB/domestic_boilers_world_market_for_heating_boilers_2019r2018_8a707622/



Current UK Boiler Production vs Imports and Exports

55% of boilers sold in the UK in 2019 were manufactured in the UK.[226] The value of central heating boilers exported by the UK more than tripled between 2014 and 2018 from £49.1 million to £170.2 million.[227]

Global refrigerant market (for AC, ventilation and refrigeration)

The global refrigerant market was estimated to be worth £12.33 billion in 2018 and is anticipated to grow at a CAGR of 4.4% from 2019 to 2026.[228]

Refrigerants can be either natural or synthetic. Synthetic refrigerants are non-toxic and non-flammable but possess high GWP. Natural refrigerants have low GWP but are toxic and flammable. The original synthetic refrigerants had high ozone depletion potentials (ODP) and so have now been phased out of the market following the Montreal Protocol. These included: CFC (R11, R12, R113, R114, R115) and HCFC (R22, R123).[229] In 2014, R22 was the most widely produced refrigerant globally, but its use was banned in 2015.[230] A new generation of synthetic refrigerants with zero ODP, but still with high GWP, have now been developed and deployed. These include HFC (R134A, R404A, R407A, R410A, and R143A among others), HFO (R1234ze, R1234yf, R1233zd), and HFC/HFO blends

[226] Building Services Research and Information Association (2020) Domestic boilers market analysis - United Kingdom, April 2020, https://www.bsria.com/uk/market-intelligence/market-reports/heating/domestic_boilers/
[227] Statista (2018), Value of central heating boilers exported by the United Kingdom (UK) from 2010 to 2018, available at: https://www.statista.com/statistics/1000616/uk-value-of-exports-of-central-heating-boilers/, accessed June 2020
[228] Polaris Market Research (2019) Refrigerant Market Size, Share, Trends - Industry Analysis Report, 2026, 2019, https://www.polarismarketresearch.com/industry-analysis/refrigerant-market
[229] Market Research Future (2017) Global Refrigerant Market Information: By Product Type (Natural, Synthetic), Application (Refrigerator, Air Conditioner, Chillers/Heat Pump), and Region -Global Forecast Till 2023, 2017, https://www.marketresearchfuture.com/reports/refrigerant-market-5879
[230] Chillventa Insights (2014) Synthetic refrigerants: markets, quantities and producers across the globe, 2014

(R448, R450, R452, R513).[231] Development of low GWP synthetic refrigerants is a topic of active research.[232] The most commonly used natural refrigerant is ammonia (R717).[233]

Of the main global regions, Asia Pacific currently has the largest market for refrigerants.[234] This is expected to increase substantially in the next few years due to rising disposable income and rapid infrastructural development generating more demand for refrigerators and air conditioners, particularly in large emerging economies such as China. The Middle East refrigerant market is also expected to increase due to ongoing infrastructural development aiming to expand the tourism industry. The North American and European refrigerant market is relatively mature and is expected to show steady growth. The Latin American market is witnessing slow growth due to overall slow economic development.[235]

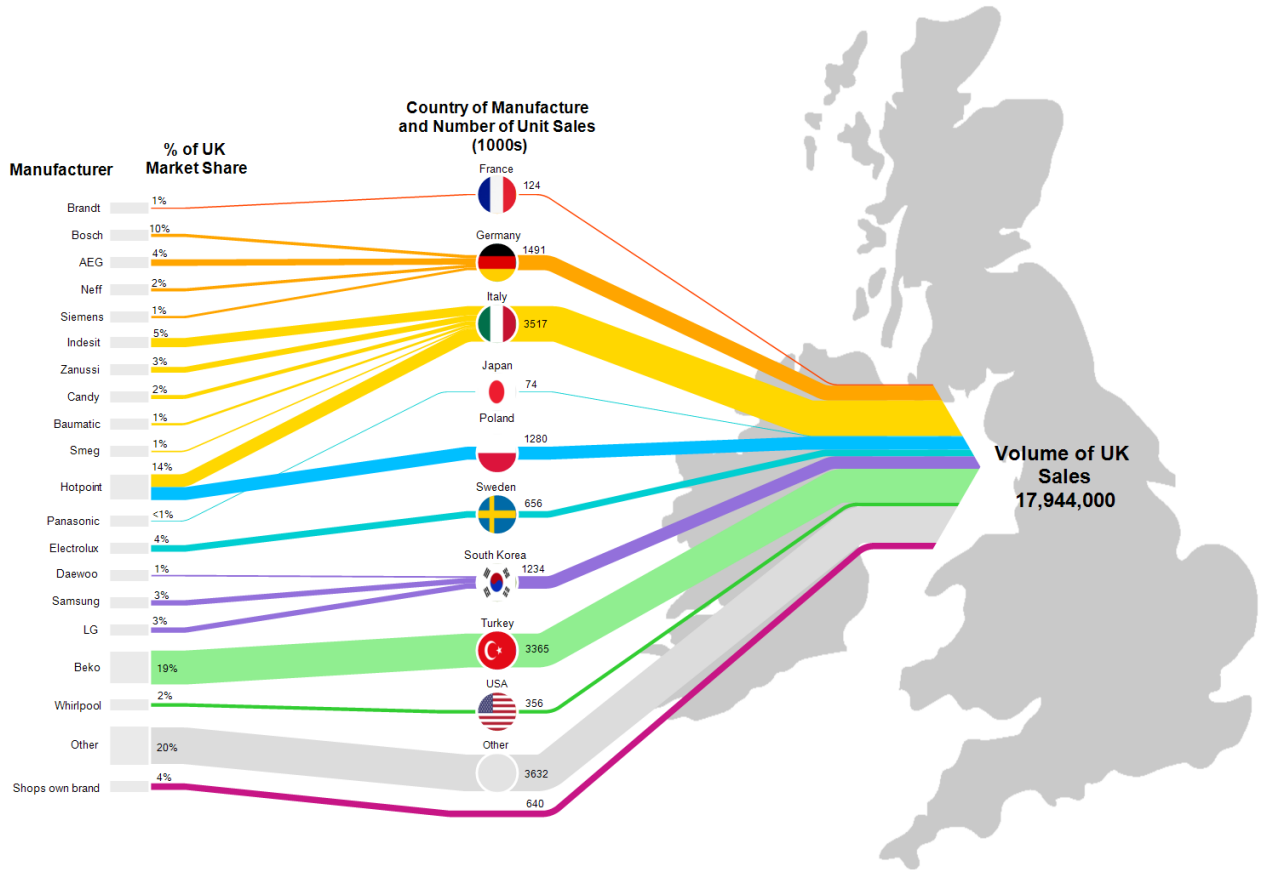
Some of the key players operating in the global refrigerant market are: Daikin (Japan), The Chemours Company. (US), Honeywell International Inc. (US), Arkema S.A. (France), Dongyue Group Co. Ltd (China), Asahi Glass Co., Ltd. (Japan), Sinochem Group (China), Mexichem S.A.B. de C.V. (Mexico), The Linde Group (Germany), SRF Limited (India), and DowDuPont Inc. (US).[236]

Key players in the UK Refrigeration Market

Figure A- 4 shows that the key refrigeration unit manufacturers in the UK market in 2018 were Beko (from Turkey), Hotpoint (from Italy/Poland) and Bosch (from Germany), accounting for 19%, 14% and 10% of the UK market share respectively.[237] These data imply that no refrigerators are currently manufactured in the UK.

Figure A- 4: Key manufacturers of refrigeration units and their proportion of the UK market share in 2018

[231] Market Research Future (2017) Global Refrigerant Market Information: By Product Type (Natural, Synthetic), Application (Refrigerator, Air Conditioner, Chillers/Heat Pump), and Region -Global Forecast Till 2023, 2017, https://www.marketresearchfuture.com/reports/refrigerant-market-5879
[232] Zion Market Research (2019) Global Low GWP Refrigerants Market: Industry Size, Share, Trends, Growth, Applications, Analysis and Forecast, 2019–2025, 2019, https://www.zionmarketresearch.com/report/low-gwp-refrigerants-market
[233] Market Research Future (2017) Global Refrigerant Market Information: By Product Type (Natural, Synthetic), Application (Refrigerator, Air Conditioner, Chillers/Heat Pump), and Region -Global Forecast Till 2023, 2017, https://www.marketresearchfuture.com/reports/refrigerant-market-5879
[234] Ibid
[235] Market Research Future (2017) Global Refrigerant Market Information: By Product Type (Natural, Synthetic), Application (Refrigerator, Air Conditioner, Chillers/Heat Pump), and Region -Global Forecast Till 2023, 2017, https://www.marketresearchfuture.com/reports/refrigerant-market-5879
[236] Ibid
[237] Statista (2018) Leading refrigerator brands in the UK 2018, available at https://www.statista.com/statistics/437601/leading-brands-of-refrigerators-in-the-uk/, accessed April 2020


Manufacturer
% of UK Market Share
Country of Manufacture and Number of Unit Sales (1000s)
Brandt
1%
Bosch
10%
AEG
4%
Neff
2%
Siemens
1%
Indesit
5%
Zanussi
3%
Candy
2%
Baumatic
1%
Smeg
1%
Hotpoint
14%
Panasonic
<1%
Electrolux
4%
Daewoo
1%
Samsung
3%
LG
3%
Beko
19%
Whirlpool
2%
Other
20%
Shops own brand
4%
France
124
Germany
1491
Italy
3517
Japan
74
Poland
1280
Sweden
656
South Korea
1234
Turkey
3365
USA
356
Other
3632
640
Volume of UK Sales 17,944,000

A - 9: Global and UK key Tier 1 and Tier 2 manufacturers

Table A- 6: Key manufacturers in the UK and global heat pump Tier 1 and Tier 2 supply chains

Tier 1			Tier 2		
Global	**UK**		**Global**		
Heat pumps	**ASHP**	**GSHP**	**Refrigerant**	**Compressor**	**Control systems**
Midea	Daikin	Kensa	Daikin (Japan)	Danfoss, Denmark	Carel (Italy)
Daikin	Hitachi	Nibe	The Chemours Company. (US)	Bitzer, Germany	Parker Hanifin (US)
Panasonic	LG	Stiebel Eltron	Honeywell International Inc. (US)	Emerson Copeland, Northern Ireland	Alco
Mitsubishi Electric	Viessmann	Vaillant	Arkema S.A. (France)	Mitsubishi, Thailand	Dixell (owned by Emerson– manufactured in Italy)
Carrier	Panasonic	Viessmann	Dongyue Group Co. Ltd (China)	Carrier, US	
Stiebel Eltron	Mitsubishi	Dimplex	Asahi Glass Co., Ltd. (Japan)		
Viessmann	Hidros	Ecoforest	Sinochem Group (China)		
Vaillant	Samsung	Geothermal Int (GI Energy)	Mexichem S.A.B. de C.V. (México)		

Tier 1	Tier 2				
Ingersoll Rand	CIAT	Finn Geotherm	The Linde Group (Germany)		
Dimplex	Toshiba Carrier	Heliotherm	SRF Limited (India)		
NIBE	Worcester Bosch	Hidros	DowDuPont Inc. (US)		
Thermia	Nibe	Worcester Bosch			
	Grant	Mastertherm			
	Vaillant	Waterkotte			
	Global Energy Systems	Mitsubishi			
	Stiebel Eltron	Neura / Pico Energy			
	Firebird	Clausius			
	Enertech (CTC)	Enertech (CTC)			
	Aermec	Earth Save			
	Dimplex				
	Vokera				
	Kingspan				
	Heliotherm				

Tier 1	Tier 2				
	Ariston				
	Aero				
	Earth Save				
	Elco				
	Ochsner				
	Big Magic Thermodynamic Box				
	Ecoforest				
	Mastertherm				
	Neura / Pico Energy				
	Waterkotte				

A - 10: Growth Rate Analysis - Model assumptions

UK Heat Pump Deployment Scenarios to 2037

The main underlying assumptions and calculations of the growth rate analysis have been described in the 'Growth in the UK Market' section, all figures were based on the expected numbers of deployed heat pumps in 2020, 2025, 2030 and 2035, as shown in Table A- 7. It was noted that all heat pumps in new build are expected to be ASHP.

Table A- 7: Heat Pump Deployment Scenarios

Scenario	Description	2020	2025	2030	2035
Low	Policy to support/regulate deployment in off gas grid areas and new build only.	30k	250k	300k	300k
Medium	Policy is the same as the Low scenario but there is also some support for deployment on the gas grid.	30k	300k	700k	1000k
High	This represents the maximum growth pathway, with support for widespread deployment of heat pumps on gas grid areas (based on reaching 1 million heat pumps by 2030 and the same number of heat pump sales as gas boilers by 2035). Off gas grid and new build is as the Low scenario.	30k	300k	1000k	1600k
Hybrids	This is the same as the Medium scenario, but on gas grid deployments are hybrid heat pumps. Numbers expressed in number of heat pumps (of which hybrids).	30k (0k)	300k (50k)	700k (400k)	1000k (700k)

Description	2020	2025	2030	2035
Installations in new builds (relates to all scenarios)	10k	50k	200k	200k

As the numbers in Table A- 7 are based on domestic installations, the split between domestic and non-domestic buildings in the UK (28 million:2 million) was used to calculate the overall number of heat pumps expected to be deployed. For example, under the medium growth rate scenario, a total of 300,000 heat pumps will be deployed in domestic buildings in 2030. This constitutes 93.33 percent of the overall number of heat pumps.

Consequently, 21,429 heat pumps will be deployed in non-domestic buildings in 2030 under this scenario.

Individual manufacturer market share for 2018 and 2019 is based on the 2020 BSRIA data. For market share estimations used for model calculations everything <1% was assumed to be 0.9%; for market shares listed by BSRIA in ranges, the median was used. Subsequently all numbers were proportionally adjusted to total 100%.

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