Heat Pumps and Heat Networks Assemblies and Key Component Analysis

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RAMBØLL

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Executive Summary

Assessment of what key components that Scottish Enterprise should focus on

Summary	• The markets for heat pumps and networks are expected to grow rapidly in the coming years and decades, primarily driven by macro-trends of decarbonisation and security of energy supply. The key components within both technologies are also expected to benefit from this strong growth. • This study identified compressors and control systems within heat pumps as the most promising components for potential Scottish market entrants, and pre-insulated steel pipes and control systems for heat networks. This is primarily due to innovation potential and share of total market value. • Scotland and the UK are both emerging markets with rapid growth rates forecast in the future. France is currently the leading European country on heat pump sales but is also expecting continuously high growth levels. By comparison, Denmark is a more mature market with a higher market penetration of heat pumps, but with steady markets in new sales and retrofits. The four markets studied here have varying levels of economic incentives for manufacturing, although this is not the only measure that companies looking to set up new manufacturing sites will consider. • Next steps for companies interested in potentially entering the markets could be more detailed market analyses, a go-to-market strategy, and a location screening.
Trends and technology assessment	• From all heat pump components, compressors and control systems were selected as most interesting for Scottish suppliers. This is due to their share of value within heat pumps, potential for future innovation, existing experience in Scotland, and challenges with current procurement. Compressors are divided into screw, scroll, and centrifugal. They are complex to manufacture and face rigorous testing requirements before they can go to market. • For heat networks, controls and pre-insulated steel pipes were selected as the two most promising for potential Scottish market entrants. This is because the pipes represent much of the value (up to 50% for the pre-insulated steel pipes), and controls have potential for interesting innovation in the future, especially for the more complex 5th Generation (5G) heat networks.
Market analysis	• Four markets were sized: Scotland, RoUK, France, and Denmark. All markets are considered growth markets although Denmark is the most mature and has the lowest growth. France is the largest market with an estimated value of GBP 4.9 bn by 2026 for heat pumps. Compressors and control systems can expect 17% and 11% of the total heat pump market respectively. • For heat networks, the size of the Scottish and UK markets were estimated based on meeting the national targets. In Scotland the market size in 2030 for pre-insulated steel pipes and control systems was estimated to be GBP 1.2 bn and GBP 0.7 bn respectively, and in the RoUK, it was estimated to be GBP 5.4 bn and GBP 3.2 bn. • From all markets, the control systems in the Scottish and UK markets (for both heat pumps and networks) were considered to be the most accessible, whilst the European markets for compressors and pre-insulated steel pipes were considered the least accessible, due to high start-up costs, quality and testing requirements, and existing incumbents.
Country and company profiles	• Two leading manufactures were identified per component. These were: Danfoss and Mitsubishi Electric for heat pump controls, Bitzer and GEA for compressors, Siemens and Danfoss for heat network controls, and Logstor and Isoplus for pre-insulated steel pipes. Competitive advantages included global presence and high-quality reputation (especially for compressors and pipes) and economies of scale for the control systems. • In each of the countries where the companies had their HQs, loans, grants, and other financial incentives were identified. Denmark had a relatively larger focus on smaller companies and innovation, whereas Germany and Japan has a higher focus on large corporate loan schemes. • When selecting new manufacturing sites, economic incentives are just one metric that potential companies should analyse.

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Assessment of what key components that Scottish Enterprise should focus on

Summary

Trends and Technology assessment

Market analysis

Company and Country profiles

- A trend and technology assessment was performed for the heat pump and heat network markets to better understand which components present the most value for the Scottish manufacturing market. Firstly, a summary for both heat pumps and heat networks was created to give an overview of the analysed technologies, including a list of constituent components. To identify the components of most interest to Scottish Enterprise, a longlisting and shortlisting process was used. This used five different metrics including: *share of final product value, existing expertise, innovation gap, procurement difficulty, and applicability to existing design.* All metrics were rated with a score between 1-4 to evaluate the components in an unbiased method across a range of different factors. The following conclusions can be made from this section:

    1) Heat pumps generally take heat from either the ***ground, water, or air*** and can service three different markets: *domestic, commercial, or industrial* heat pumps. The key components identified for heat pumps were **controls** and **compressors** as they scored relatively high on all of the five metrics. The control system is a valuable component with a large potential for innovation. The need for ever-greater efficiency is driving much of the innovation in heat pumps and their components, including compressors. There is also a strong demand for refrigerants with lower Global Warming Potential (GWP), which has important implications for compressors. Compressors are the most expensive part of a heat pump and small improvements can have a large impact on heat pump efficiency. Compressors can either be ***Scroll, Screw or Centrifugal*** compressors, while controls include ***thermostats, timers, and smart system controls.***
    2) 4th generation (4G) and 5th generation (5G) are the most recent types of heat networks. 5G offers ambient temperatures, controls integration*, heating and cooling, and modular expansion.* The majority of heat network components are shared between 4G and 5G networks. The key components identified for heat networks were ***pre-insulated steel pipes*** *(not applicable for 5G)* and ***controls.*** Pre-insulated steel pipework is one of the largest costs in a heat network and can be difficult to source. Heat network control systems can both be complex but effective if used correctly and advances can have large impacts on efficiency of the entire network.

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Assessment of what key components that Scottish Enterprise should focus on

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- Market analyses for heat pumps and heat networks have been done for four countries to size the total markets and the markets for each key component. A qualitative market accessibility assessment was also completed to better understand which component(s) could be most promising for potential Scottish entrants. The following conclusions can be made from this section:

    1) The four markets that were sized were: **Scotland, RoUK, Denmark,** and **France.** The market analyses focused on estimating the total market size in both MW and GBP for the heat pumps and the key components identified earlier in the trends and technology assessment. It was estimated that **Scotland** in 2026 will have a market value of **GBP 359 m /2,544 MW** (**GBP 61 m** for compressors/ **39.5 m** for controls). It was estimated that **RoUK** in 2026 will have a market value of **GBP 1,831 m /18,978 MW** (**GBP 311 m** for compressors / **GBP 201 m** for controls). It was estimated that **Denmark** in 2026 will have a market value of **GBP 857 m / 6,107 MW** (**GBP 146 m** for compressors / **94m** for controls). Lastly it was estimated that **France** in 2026 will have a market value of **GBP 4,948 m** / **104,307 MW** (**GBP 841 m** for compressors/ **GBP 544 m** for Controls).
    2) The market analysis of heat networks focused on two countries being **Scotland** and **RoUK.** The goal was to identify the market size based on national targets set by Scotland an RoUK. **Scotland** has a target of reaching **6 TWh by 2030**, while **RoUK** has a target of **36 TWh by 2030.** Through desktop research and Ramboll expert interviews it was estimated that the typical **CAPEX** of heat networks is **GBP 1,085.24/MWh**. The total market size for **Scotland in 2030** was therefore estimated to be worth **GBP 5.23 bn** and the RoUK was estimated to be worth **GBP 26.74 bn.** Out of the total market value, pre-insulated steel pipes were estimated to take up **22%** of the total market value (**GBP 1.15bn** for Scotland, and **GBP 5.9 bn** for RoUK) while electronic controls were estimated to take up **13%** of the total market value (**GBP 0.68 bn** for Scotland, and **GBP 3.5 bn** for RoUK)**.**
    3) The last part of the market analysis aimed to identify which of the component markets could be most accessible for potential new Scottish entrants. The market accessibility assessment focused on various drivers that could impact the accessibility of the component markets both positively and negatively**.** It was estimated that **controls** for both heat pumps and networks are the most accessible market due to *low start-up costs, strong demand for new players on the market, flexible products that can be applied to all parts of the heat pump and heat network market*. **Pre-insulated steel pipes** and **compressors** are on the other hand less accessible markets due to *high/medium start-up costs, complex testing requirements for compressors, quality and industry reputation, competitors producing their compressors, and large competing players on the market*. It can therefore be concluded that controls are a more accessible market than pipes and compressors, but also holds smaller value. It was also noted that there may be other relevant sectors for potential new component manufacturers to consider in a market analysis (e.g. refrigerant markets for compressors).

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Trends and Technology assessment

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Company and Country profiles

- A company and country profile was done to clarify what competitive advantages the leading manufactures of the key components have, and if they are benefitting from any economic support schemes from their country of origin. The following conclusions can be made from this section:

1) A high-level analysis of 8 companies has been made to identify their competitive advantages. The **8 companies** analysed were: *Danfoss x2, Siemens, Mitsubishi Electrics, Bitzer, GEA, Logstor, and Isoplus. I*t was concluded that the market leaders of each component have many of the **same competitive advantages**. The most relevant competitive advantages identified for the manufactures were: *high quality products, good reputation, flexible solutions, and country of origin (as it gives a stamp of quality)*. High quality and reputation were especially highlighted as important competitive advantages for pre-insulated pipes, as the cost of fixing broken pipes is high. Low prices and flexible solutions were highlighted as important competitive advantages for controls, as high flexibility makes it possible to adjust their products to customer needs.
2) A country profile analysis was completed to understand if economic support schemes were available. The 8 leading manufactures' country of origin were either **Denmark, Germany, or Japan.** The types of economic support assessed were *grants, loans and others (*such as company investments and tax reductions/incentives). The economic support available in **Denmark** is more focused on grants supporting small start-up companies, while Germany has a broader focus, mainly with loans. Japan is more focused on area-based economic support, and grants for making large manufacturing companies move production back from China.
3) Finally, it is noted that when selecting new manufacturing sites, companies will look at a range of indicators to assess the attractiveness of certain sites. These may include t*rade conditions, market attractiveness, cost attractiveness, labour supply, and political and legal stability.*

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Introduction

- This report presents the findings from technical and market analyses of key components from heat pumps and heat networks conducted by Ramboll for Scottish Enterprise.
- Heat pumps and heat networks are expected to see rapid growth in the UK and across Europe, driven by macro-trends of decarbonisation and security of energy supply.
- Each of the technologies has an existing supply chain that Scottish Enterprise is interested in examining further, in order to identify potential economic opportunities for Scottish companies.
- In the first half of this report, a technical analysis is presented, identifying the two key components from each technology. In the second half, the markets in Scotland, the rest of the UK (RoUK), Denmark and France are analysed, both in terms of size and accessibility for potential new entrants.
- The current market leaders for each of the components are also identified and analysed, both in terms of their business and products, as well as competitive advantages.
- Finally, the countries of origin of the leading manufacturers are identified, and any economic incentives for manufacturers are provided.

Danish district heating pipes being prepared for installation.

The report consists of 3 main sections as described below

The icons above provide guidance about when heat pumps or networks are the focus.

	Trends and Technology Assessment	Market Analysis	Country and Company Profiles
Purpose	• Analysis of key components in heat pumps and heat networks, in order to understand what components are of most interest to manufacture in terms of value, innovation opportunities, applicability, and procurement.	• A market analysis of the key components for heat pumps and heat networks across Scotland, RoUK, Denmark, and France, in order to identify potential export markets (if relevant) for Scotland. Also to identify what markets and components are the most accessible	• An analysis of the leading manufacturers within the key components identified for heat pumps and heat networks. The goal is to identify what competitive advantages the leading manufacturers have, and if they are benefitting from economic support schemes.
Methodology	• Data collection process involving desktop research, Ramboll expert interviews, and industry supplier interviews. • Qualitative analysis to identify capabilities and gaps, and light quantitative analysis to identify components of most value.	• Desktop research including the academic literature, previously conducted Scottish Enterprise consulting reports, government reports, and private sector literature. • Ramboll expert interviews, and Scottish, UK, and European industry expert interviews with knowledge on heat pumps and networks.	• Desk research and interviews with Ramboll experts, heat pump manufacturers, and network developers to identify competitive advantages for each manufacturer. • Qualitative analysis through desk research and interviews to gather data about the economic support that the leading companies might receive.
Reader's guide	• The section is structured as follows: 1. Identification of components in heat pumps and networks. 2. Assessment of the identified components rating them on various criteria. 3. Overview of the two most valuable components in heat pumps and networks and the leading manufacturers.	• The section is structured as follows: 1. Market sizing for heat pumps and key components across four markets in MW CAGR and GBP. 2. Market sizing for heat networks and key components based on national targets. 3. Qualitative analysis of market accessibility for key components.	• The section is structured as follows: 1. High level company profiles, and their perceived competitive advantages. 2. Country profiles of where manufacturers' HQs are located, focusing on the types of economic support available.

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Data collection involved literature and interviews with varied stakeholder groups

Data Collection Summary:

This research was informed by an extensive **literature and information review** including previous Ramboll studies, relevant academic research, and market intelligence from publicly available sources and databases.

In addition, **8 expert interviews** were conducted from the following four categories: Ramboll experts, wider stakeholders, heat pump experts, and heat network experts.

The interviews covered 4 main topics:

1. Evaluation of key components
2. Market drivers and barriers for chosen markets
3. Market sizing and demand estimations
4. Competitive advantages

A representative from each of the following organisations were interviewed for this project, with the exception of Ramboll, where 4 experts were interviewed across the business

Category	Type	Company
Ramboll Experts	Consultancy	RAMBOLL
Wider Stakeholders	Public Sector	ZERO WASTE SCOTLAND

Category	Type	Company
Heat pump experts	Design/Manufacturing	Kensa Heat Pumps
	Design	GEA
	Design/Manufacturing	Carrier
	Manufactur-ing	AERMEC

Category	Type	Company
Heat network experts	Operator/ Contractor	FES
	Industry network and research hub	mini bems
	Manufactur-ing/ Research	VITAL ENERGi

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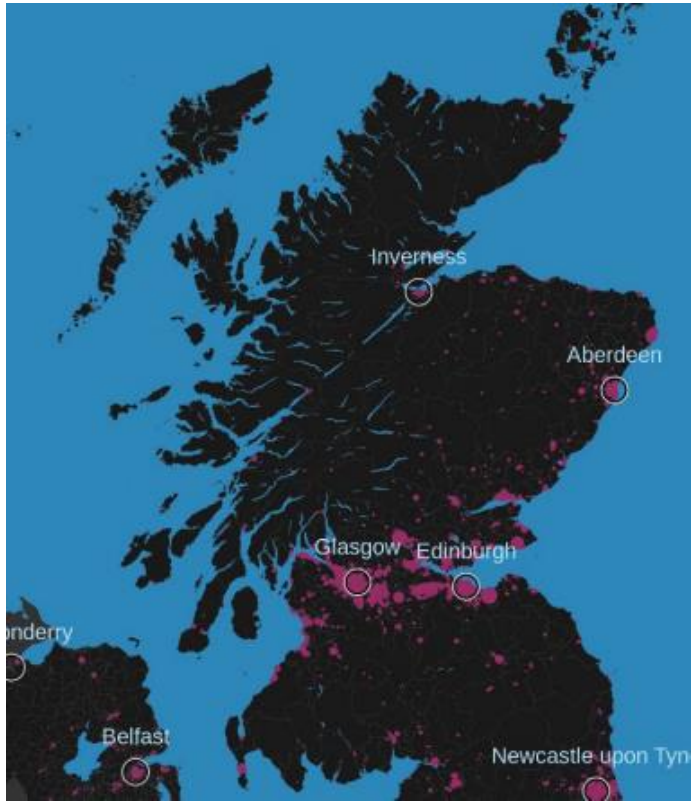
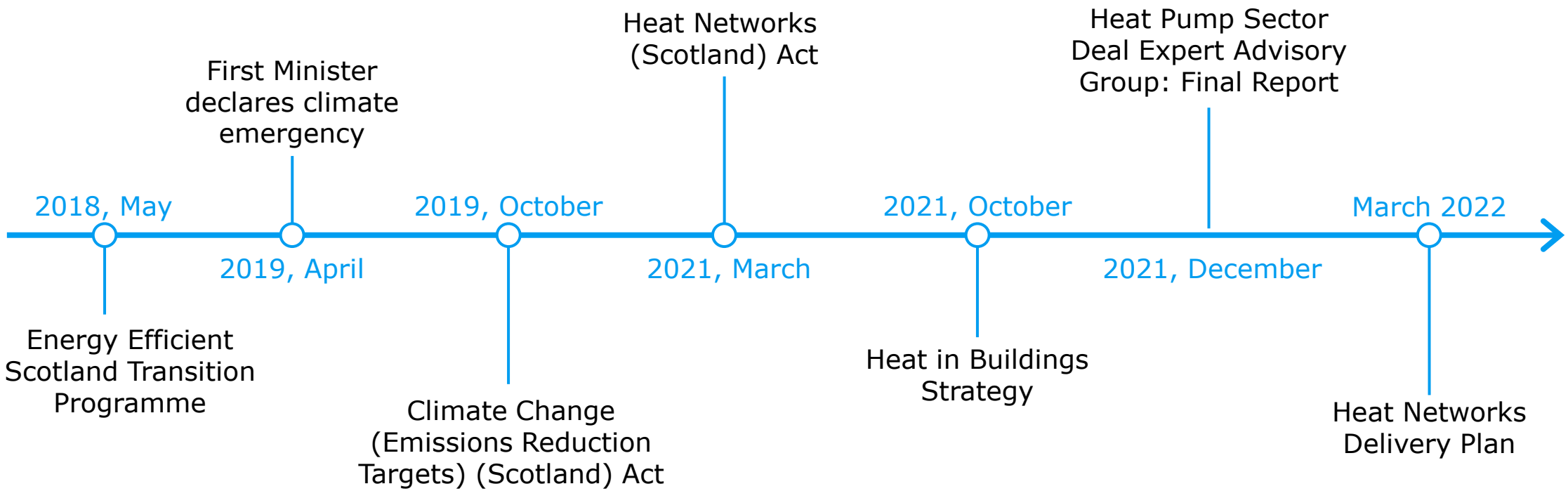
The Scottish energy system is characterised by ambitious carbon targets, but historical reliance on gas



Areas with potential for economically viable heat networks (15TWh = 28% of total heat demand);
Source: Opportunity Areas for district heating networks in the UK, BEIS 2021

Characteristic	Description
Target to reach net zero by 2045	• In April 2019, the Scottish First Minister, Nicola Sturgeon, declared a Climate Emergency. This was followed by amendments to the Climate Change (Scotland) Act to update the legally binding **target to reach net-zero greenhouse gas emissions by 2045.**
High penetration of gas boilers for heating buildings	• ~80% of homes & 30% of non-domestic buildings use gas as the primary heating source. • The last estimate (2018) suggested 34,000 homes are connected to a heating network and ca. 278,000 have a renewable or very low emissions heating system (heat pump, biomass boiler, or electric storage heating). • There is low consumer awareness of district heating and heat pumps. • The commercial business case for low carbon district heating is challenging against the current counterfactual of gas boilers.
District heating and heat pumps seen as a key technology for decarbonisation	• In the short term, Scottish energy policy focuses on "no and low regrets" strategic technologies. This includes a focus on "areas most suitable for heat networks", that will be supported by a heat network zoning analysis conducted by local authorities. • The Heat in Buildings Strategy declares that "early progress must be made deploying heat pumps in buildings for which they are the right long-term solution."
Supply chain capacity and skills gaps	• There are a range of skills gaps creating challenges in the district heating and heat pump sectors, covering areas of project management, heat network design, installation, as well as technical operation and maintenance. Successful rapid scale-up of heat networks and pumps in Scotland will rely on upscaling and upskilling of the supply chains across the whole sector.
Developing policy landscape to support low-carbon heating	• The Scottish Government Heat in Buildings Strategy (2021) committed to invest "£1.8bn capital funding over the lifetime of this parliament on energy efficiency and low carbon heat". See the next page for details.

A timeline of Scottish policy and regulation to promote the development of district heating and heat pumps (1/3)



 Source: Scottish Government, Scottish Parliament

A timeline of Scottish policy and regulation to promote the development of district heating and heat pumps (2/3)

Date	Policy/legislation	Key features
2018, May	**Energy Efficient Scotland Transition Program** **MKM me**	• Supported the piloting of **Local Heat and Energy Efficiency Strategies (LHEES),** aiming to develop a consistent approach to local energy planning, including identification of heat network zones. • **Funding** for local authorities to offer **end-to-end support for energy efficiency** in domestic and non-domestic markets. • **Allocation of funding** for fuel poverty programmes.
2019, April	**First Minister declares climate emergency**	• Followed by Climate Change action, amendments to the Climate Change Bill to set a legally binding target of net-zero greenhouse gas emissions by 2045.

2019, October	**Climate Change (Emissions Reduction Targets) (Scotland) Act**	• Introduces **three emission reduction targets**:
		  • 2045 as the net-zero emission target year
		  • Interim emission reduction targets for 2030 and 2040 (of 75% and 90% respectively)
		• Introduces changes to emissions accounting, reporting and planning duties, other duties, minor and consequential modifications, final provisions.

2021, March	**Heat Networks (Scotland) Act**	**Regulations to promote and support heat networks** including: Technical standards, consumer protection, granting licenses, issuing permits (exclusive rights), and establishing planning for heat network zones. The Act sets specific targets for **heat networks** to supply 2.6 TWh of heat by 2027 and 6 TWh of heat by 2030. This should include connection of 120,000 homes by 2027 and 650,000 homes by 2030.

A timeline of Scottish policy and regulation to promote the development of district heating and heat pumps (3/3)

Date	Policy/legislation	Key features
2021, October	**Heat in Buildings Strategy**	• **Funding** will be available through a successor to the Low Carbon Infrastructure Transition Programme and a refocussed **district heating loan fund.** • A **review of evidence on heat pumps in Scotland** will be published during the first quarter of 2021. • A **Heat Network Investment Prospectus** will be published during the next financial year which will demonstrate the size and location of heat network and opportunities across Scotland, as well as information on the decarbonisation requirements of existing networks in Scotland. • **Develop a Heat Pump Sector Deal Expert Advisory Group** to make recommendations to the Scottish Government by Summer 2021 on how industry and Government can work together to set a clear pathway for accelerated deployment of heat pumps. • Creation of a **Heat Networks Delivery Plan** by April 2022 setting out how the Heat Networks Act and wider policy will increase the use of heat networks in Scotland (including meeting the targets set out by the Act).
2021, December	**Heat Pump Sector Deal Expert Advisory Group: final report**	• Publication of a **final report from the Expert Advisory Group** set up to provide recommendations to Scottish ministers on the potential scope and content of a heat pump sector deal. • **Recommendations** include: "Scotland's enterprise agencies should work with industry to support Scotland as a global centre of excellence for heat pump manufacturer".
2022, March	**Heat Networks Delivery Plan**	• **Outlines the steps** that the Scottish Government will take to **accelerate the development of heat networks** across Scotland, contributing to the climate change and fuel poverty targets. • **Sets out actions** that are being taken and recommendations for the UK Government to complement Scottish efforts.

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2. Trends and technology assessment for heat pumps and heat networks

The icons above provide guidance about when heat pumps or networks are the focus.

Introduction to report section

Trends and Technology | Market analysis | Company & Country profiles | Conclusions

The following section summarises the components found in heat pumps and heat networks and identifies the two most valuable for the Scottish manufacturing sector. The analysis consists of three main deliverables:

1. A breakdown of heat pump and district heating network components.
2. A shortlist of the most valuable components.
3. A trends and technology review of each shortlisted component.

Methodology applied in report section

The overview of the trends and technology analysis and accessibility assessment was conducted using the following method:

- Identify list of components.
- Create a longlist to filter out the least valuable components.
- Create a shortlist to identify the two most valuable components, assessed according to five metrics.
- Determine technology trends and summary of manufacturing methods and characteristics.

These steps were supported by sector experts, interviews with industry suppliers and desk-based research.

Highlighted conclusions

Control systems and compressors are the two most valuable heat pump components.

Heat pump control systems are a valuable component with a large potential for innovation. Compressors are the most expensive part of a heat pump and small improvements can have a large impact on heat pump efficiency.

Pre-insulated steel pipe and control systems are the two most valuable heat network components.

Pre-insulated steel pipework is one of the largest costs in a heat network and can be difficult to source. Heat network control systems are complex and advances in control systems can have large impacts on the entire network.

Efficiency improvements and refrigerants are innovation drivers for heat pumps

The drive for ever-greater efficiency is driving much of the innovation in heat pumps and their components, including compressors. There is also a strong demand for refrigerants with lower Global Warming Potential (GWP), which has important implications for compressors.

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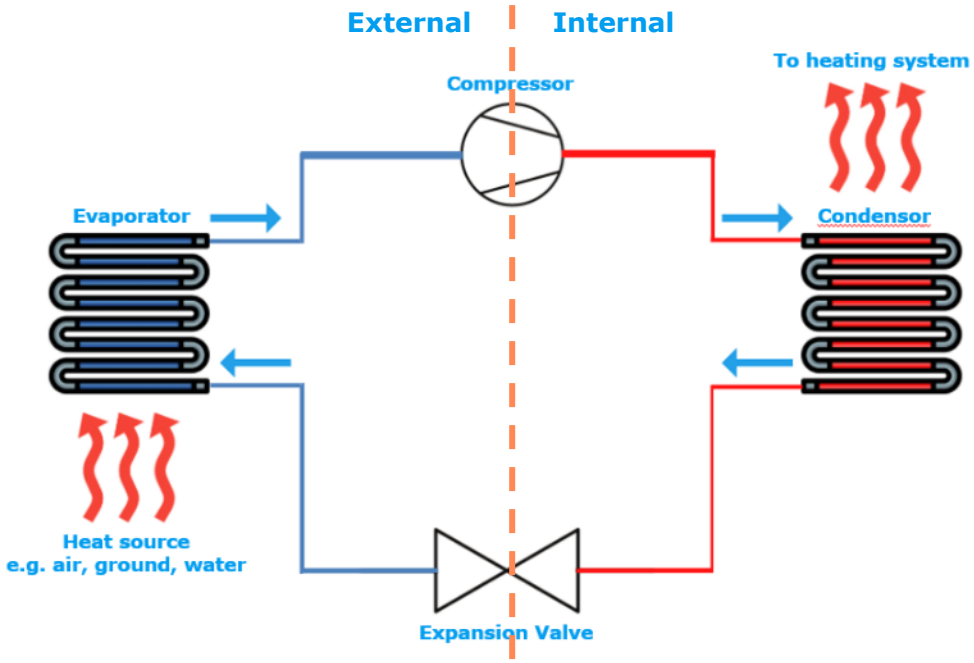
Heat pumps differ in size and heat source, but share the same components

Introduction to heat pumps

- Heat pumps use a refrigeration circuit, driven by an electrical compressor, to transport heat from a source to a demand. This source can be a river, boreholes, a sewer or even the ambient air and can be harnessed to supply heating (or cooling) without burning fossil fuels.
- While heat pumps can be used for many different purposes, the core components remain the same, seen in the diagram below. They are used across the domestic (<15kW); commercial (15-20 kW); or industrial (>20 kW) sectors with few changes to design. The internal system remains the same, but the external varies according to the heat source.

The external system…

…consists of a heat exchanger which recovers heat from a heat source, pipework, and the evaporator heat exchanger (ASHP's only have one heat exchanger which performs both of these roles).



The internal system…

…is the same across all heat sources and begins with the condenser heat exchanger. This is connected either to a low temperature hot water circuit or a water-air heat exchanger.

Types of heat source:

Ground - GSHP

- Relatively constant source of heat independent of seasons.
- Enables high efficiencies with closed or open loop boreholes.
- Costly installation of pipework: 2-3 times more than air source heat pumps.

Water - WSHP

- Water sources can include rivers, lochs, industrial effluent, mine water, the sea or sewers.
- Water is an extremely effective working fluid, also enabling high efficiencies.
- Require additional filters/alternative materials in order to avoid biological fouling and heat exchanger degradation.
- Normally used for larger heat demands.

Air - ASHP

- Generally less efficient than those using alternative sources.
- Require much less infrastructure (only a small heat exchanger and fan).
- Often most affordable.

The following heat pump components vary between different heat pump types

Component	Description
Compressor	Circulates refrigerant around the heat pump
Reversing valve	Enables the heat pump to cool or heat depending on conditions
Expansion valve	Reduces the pressure and temperature of refrigerant
General valves	Controls the flow of the refrigerant
Condenser (Heat exchanger)	Deposits heat from the refrigeration circuit to the end user
Evaporator (Heat exchanger)	Takes heat from a heat source and deposits it to the refrigeration circuit
Expansion vessel/device	Maintains the desired pressure in the system
Filter	Prevents contaminants/damage in air flow and water flow
Fan	Increases air flow, improving heat pump efficiency
Mounting brackets	To mount the equipment/unit on a flat surface
Flow switch	Controls fluid flow through the heat pump
Pump	Circulates water around the heating system
Inverter	Electronic component which normalises electricity supply

The components listed here will be custom-made depending on if they are for domestic (<15kW); commercial (15-20 kW); or industrial (>20 kW).

Other components are suitable for a variety of heat pump sizes

Components	Description
Temperature sensor	Monitors temperature for safety and efficient operation
Pressure sensor	Monitors pressure for safety and efficient operation
Control system	Enables monitoring and advanced control of the system
Pipework	Transports working fluid around the heat pump
Glycol	Prevents inline water freezing
Refrigerant	A working fluid that is effective at transporting heat
Insulation	Reduces heat loss and noise levels
Casing	Protects internal elements

The components listed here are suitable for any size of heat pump, except casing, which is usually not required for industrial heat pumps.

Heat pump components were assessed to give a shortlist of the top five most valuable components

Heat pump parts	Share of total cost (1-4)	Potential growth (1-4)	Rating (1-4)
Compressor	**4**	**4**	**4**
Reversing valve	1	2	1.5
Expansion valve	1	3	2
General valves	1	1	1
Condenser (Heat exchanger)	**3**	**3**	**3**
Evaporator (Heat exchanger)	**3**	**3**	**3**
Expansion vessel/device	1	1	1
Filter	1	2	1.5
Fan	1	2	1.5
Mounting brackets	1	1	1
Flow switch	1	2	1.5
Pump	2	3	2.5
Inverter	2	3	2.5
Temperature sensor	1	1	1
Pressure sensor	1	1	1
Control system	**3**	**4**	**3.5**
Pipework	1	1	1
Glycol	1	2	1.5
Refrigerant	**2**	**4**	**3**
Insulation	1	1	1
Casing	1	3	2

Summary and method

A longlist of all components found in heat pumps was evaluated against two criteria in order to establish what would be most suitable for a manufacturer in Scotland.

Share of total cost:
Each component was ranked from 1 (low) to 4 (high) on its value compared to the overall value of the heat pump. This indicates its financial value.

Potential growth in area:
Each component was ranked from 1 (low) to 4 (high), taking market growth, market access and innovation into account. This indicates the future potential for the component.

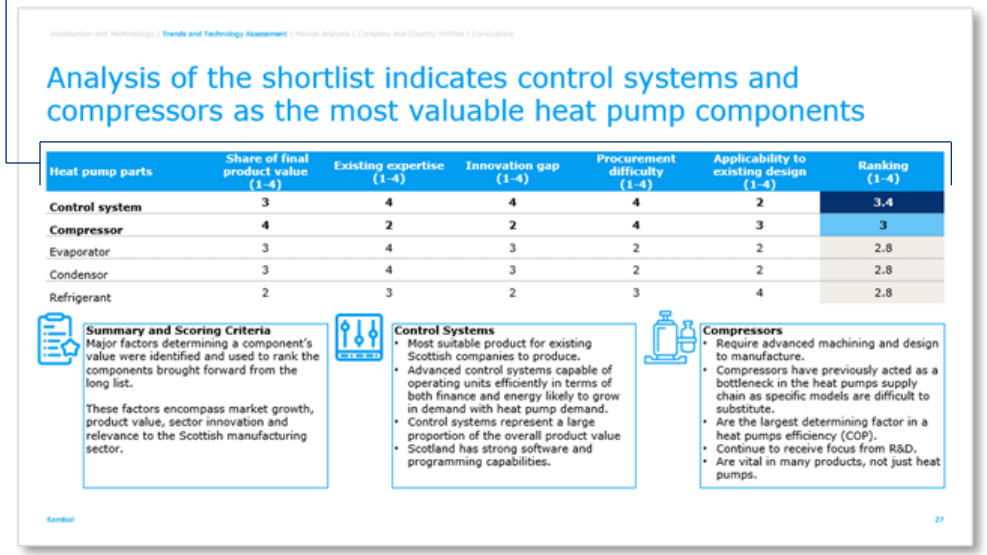
To go from five shortlisted components to two, we scored the components according to five metrics

Summary:

The shortlisted components were each assigned a ranking between 1-4 for each of the five criteria below. This process was informed through interviews with Ramboll experts, with scores validated by industry representatives.

- **Share of final product value:** How much of the final value is the component responsible for? This was mainly established from past heat pump quotes and discussions with suppliers.
- **Existing expertise:** This metric evaluates the familiarity and skills available within the Scottish workforce for each of the components. Key methods of production and installation for each component were identified and compared against existing expertise in Scotland.
- **Innovation:** Indicates the extent of innovation potential for each of the components. For example, if there are any new developments that have recently come onto the market, or any areas that are forecasted in the near future.
- **Procurement difficulty:** This indicates how easy it is for suppliers to procure the components and could indicate a shortage in the supply chain that could be addressed by Scottish companies. Procurement can be volatile but is an important factor for manufacturers. This score was established through discussions with suppliers to ensure up to date information.
- **Applicability to existing design:** This metric indicates the ease of retrofitting a new component into an existing design. Components that score higher on this may have a larger total serviceable market, rather than only focusing on new heat pumps. These values were decided by consulting with an internal heat pump expert.

The five criteria used to score components



Analysis of the shortlist indicates control systems and compressors as the most valuable heat pump components

Heat pump parts	Share of final product value (1-4)	Existing expertise (1-4)	Innovation gap (1-4)	Procurement difficulty (1-4)	Applicability to existing design (1-4)	Ranking (1-4)
Control system	3	4	4	4	2	3.4
Compressor	4	2	2	4	3	3
Evaporator	3	4	3	2	2	2.8
Condensor	3	4	3	2	2	2.8
Refrigerant	2	3	2	3	4	2.8

See next slide for shortlist analysis

Analysis of the shortlist indicates control systems and compressors as the most valuable heat pump components

Heat pump component	Share of final product value (1-4)	Existing expertise (1-4)	Innovation gap (1-4)	Procurement difficulty (1-4)	Applicability to existing design (1-4)	Ranking (1-4)
Control system	**3**	**4**	**4**	**4**	**2**	**3.4**
Compressor	**4**	**2**	**2**	**4**	**3**	**3**
Evaporator (Heat exchanger)	3	4	3	2	2	2.8
Condenser (Heat exchanger)	3	4	3	2	2	2.8
Refrigerant	2	3	2	3	4	2.8

Summary and Scoring Criteria

- Major factors determining a component's value were identified and used to rank the components brought forward from the long list.
- These factors encompass market growth, product value, sector innovation and relevance to the Scottish manufacturing sector.

Control Systems

- Most suitable product for existing Scottish companies to produce.
- Advanced control systems capable of operating units efficiently in terms of both finance and energy likely to grow in demand with heat pump demand.
- Control systems represent a large proportion of the overall product value.
- Scotland has strong software and programming capabilities.

Compressors

- Require advanced machining and design to manufacture.
- Compressors have previously acted as a bottleneck in the heat pumps supply chain as specific models are difficult to substitute.
- Are the largest determining factor in a heat pumps efficiency (COP).
- Continue to receive focus from R&D.
- Are vital components of many products, not just heat pumps.

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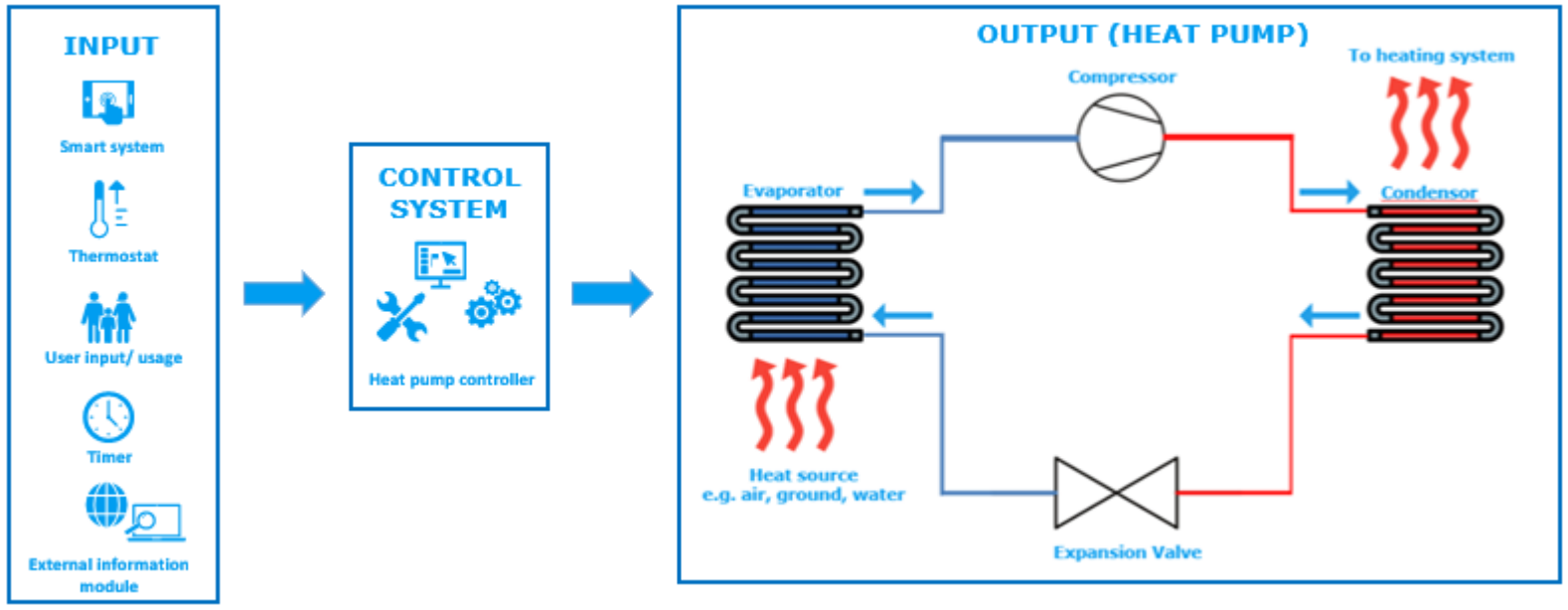
Heat pump control systems are vital for effective operation

Introduction to control systems

- The control system comprises a set of electronic components that have been programmed to operate the valves, compressor, and sensors.
- The control system is one of the most important components and is responsible for effective and efficient operation.
- A well designed control system will prevent inefficient operation such as unnecessary cycling, incorrect flow rates, and poor temperature control.



Schematic for control system operation

User inputs to heat pump control systems

- There are several ways that users can control a heat pumps operation. These include the following options:

Thermostat

- Sets a temperature which must be achieved.
- Will keep operating until the temperature is met.
- Effectiveness depends on placement of sensor.

Timer

- Sets times of operation for unit.
- Usual also uses a set point.
- Enables more control over operation.

Smart system

- Uses external data to efficiently operate.
- Best used with thermal store.
- Recognises low tariffs.

Heat pump control system design is a balance between programming and manufacturing

Control system manufacture

Control system manufacturing involves two main sections: software design and computer parts manufacture. Sensors were not included in the controls systems analysis. The design/manufacture process is as follows:

Software design

- Data gathering and logic creation – determining how the heat pump will react to a range of inputs and demands.
- Software design – translating the required logic into a programming language that is compatible with electronic components.

Computer parts manufacture

- Electronic system design – mapping of physical electronic components and connections to apply the designed software package.
- Electronic component manufacture – creation of electronic parts such as Printed Circuit Boards (PCBs). This can include composite manufacture such as epoxy infused fiberglass sheets, pressing, conductive metal deposition, soldering, and etching.

Innovation trends – current and future development

- **Efficiency**: A drive for greater efficiency is prevalent throughout the heat pump industry, this includes through the control systems. Companies are adding additional sensors throughout the building and are using advanced programming to enable more efficient and effective heating. This could be through utilising thermal stores more efficiently, operating the heat pump more efficiently or only operating when required.
- **'Smart' controls**: Traditionally, heat has been produced either when a certain temperature is met or when switched on. In reality, building temperature and comfort are not as simple and require more effective controls. Control systems can interact with external data e.g. weather or varying tariffs to reduce energy wastage – for example increasing the heating if cold weather is forecast and turning off once sufficient heat was produced. The system could also 'learn' occupants' behaviour in order to predict heat loads, maximising building comfort.
- **Predictive maintenance:** It is vital that heating systems are always available to ensure comfort and safety, especially in winter. Currently, most systems will give little warning that they are going to fail. Predictive maintenance could alert the occupants to failing components and even remind them to perform upkeep such as cleaning filters and removing dust from the heat exchanger.

Market summary and leaders

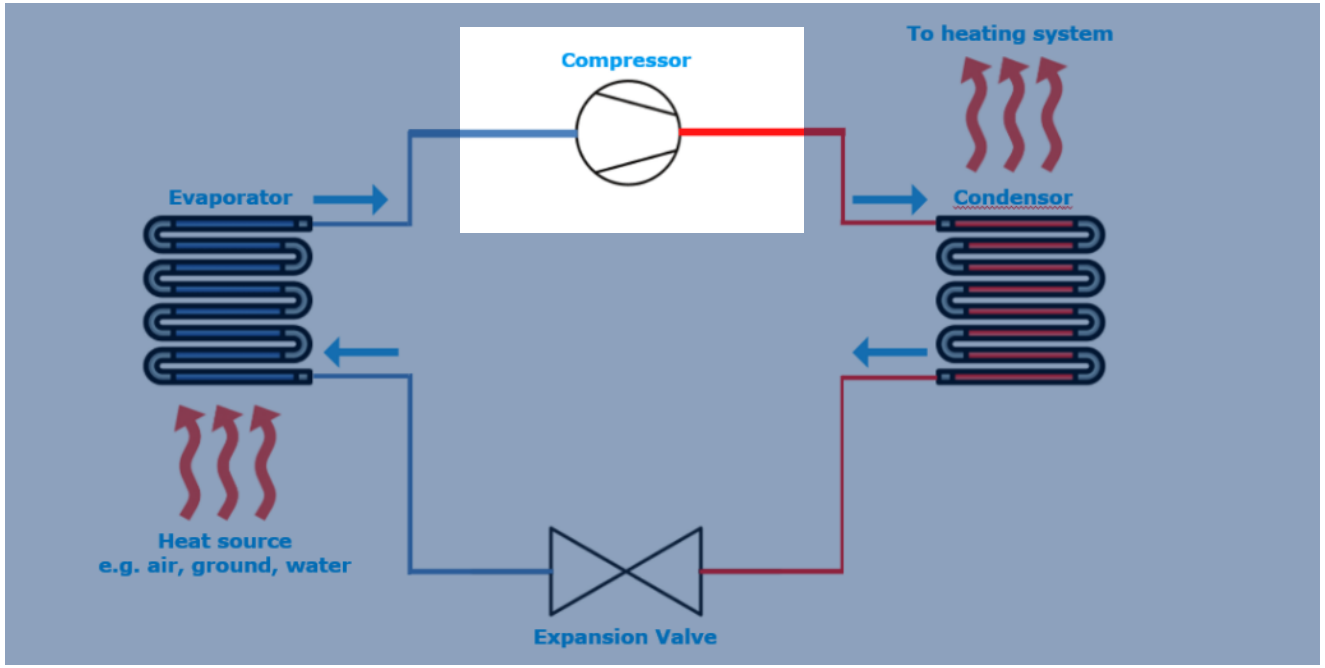
- Danfoss and Mitsubishi electric have been identified as the main market leaders, but there are numerous alternatives on the market.

- Danish company, global presence. See company profile for more details.
- Japanese multinational company with controls division See company profile for more details.

Compressors come in three main varieties but have the same purpose

Introduction to compressors

- The compressor is the most expensive component in a heat pump and contains gears or other shaped moving parts housed in a metal casing. The compressor raises the pressure of refrigerant, effectively driving the refrigeration circuit to enable heat recovery.
- Compressors are the main consumer of electricity in a heat pump and one of the few components which has moving parts. They require precision engineering with similar manufacturing processes as Formula 1 gearboxes.
- As they contain the majority of moving parts that can be found in a heat pump, they must be robust and able to withstand a large number of cycles before failure.



Compressor types

- There are three types of compressors that are usually used in heat pumps, each with their own properties.

- Cheap
- Noisy
- Used for industrial purposes

- Can operate at high temperatures
- Expensive
- Suitable for most heat pumps

- Quiet, compact, and efficient
- Not easily repaired
- Domestic and commercial use

Compressor manufacturing is complex and requires large start-up costs for machinery

Compressor manufacturing

Casing

Casting: molten metal is poured into a mould and then cooled to create a product.

Metal forming: heated metal sheets are bent into the required shape by running through a number of forming machines.

Shaft

The shaft is forged, ensuring that it can withstand the stresses that repetitive acceleration and deceleration during operation will introduce.

Metal forging: sections of metal are heated to make them mailable and are formed into the desired shape.

Working components

CNC machining (turning, milling, grinding): removing material from a pre-made block in order to create a component with uniform properties independent of geometry.

Innovation trends – current and future development

- **Efficiency:** As the driver of the heat pump system, the compressor has a large impact on the overall unit efficiency. Small improvements in the compressor can have large impacts on the overall system efficiency. Some current and future improvements include intelligent variable speed drives which enable high efficiencies over a range of operating conditions. Another advance includes the design of the physical compressor parts.
- **Quality**: Compressors are the most expensive component in a heat pump, therefore improved durability is an important factor. Reduced maintenance through design and materials advancement can increase the heat pump lifespan.
- **Size and noise**: As the domestic and commercial heat pump markets expand, development of smaller, quieter compressors has increased as these are two of the main factors which limit their implementation, especially in built-up areas. As the main component in heat pumps with moving parts, noise is mainly generated by the compressor.

Market summary and leaders

- Heat pump manufacturers generally have established suppliers.
- Many manufacturers currently produce compressors in central Europe, close to main demand.

- German company, producing compressors for a range of sizes. See company profile for more details.
- German compressor producer specialising in large (industrial) compressors. See company profile for more details.

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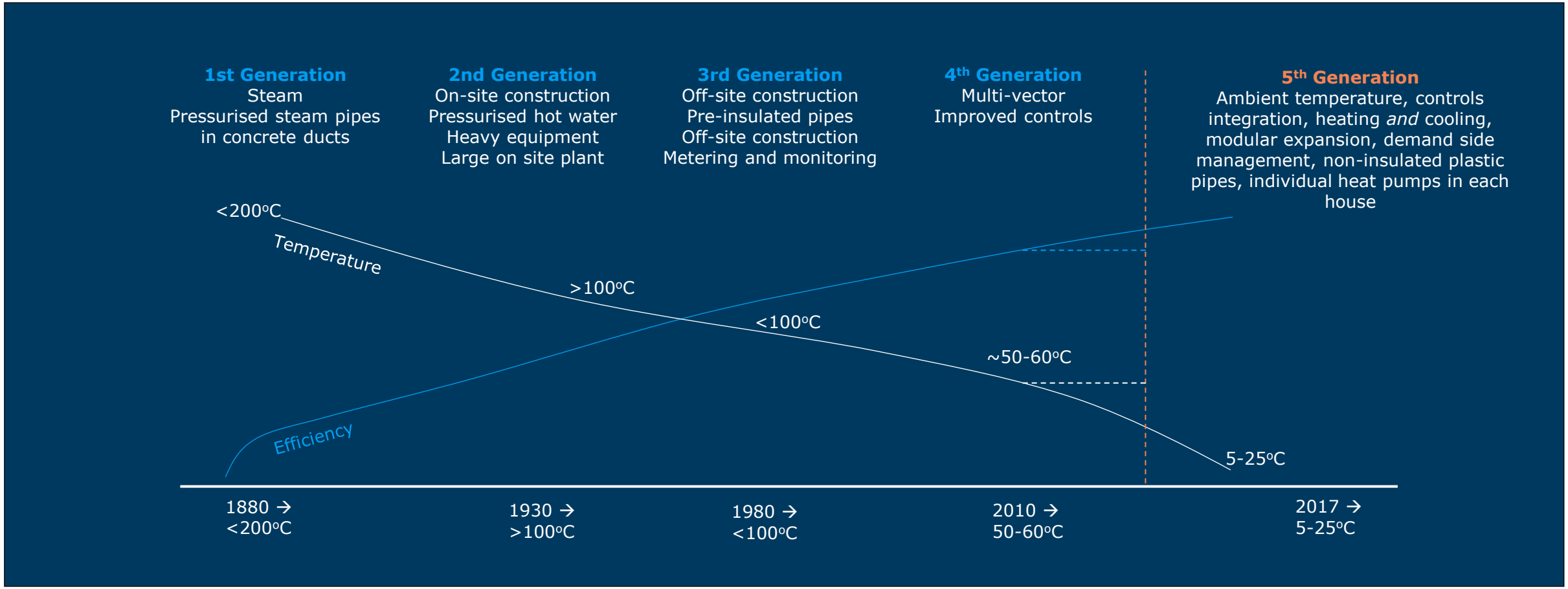
Introduction to the heat network Generations



 Source: CIBSE (2019) Intranets for heat: Introducing BEN networks

Definitions of 4G and 5G District Heating and Cooling

5th Generation District Heating and Cooling (5GDHC)

- 5GDHC systems are defined as decentralised networks (i.e. a heat pump is located in each building) which operate at ambient temperature and are capable of supplying both heating and cooling.

4th Generation District Heating (4GDH)

- 4GDH systems are defined as centralised heat networks which operate at low temperatures and incorporate renewable energy.

Characteristics

- The definition is still under debate. There is not yet an industry consensus about 5GDHC systems, with shared ground loop technology considered a grey area.
- 5GDHC networks are characterised by low distribution temperatures (typically 5-25^{O}C), diminishing the need for pipe insulation and reducing heat loss.
- The network connects a combination of heating and cooling capacity through the use of distributed heat pumps located in decentralised building-level plantrooms to pressurise and balance the system – they are not normally centrally pumped.
- They utilise a wide variety of heat sources, offer a demand side response and integrate waste and excess heat capturing capability with storage.
- Flow is often bi-directional, meaning the water in the network flows one way or another depending whether heating or cooling is required.

- 4GDH networks are a clear progression from generations 1 to 3 with a higher efficiency and lower temperatures in the same centralised design.
- 4GDH systems commonly use 60^{O}C supply and 30^{O}C return temperatures, but centralised systems with temperatures between 30-70^{O}C can be classified as 4GDH. This is lower than the temperature of 3GDH systems, but higher than 5GDHC systems.
- Introduction of low temperature waste heat and renewable heat sources as part of supply, with large heat pumps often used.
- 4GDH systems cannot provide cooling without the addition of an extra network in a 4-pipe setup.

Equipment

• Heat taken from cooling (these customers are referred to as prosumers) • Waste/low grade heat directly into loop	**Heat Sources**	• Large centralised heat pumps • High grade waste heat	• Combined Heat and Power (CHP) • Energy From Waste
• Uninsulated pipework • Pumping generally done by distributed pumps in consumer buildings	**Transmission/ Distribution**	• Insulated pipework • Large centralised pumps	
• Separate heat pump and chiller; or reversible/simultaneous heat pump	**Customer Connections**	• Heat interface units (i.e. heat exchangers); or • Direct connection to network (i.e. network flows directly into buildings)	

The majority of heat network components are shared between 4G and 5G networks (1/2)

Component*	Description
Energy Centre pipework	Pipes which transport fluid around the energy centre
Buffer vessel	Short term LTHW storage capacity for peaks in demand
Pumps	To circulate the LTHW around the system
Filters	Remove contaminants from in line pipes
Valves	Allow control of fluid flow to areas of the network
Thermal store	LTHW storage for more efficient sizing and use of heat source
Heat/energy meters	Record the energy consumed in specific areas of the network
Energy Centre structure	Acts as housing for a central heat source (not at the house level)
Controls	Operate the heat network efficiently
Sensors	Gather operational data from the network
Transformer	Varies the voltage and current of electrical supply
Expansion vessel	Maintains the correct level of pressure in the system

The components listed here are used in **both 4G and 5G** district heating systems.

 *All components are considered excluding primary heat plants such as heat pumps or CHP engines.

The majority of heat network components are shared between 4G and 5G networks (2/2)

Component	Description
Pressurisation equipment	Pressurises the network to meet operating requirements
Water treatment	Protects the system components from chemical degradation
Degasser	Removes gas from the systems' water including dissolved gas
Inverters	Electronic component which normalises electricity supply
Dirt/air separators	Remove any impurities in the water
Control valves	To control differential pressure, varying flow rate
Actuators	Enable the regulation of pressure by operating valves
Leak detection system	Identifies leaks in pipes or equipment
Dry air coolers	Reject heat to the ground
Electric boilers	Serve as a heat source, backup capacity and top up
Automatic metering	Collects data from remote metering devices
Pre-insulated pipework	Large underground insulated pipes used to transport water
Heat Interface Unit (Heat exchanger)	Allows transfer of heat between the network and end user
Plastic pipework	Large underground uninsulated pipes used to transport water
Heat pump booster (5th Gen)	Allows heating and cooling between the network and end user

The components listed here are used in **both 4G and 5G** district heating systems

4G only

5G only

Heat network components were assessed to give a shortlist of the top five most valuable components (1/2)

Heat network parts	Share of total cost (1-4)	Potential growth in area (1-4)	Rating
Energy Centre pipework	2	3	2.5
Buffer vessel	3	2	2.5
Pumps	3	2	2.5
Filters	1	1	1
Valves	1	1	1
Thermal store	3	2	2.5
Heat/energy meters	1	2	1.5
Energy Centre structure	2	1	1.5
Controls	3	4	3.5
Sensors	1	1	1
Transformer	2	2	2
Expansion vessel	2	2	2
Presurisation equipment	2	2	2

Summary and method

A longlist of all components found in heat networks was evaluated against two criteria in order to establish which would be most suitable for manufacturing in Scotland:

Share of total cost:
Each component was ranked from 1 (low) to 4 (high) on its value compared to the overall value of the heat network. This indicates its financial value.

Potential growth in area:
Each component was ranked from 1 (low) to 4 (high), taking market growth, market access and innovation into account. This indicates the future potential for the component.

Heat network components were assessed to give a shortlist of the top five most valuable components (2/2)

Heat network parts	Share of total cost (1-4)	Potential growth in area (1-4)	Rating (1-4)
Water treatment	2	1	1.5
Degasifier	2	1	1.5
Inverters	2	2	2
Dirt/air seperators	1	1	1
Control valves	1	1	1
Actuators	1	1	1
Leak detection system	2	1	1.5
Dry air coolers	2	1	1.5
Electric boilers	3	3	3
Automatic metering	2	2	2
Pre-insulated pipework	4	3	3.5
Plastic pipework	3	4	3.5
Heat Interface Unit (Heat exchanger)	3	3	3
Heat pump booster (5th Gen)	4	4	4

Summary and method

A longlist of all components found in heat networks was evaluated against two criteria in order to establish which would be most suitable for manufacture in Scotland:

Share of total cost:
Each component was ranked from 1 (low) to 4 (high) on its value compared to the overall value of the heat pump. This indicates its financial value.

Potential growth in area:
Each component was ranked from 1 (low) to 4 (high), taking market growth, market access and innovation into account. This indicates the future potential for the component.

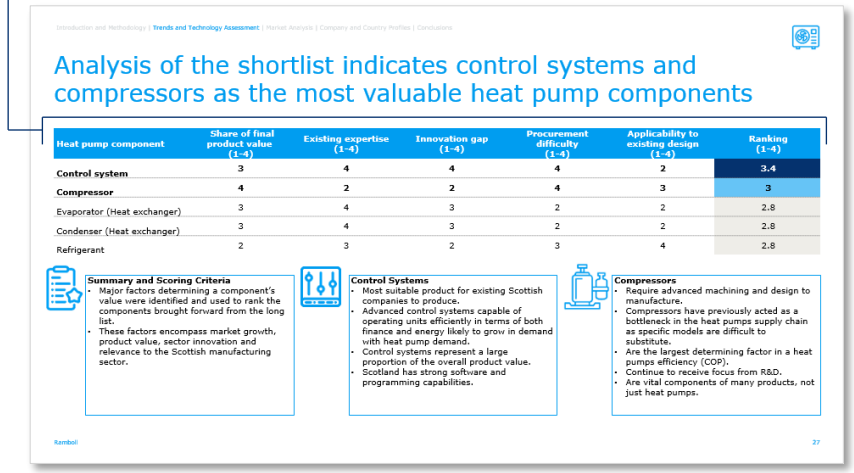
To go from five shortlisted components to two, we scored the components according to five metrics

Summary:

The shortlisted components were each assigned a ranking between 1-4 for each of the five criteria below. This process was informed through interviews with Ramboll experts, with scores validated by industry representatives.

- **Share of final product value:** How much of the final value is the component responsible for? This was mainly established from past heat pump quotes and discussions with suppliers.
- **Existing expertise:** This metric evaluates the familiarity and skills available within the Scottish workforce for each of the components. Key methods of production and installation for each component were identified and compared against existing expertise in Scotland.
- **Innovation:** Indicates the extent of innovation potential for each of the components. For example, if there are any new developments that have recently come onto the market, or any areas that are forecasted in the near future.
- **Procurement difficulty:** This indicates how easy it is for suppliers to procure the components and could indicate a shortage in the supply chain that could be addressed by Scottish companies. Procurement can be volatile but is an important factor for manufacturers. This score was established through discussions with suppliers to ensure up to date information.
- **Applicability to existing design:** This metric indicates the ease of retrofitting a new component into an existing design. Components that score higher on this may have a larger total serviceable market, rather than only focusing on new heat pumps. These values were decided by consulting with an internal heat pump expert.

The five criteria used to score components



See next slide for shortlist analysis

Analysis of the shortlist indicates pre-insulated steel pipework and controls as most valuable network components

Heat network parts	Share of final product value (1-4)	Existing expertise (1-4)	Innovation gap (1-4)	Procurement difficulty (1-4)	Applicability to existing design (1-4)	Ranking
Pre-insulated steel pipework	**4**	**4**	**2**	**4**	**4**	**3.6**
Controls	**2**	**4**	**4**	**3**	**3**	**3.2**
Plastic pipework	3	3	2	3	4	3
Heat pump booster (5th Gen)	3	2	3	2	4	2.8
Electric boilers	2	2	3	3	4	2.8

Summary and Scoring Criteria

- Major factors determining a components value were identified and used to rank the components brought forward from the long list.
- These factors encompass market growth, product value, sector innovation and relevance to the Scottish manufacturing sector.

Pre-insulated steel pipework

- Pipework is the single largest cost in most heating networks, with large capital, delivery and installation costs.
- Delivery time is also a major factor in most projects and there is a strong set of expertise in the Scottish oil and gas sector that could be developed to manufacture these.

Controls

- More developed than for heat pumps but remain a quickly evolving aspect of heat networks that have a large impact on systems.
- They are an expensive element of the project and are still undergoing major innovation.
- Scotland is well placed to address these challenges.

Pre-insulated steel pipes are used extensively in heat networks

Introduction to pre-insulated steel pipes

- Pre-insulated steel pipes are used to deliver heat (via low temperature hot water) to customers in the network. They are used in more traditional district heating systems with high flow temperatures (primarily 3rd and 4th generation and not 5th generation). The pre-insulated steel pipes are generally the most expensive component of a heating network.
- Two lines of pipe will be buried side-by-side in order to provide flow and return water to customers, often requiring several kilometres of pipe, which connects them to the energy centre.
- The pipes have inbuilt leak detection in the form of two copper wires running the length of the network.

Pre-insulated steel pipes are designed to reduce heat losses from district heating systems.

Pre-insulated steel pipe cross section.

Pipe sections:

★1 Inner pipe

- Steel pipe physically carries the low temperature hot water, often at pressure between the energy centre and heat customers.
- Corrosion can occur should the water be dosed incorrectly or the steel be chosen without considering the water's composition.

★2 Insulation

- Surrounds inner pipe, typically Polyurethane foam or similar, and minimises heat loss.
- Degrades once wet, so must remain dry in order to be effective.
- Two copper wires run through the insulation, acting enabling leak detection in the pipe.

★3 Outer pipe

- Outer steel or plastic pipe.
- Protects the layer of insulation physically and ensures the insulation doesn't get wet.
- A diffusion barrier is also sometimes installed to prevent gas in the foam from escaping.

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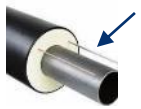
Pre-insulated steel pipe manufacturing consists of three main sections

Pre-insulated steel pipe manufacturing



Inner pipe

- The inner pipe contains pressurised water and is typically either welded or seamlessly produced.
  - Welding: sheet steel is formed into a pipe shape by running through a line of forming machines. The seam is then welded to seal the pipe. This is a widely used process.
  - Seamless: a cylinder of steel is heated and then pushed over a bullet shaped form, punching a hole through the centre of the cylinder. This process is more technical and less widespread than welding.

Insulation

- The insulation is produced through chemical processes to create foams such as Polyurethane which is a class of polymers. This involves mixing two or more liquid streams together and directing the mixture to the desired surface for application.
- Can be recycled into packaging, underlay, other forms of insulation or used as fuel in combustion.

Outer jacket

- The outer jacket is produced in a similar way to the inner pipe although can also be extruded plastic.

Innovation trends – current and future development

- **Materials:** There is ongoing R&D to improve the efficiency in the insulation by preventing heat loss as well as new outer jacket materials to reduce cost and increase effectiveness.
- **Quality**: Making repairs to district heating pipes can be a difficult and costly process, so there is a drive to improve the leak detection systems to be able to isolate leaks more efficiently and reduce maintenance costs. Improving the insulation properties can also help to prevent degradation and increase lifespan.
- **Sustainability**: Steel is one of the most difficult-to-decarbonise sectors, but with the drive to net-zero emissions, reducing the carbon involved from steel manufacturing is becoming more important to district heating customers.

Market summary and leaders

- There is a small group of market leaders, mostly based in Scandinavia, although smaller players have been entering the market in recent years.

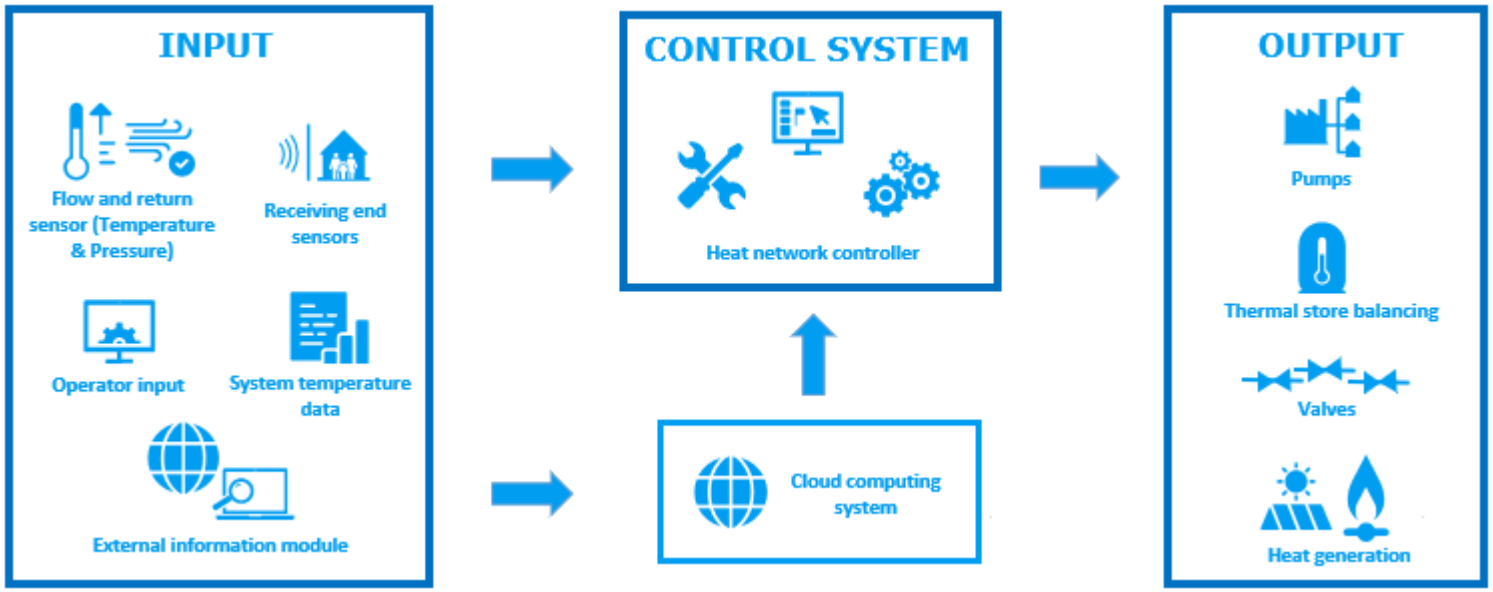
LOGSTOR - Danish company, founded in 1960. See company profile for more details.

isoplus - Danish company, founded in 1993. See company profile for more details.

Control systems are vital for effective heat network operation

Introduction to control systems

- Control systems ensure that the heat network operates as required. This is extremely complex, operating all components in order to deliver heat where it is needed.
- Heat networks often supply whole communities with heat and each heat demand must be met while entire buildings can vary from 100% occupancy to entirely vacant over the network's lifetime.
- Physically, control systems can range from a number of switches within a small housing network to a large computer in an energy centres office which are linked to a number of sensors across the system.



Schematic for control system operation

Challenges associated with 5G Heat Networks

- Multiple heat/cooling sources that must be balanced in order to service the network.
- Customers can provide or take heat from the network using individual heat pumps which must be balanced with the primary plant.

Physical control system units: sizes range from small units in a simple system to a large computer capable of delivering complexities of a large 5G district heating network.

Heat network control system design is a balance between programming and manufacturing

Control system manufacture

Control system manufacturing involves two main sections: software design and computer parts manufacture. Sensors were not included in the controls systems analysis. The design/manufacture process is as follows:

Software design

- Data gathering and logic creation – determining how the heat pump will react to a range of inputs and demands.
- Software design – translating the required logic into a programming language that is compatible with electronic components.

Computer parts manufacture

- Electronic system design – mapping of physical electronic components and connections to apply the designed software package
- Electronic component manufacture – creation of electronic parts such as Printed Circuit Boards (PCBs). This can include composite manufacture such as epoxy infused fiberglass sheets, pressing, conductive metal deposition, soldering, and etching.

Innovation trends – current and future development

- **Demand and supply:** Due to heat networks often being several kilometres long, it is difficult for the system to quickly adapt to changes in demand. Improved design and sensor placement can counter this.
- **'Smart' controls**: Use of external data or advanced detection systems can enable more efficient operation of plant by using thermal stores to maximise plant efficiency.
- **5G advances:** With added complexities of balancing heating and cooling demand and bidirectional flow, control systems for 5G district heating networks are expected to become much more advanced in the coming years. This system moves thermal energy to where it is needed rather than expelling and generating it.

Market summary and leaders

- Two market leaders include Danfoss and Siemens although there are also other notable manufacturers.

Danfoss - Danish company, global presence. See company profile for more details.

SIEMENS - Japanese multinational company with controls division. See company profile for more details.

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3. Market analysis for heat pumps and heat networks

The icons above provide guidance about when heat pumps or networks are the focus.

Introduction to report section

Trends and Technology | **Market analysis** | Company & Country profiles | Conclusions

The following section includes a market analysis of the key components for heat pumps and heat networks across Scotland, RoUK, Denmark, and France. The analysis consists of three main deliverables:

1. A demand sizing (MW and GBP) for the heat pump and key component markets across the four markets identified, focusing on total market, market forecasts, and short-term market growth. Market value is based on domestic and commercial market.
2. A heat network key component market demand sizing in GBP for UK/Scotland based on national targets.
3. A qualitative analysis of the market accessibility for potential new Scottish suppliers.

Methodology applied in report section

The overview of the market analysis was conducted using the following method:

- Desktop research including the academic literature, previously conducted Scottish Enterprise consulting reports, government reports, and private sector literature.
- Ramboll expert interviews, and Scottish, UK, and European industry expert interviews.

The breadth of the interview groups was designed to provide confidence in the research findings, allowing triangulation of perspectives across different actors.

Highlighted conclusions

France is the largest market for heat pumps, but the UK market is expected to grow rapidly

France is currently the biggest market for heat pumps in the EU in terms of both MW and new heat pumps installed. By comparison, the UK has a much smaller market but is expected to grow rapidly in the future due to national targets of installing up to 600,000 heat pumps per year up to 2028.

Compressors hold more value but face greater entry barriers than controls

Compressors (17%) represent a greater share of the value from a heat pump than controls (11%) but it is a less accessible market across all countries due to high start-up costs, manufacturers producing their own compressors, and complex testing requirements for new compressors.

The market size of Scottish and RoUK heat networks may be worth as much as GBP 32 bn

The market size of the UK split up in Scotland and RoUK shows a market worth more than GBP 32 bn. The total market demand for heat networks is forecast to become more than 29 TWh in the whole of the UK by 2030. Pre-insulated pipes (22%) and controls (13%) accounts for 35% of the total market value.

Pre-insulated steel pipes are the most valuable but the market is relatively inaccessible

Pre-insulated steel pipes represent a greater share of value from heat networks, but the market is relatively inaccessible due to quality and reputation requirements, driven by the desire to avoid unnecessary maintenance/ repair work. Controls are more accessible but less valuable.

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Methodology for estimating market size for heat pumps in MW and GBP

To estimate the market value of heat pumps from 0-50 kW in GBP and MW, the following steps and methodology have been made:

Estimation of heat pump market value in GBP in steps

1. **Total heat pump market value of the EU in GBP**
   Discovered through desktop research
2. **Total heat pumps sold in EU in units**
   Discovered through desktop research
3. **Heat pumps installed in specific country in units**
   Discovered through desktop research
4. **Market share of total EU market**
   *Calculated: **Step 2** divided by **Step 3***
5. **Market value of country in GBP**
   *Calculated: **Step 4** multiplied by **Step 1***

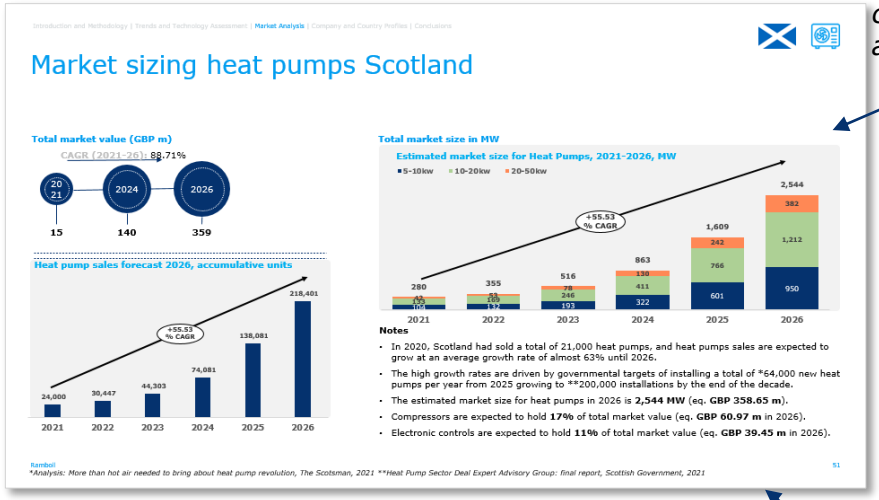
Estimation of heat pump market value in MW in steps

1. **Avg. size of heat pumps in % and kW**
   Discovered through desktop research
2. **Heat pumps installed in specific country in units (accumulated)**
   Discovered through desktop research
3. **Market value of country in MW**
   *Calculated: **Step 1** multiplied by **Step 2***

The next four slides will give an overview of each country's market up until 2026 in both GBP, MW and units sold. The market size for compressors and electronic controls has been estimated based on desktop research and estimates given in interviews by Ramboll experts and component suppliers. Market value only includes sales value of units (not distribution, installation etc.).

Total market value in GBP m and CAGR

Total market size (all installed capacity) in MW and CAGR

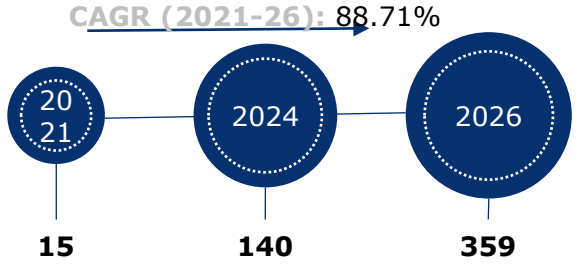


Estimated units sold in the specific country (accumulated)

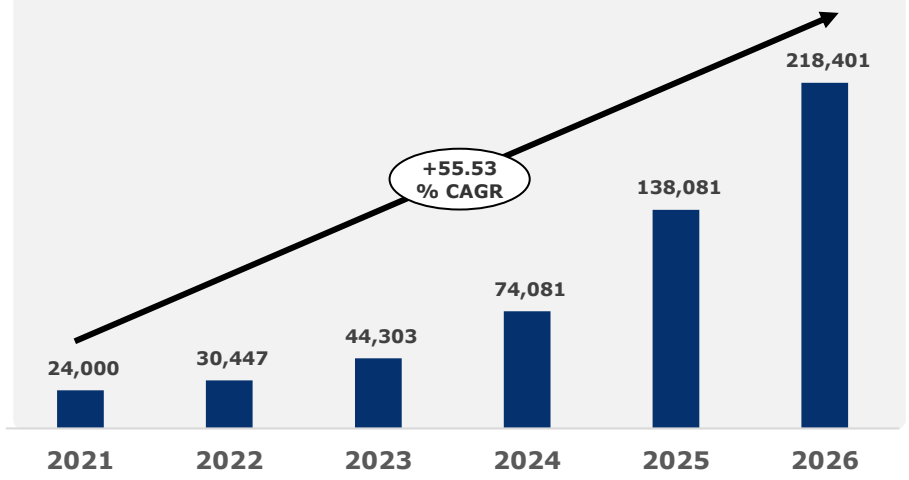
Market size in GBP for compressors and electronic controls

Market sizing heat pumps Scotland

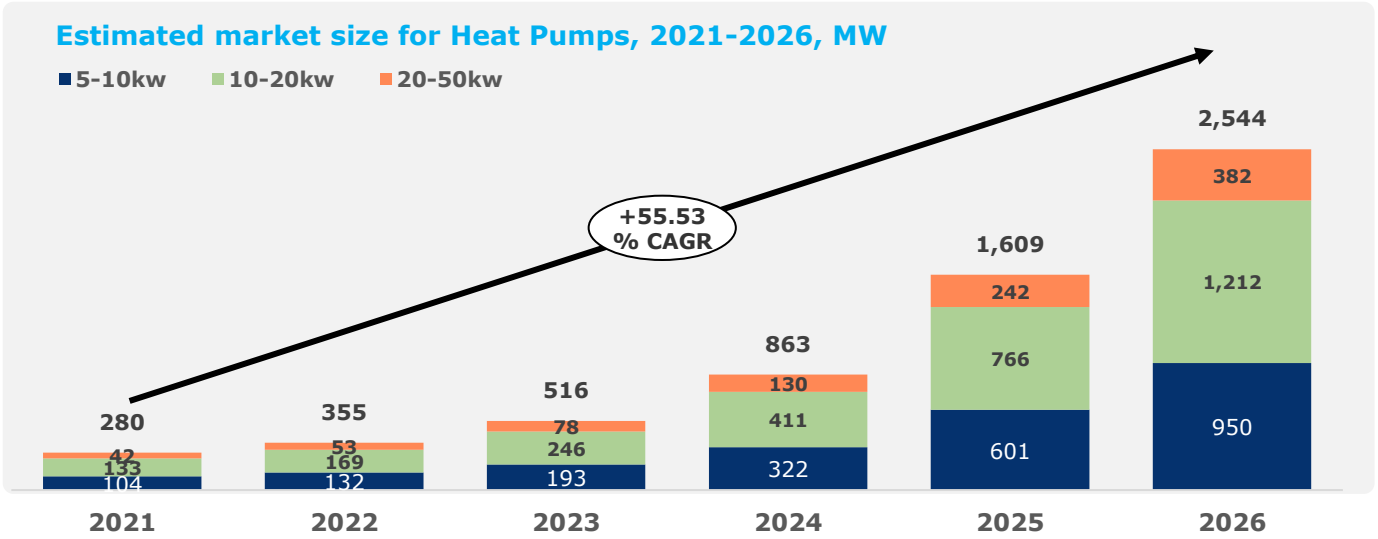
Total market value (GBP m)



Heat pump sales forecast 2026, accumulative units



Total market size in MW



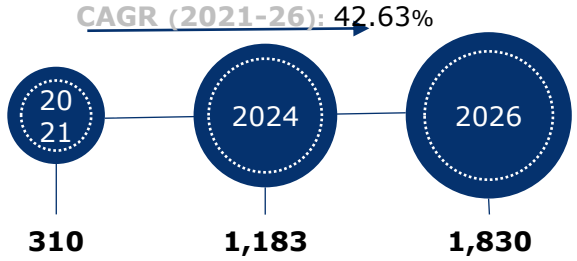
Notes

- In 2020, Scotland had sold a total of 21,000 heat pumps, and heat pumps sales are expected to grow at an average growth rate of almost 63% until 2026.
- The high growth rates are driven by governmental targets of installing a total of *64,000 new heat pumps per year from 2025 growing to **200,000 installations by the end of the decade.
- The estimated market size for heat pumps in 2026 is **2,544 MW** (eq. **GBP 358.65 m**).
- Compressors are expected to hold **17%** of total market value (eq. **GBP 60.97 m** in 2026).
- Electronic controls are expected to hold **11%** of total market value (eq. **GBP 39.45 m** in 2026).

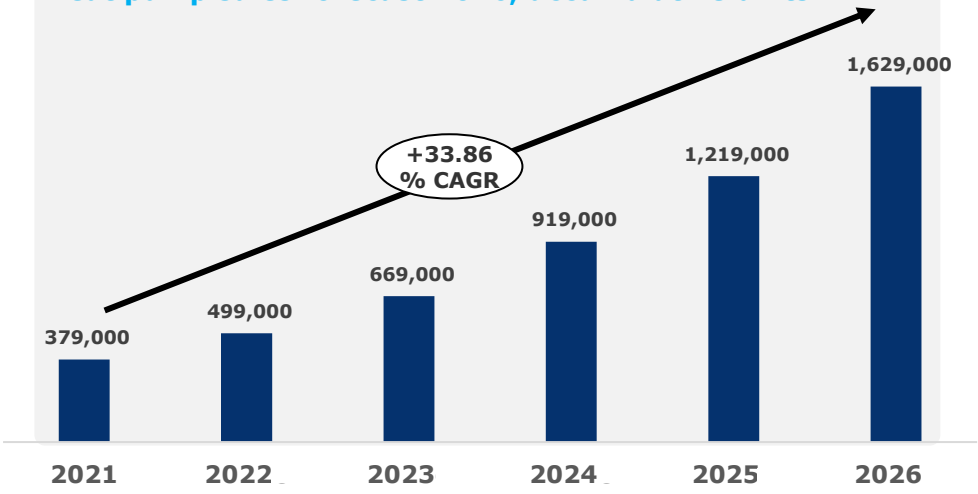
*Analysis: More than hot air needed to bring about heat pump revolution, The Scotsman, 2021 **Heat Pump Sector Deal Expert Advisory Group: final report, Scottish Government, 2021*

Market sizing heat pumps RoUK

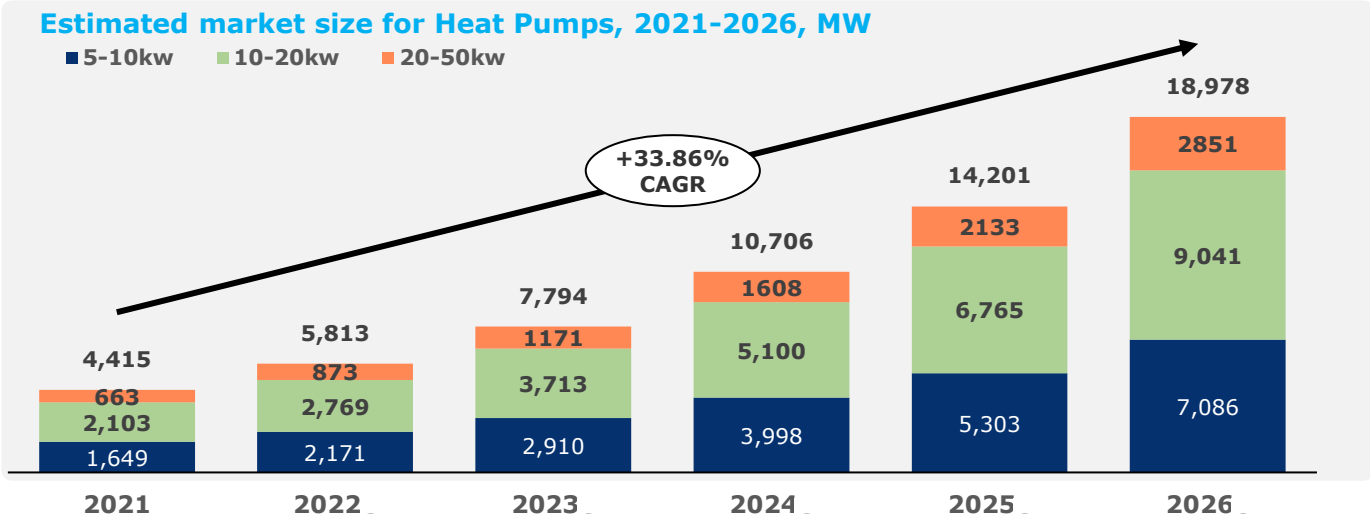
Total market value (GBP m)



Heat pump sales forecast 2026, accumulative units



Total market size in MW

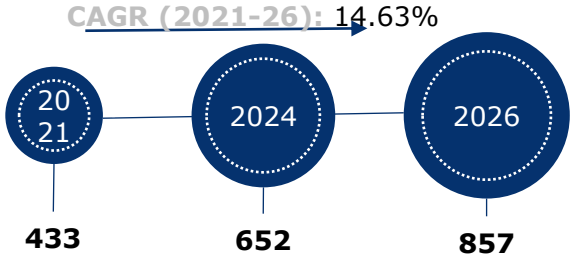


Notes

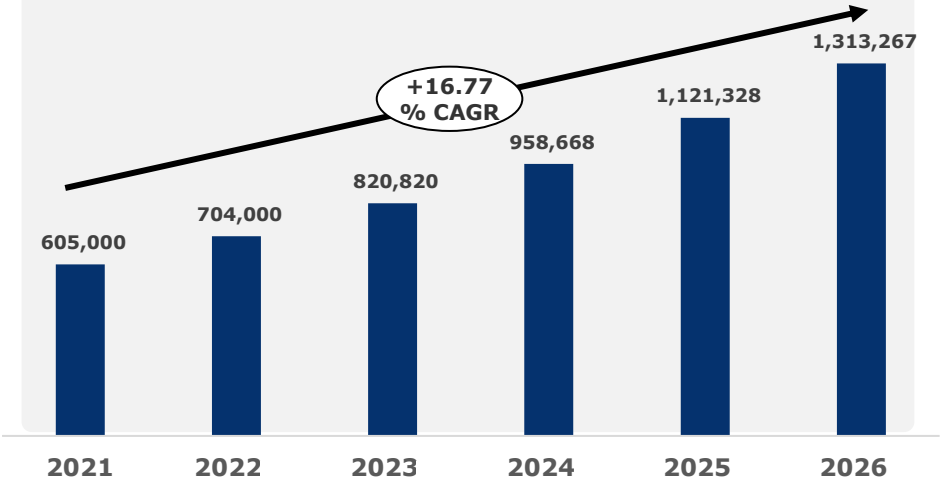
- In 2020, RoUK had sold a total of 319,000 heat pumps. An annual average growth rate of almost 34% is expected until 2026.
- The high growth rates are driven by the increasing demand and governmental targets of installing 600,000 new heat pumps per year from 2028.
- The estimated market size for heat pumps in 2026 is **18,978 MW** (eq. **GBP 1,830.76 m**).
- Compressors are expected to hold **17%** of total market value (eq. **GBP 311.23 m** in 2026).
- Electronic controls are expected to hold **11%** of total market value (eq. **GBP 201.38 m** in 2026).

Market sizing heat pumps Denmark

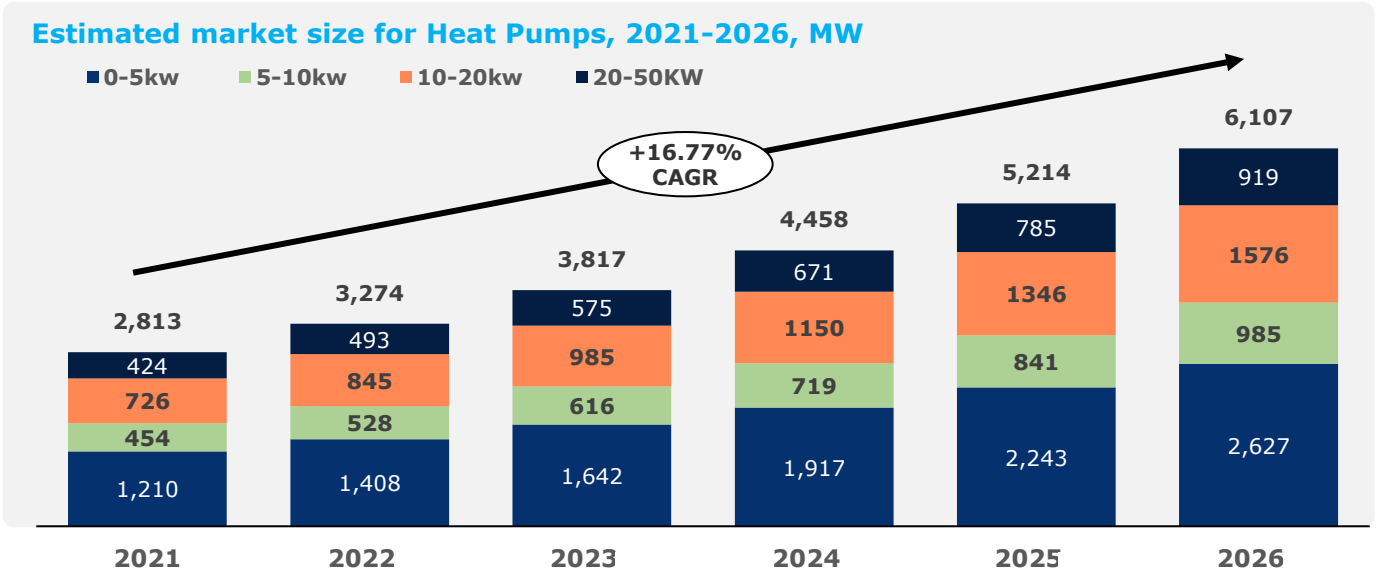
Total market value (GBP m)



Heat pump sales forecast 2026, accumulative units



Total market size in MW

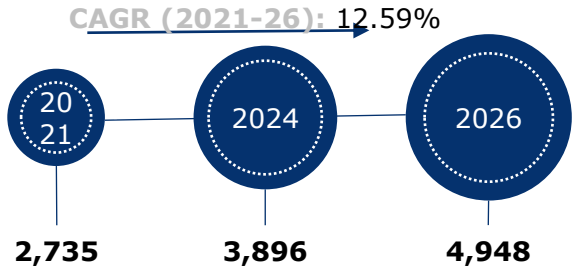


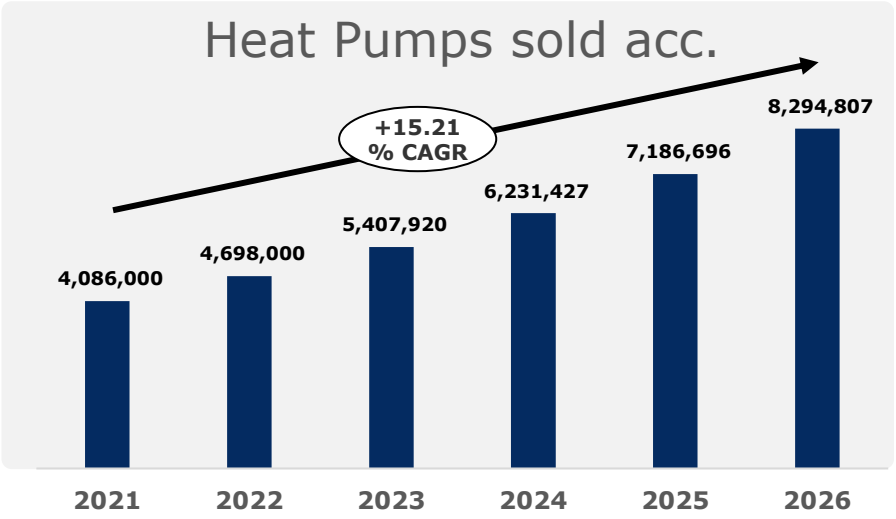
Notes

- In 2020, Denmark had sold a total of 521,000 heat pumps. An annual average growth rate of almost 17% is expected until 2026.
- Denmark has not set any targets for reaching a specific amount of heat pumps installed per year.
- The estimated market size for heat pumps in 2026 is **6,107 MW** (eq. **GBP 857.06 m**).
- Compressors are expected to hold **17%** of total market value (eq. **GBP 145.70 m** in 2026).
- Electronic controls are expected to hold **11%** of total market value (eq. **GBP 94.28 m** in 2026).

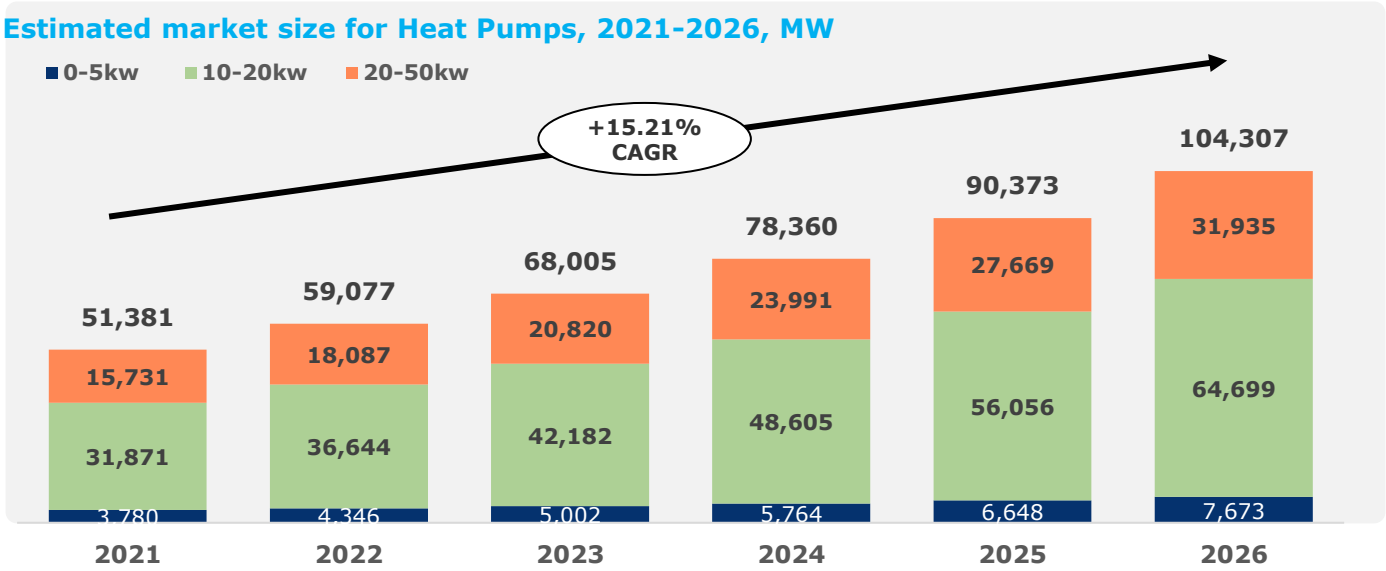
Market sizing heat pumps France

Total market value (GBP m)





Total market size in MW

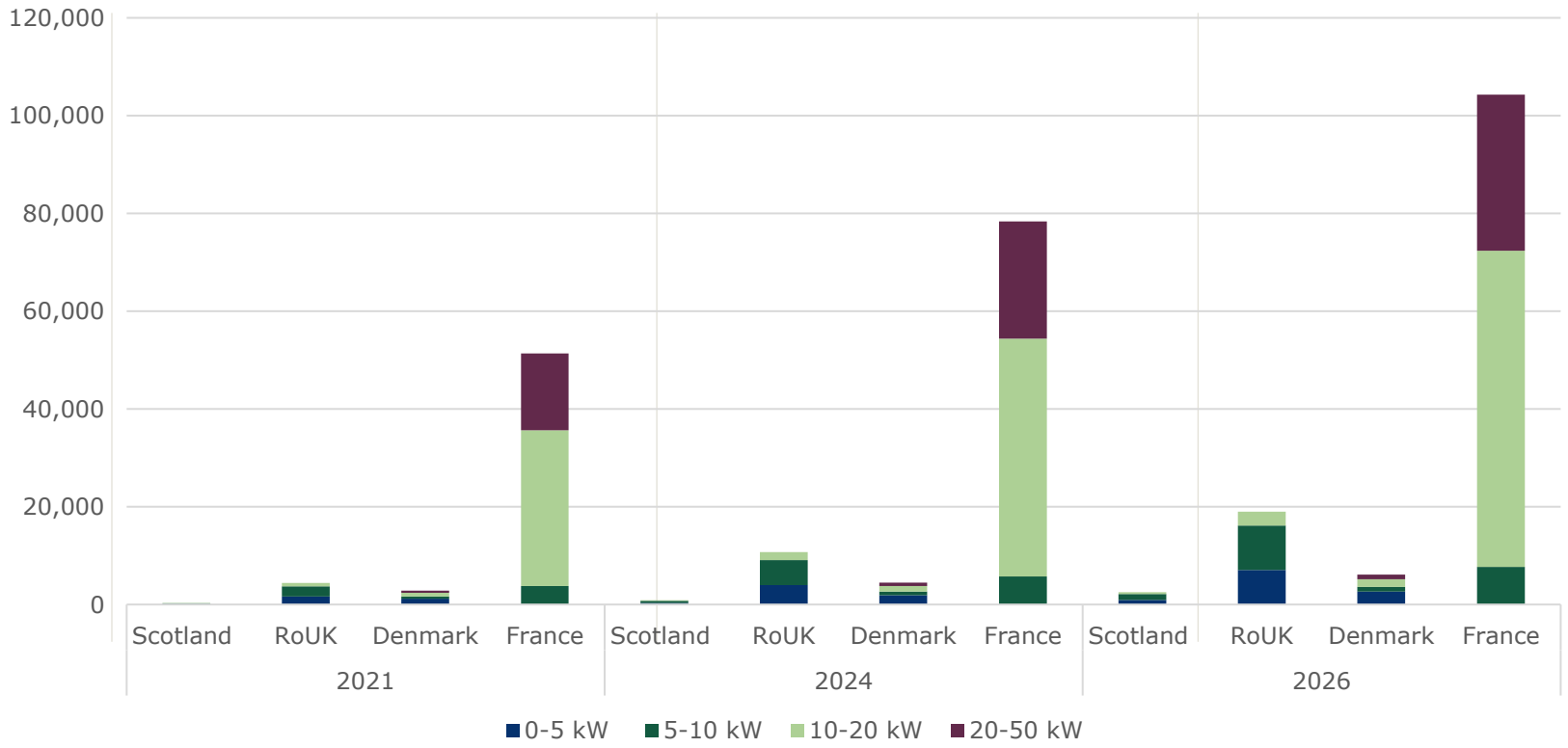


Notes

- In 2020, France had sold a total of 3,556,000 heat pumps. An annual average growth rate of almost 13% is expected until 2026.
- France has not set any targets for reaching a specific amount of heat pumps installed per year.
- The estimated market size for heat pumps in 2026 is **104,307 MW** (eq. **GBP 4,948 m**).
- Compressors are expected to hold **17%** of total market value (eq. **GBP 841.16 m** in 2026).
- Electronic controls are expected to hold **11%** of total market value (eq. **GBP 544.28 m** in 2026).

Heat pump market sizing: France is a large and growing market but the UK is also growing fast

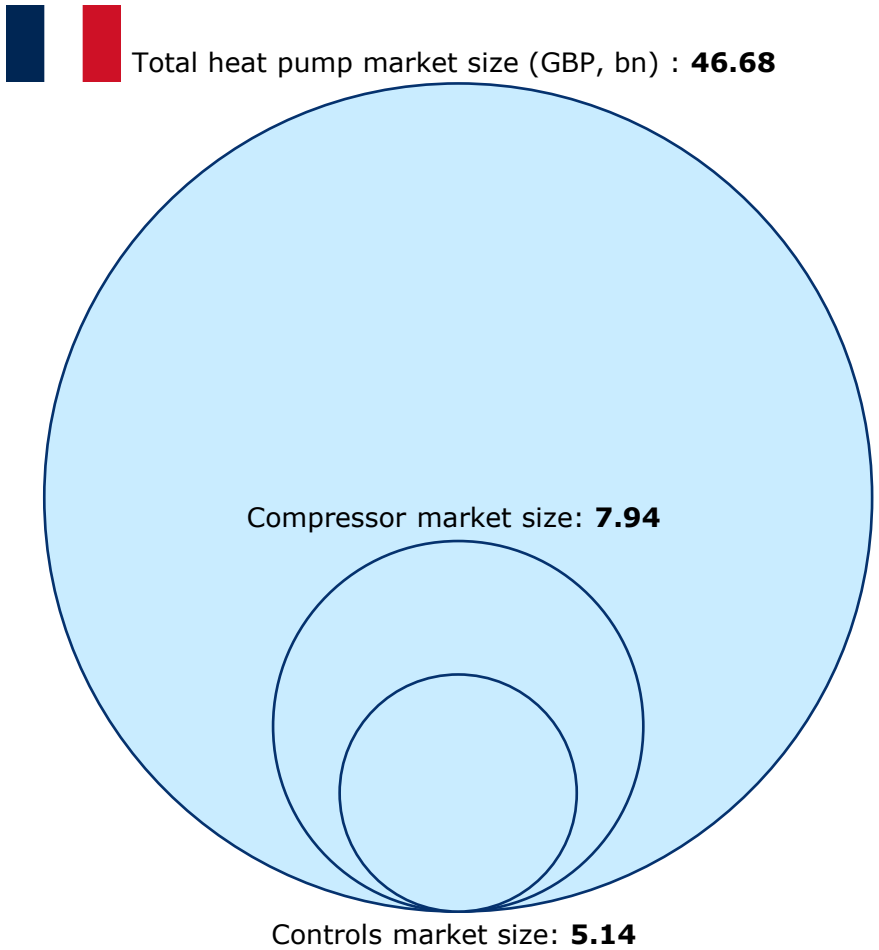
Estimated market size for Heat Pumps, 2021-2026, MW



Notes

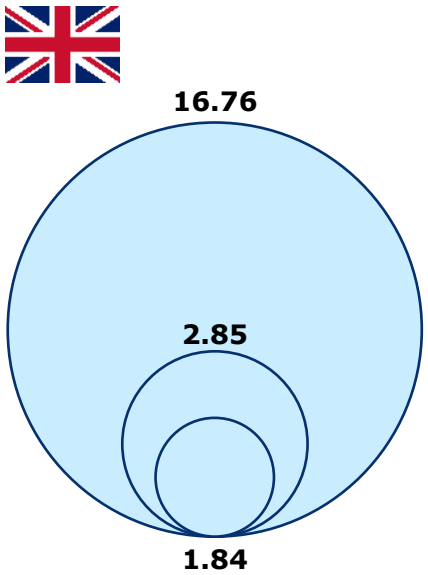
- This graph shows the estimated heat pump market size in MW from 2021-2026 in Scotland, RoUK, Denmark, and France, divided by heat pump size.
- RoUK shows strong growth through to 2026.
- France is the largest of these markets and is expected to grow fast to 2026.
- The RoUK is expected to see CAGR of almost 34%.

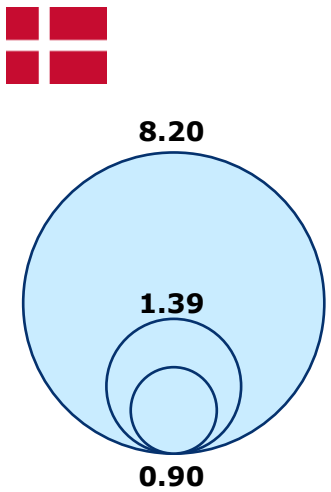
Heat pump market sizing forecast for France, RoUK, Denmark, and Scotland 2022-2030

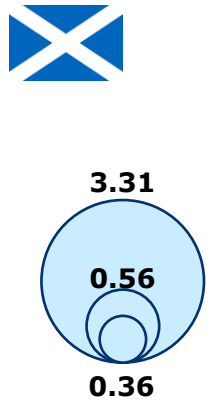


Notes

- These graphs show the total estimated market sizes for the four countries from 2022 to 2030 based on sales only of heat pumps between 0 and 50 kW.
- This market sizing is estimated using a combination of annual sales forecasts and average unit prices. Scottish and RoUK annual sales are based on national targets being met, whereas estimates for France and Denmark are based on assumptions of continuous growth levels from 2022 to 2030 from EHPA estimates*.
- Market size estimates are only indicative of heat pump sales and do not include value from installation or service.







**EHPA 2020. European Heat Pump Market and Statistics Report 2020.*

Methodology for estimating market size for heat network in GBP based on national targets

Based on desk research and interviews, it has been possible to estimate the market size from 2022 – 2030 for heat networks and the components. To estimate the market value of heat networks and the components in GBP, the following steps and methodology have been made:

Estimation of heat network market value in GBP:

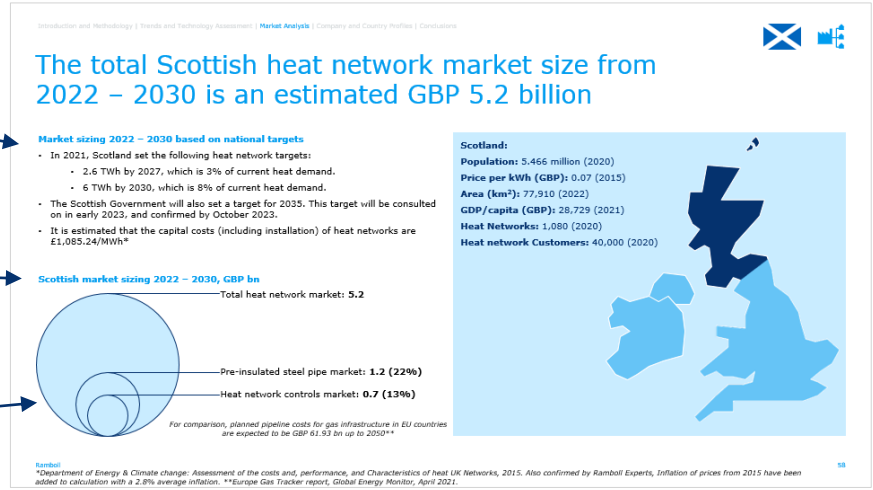
1. **2030 total heat network market size in MWh**
   Discovered through desktop research, based on national targets being met, minus existing capacity.
2. **CAPEX for installing heat networks in GBP per MWh**
   Discovered through desktop research, inflation added
3. **Market size of heat network 2022 – 2030 in GBP**
   *Calculated: **Step 1** multiplied by **Step 2***
4. **Component value of whole network in %**
   Discovered through interviews
5. **Market size of components in GBP**
   *Calculated: **Step 3** multiplied by **Step 4***

The next two slides give an overview of the size of Scotland's and RoUK's heat network market size from 2022 – 2030 in GBP, based on national targets set by the government. This includes costs for installation. The market size for pre-insulated steel pipes and network controls has been estimated based on desktop research and estimates given in interviews by Ramboll experts and component suppliers. The market has not been divided into 4G and 5G networks due to lack of data.

National targets for 2030 in TWh.

Total market size for heat networks in GBP

Market size for PISP and Network controls in GBP

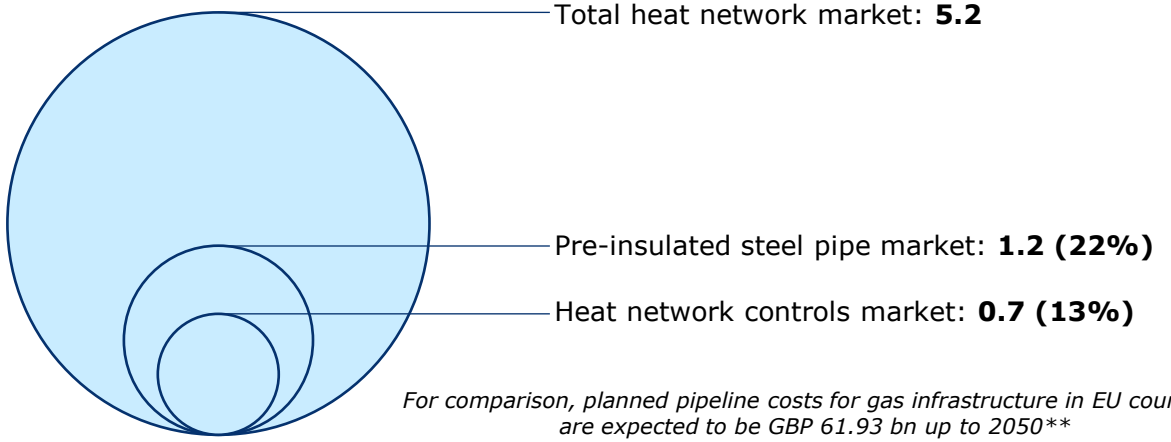


The total Scottish heat network market size from 2022 – 2030 is an estimated GBP 5.2 billion

Market sizing 2022 – 2030 based on national targets

- In 2021, Scotland set the following heat network targets:
  - 2.6 TWh by 2027, which is 3% of current heat demand.
  - 6 TWh by 2030, which is 8% of current heat demand.
- The Scottish Government will also set a target for 2035. This target will be consulted on in early 2023, and confirmed by October 2023.
- It is estimated that the capital costs (including installation) of heat networks are £1,085.24/MWh*

Scottish market sizing 2022 – 2030, GBP bn



*For comparison, planned pipeline costs for gas infrastructure in EU countries are expected to be GBP 61.93 bn up to 2050***

Scotland:

Population: 5.466 million (2020)

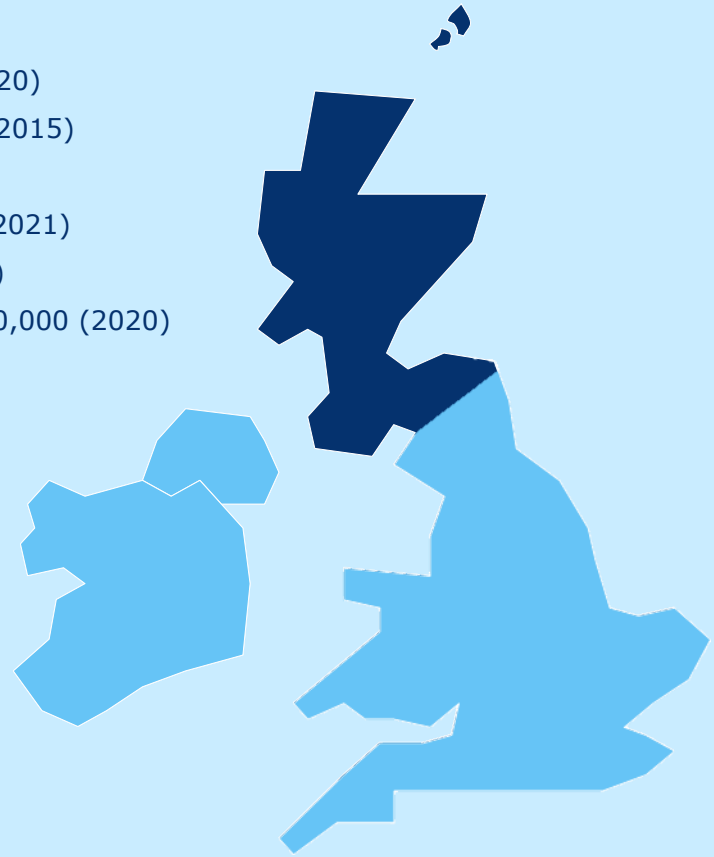
Price per kWh (GBP): 0.07 (2015)

Area (km²): 77,910 (2022)

GDP/capita (GBP): 28,729 (2021)

Heat Networks: 1,080 (2020)

Heat network Customers: 40,000 (2020)



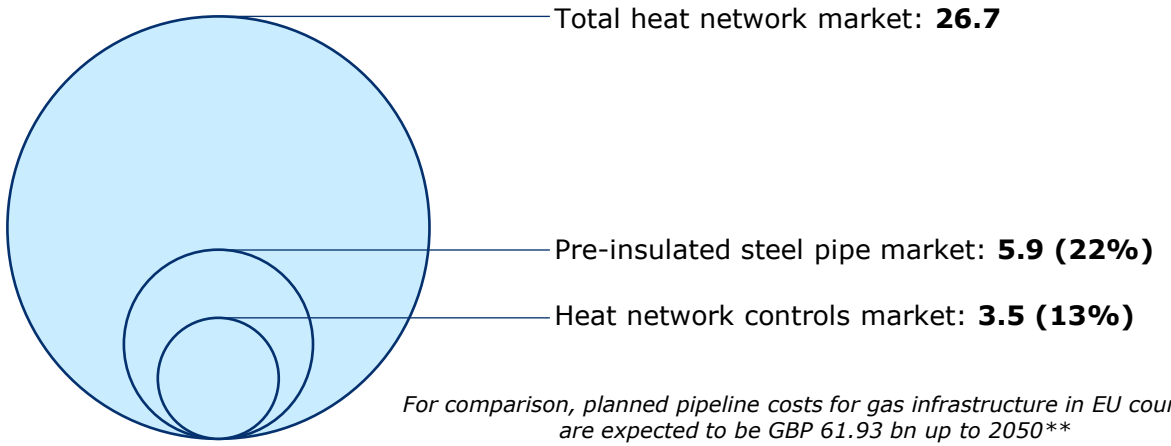
*Department of Energy & Climate change: Assessment of the costs and, performance, and Characteristics of heat UK Networks, 2015. Also confirmed by Ramboll Experts, Inflation of prices from 2015 have been added to calculation with a 2.8% average inflation. **Europe Gas Tracker report, Global Energy Monitor, April 2021.

The total heat network market size from 2022 – 2030 in RoUK is an estimated GBP 26.7 billion

Market sizing 2022 – 2030 based on national targets

- The potential contribution of heat networks to total heat demand in 2030 in RoUK ís estimated at **36 TWh**. The heat demand is furthermore estimated to grow to **80 TWh** in 2050.
- The Government's climate advisory body, the Climate Change Committee (CCC), has recommended that at least 18% of the UK's domestic heat demand is met with heat networks by 2050 (80 TWh), up from 2% in 2020.
- It is estimated that the capital costs (including installation) of heat networks are £1,085.24/MWh*.

RoUK market sizing 2022 – 2030, GBP bn



*For comparison, planned pipeline costs for gas infrastructure in EU countries are expected to be GBP 61.93 bn up to 2050***

RoUK:

Population: 61.766 million (2020)

Price per kWh (GBP): 0.1 (2015)

Area (km²): 166,910 (2022)

GDP/capita (GBP): 30,895 (2021)

Heat Networks: 14,000 (2020)

Heat network Customers: 500,000 (2020)

*Department of Energy & Climate change: Assessment of the costs and, performance, and Characteristics of heat UK Networks, 2015. Also confirmed by Ramboll Experts, Inflation of prices from 2015 have been added to calculation with a 2.8% average inflation **Europe Gas Tracker report, Global Energy Monitor, April 2021.

Executive Summary
1. Introduction
2. Trends and Technology Assessment
3. Market Analysis
3.1 Sizing Key Markets
3.2 Accessible Market
4. Company and Country Profiles
5. Conclusions

Methodology for estimating market accessibility for each component in the three markets outside Scotland

To understand how accessible each market is for the identified components it is first necessary to understand the drivers and barriers that could have an effect on the accessibility of the market. The following steps and methodology have been made:

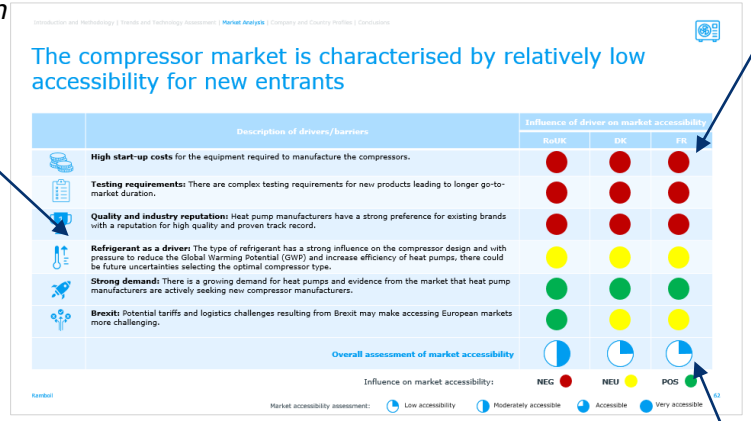
Estimation of market accessibility for the components markets

1. **Identify drivers and barriers that affect accessibility**
   Discovered through desktop research and interviews with Ramboll Experts and component suppliers
2. **Evaluate the influence of each driver and barrier on accessibility**
   Rated from highly negative to highly positive
3. **Overall assessment of market accessibility**
   *Calculated: Average scoring from **step 2.***
   Rated from low accessibility to very accessible

The next three slides give an overview of how accessible each market is estimated at being for the key components. The accessibility is evaluated based on identified drivers and barriers.

Drivers and barriers identified for each components that have an effect on the accessibility for each market.

Assessment of accessibility for each country.



Overall market assessment of the accessibility for each market.

The compressor market is characterised by relatively low accessibility for new entrants

	Description of drivers/barriers	Influence of driver on market accessibility		
		RoUK	DK	FR
	High start-up costs for the equipment required to manufacture the compressors.	NEG	NEG	NEG
	Testing requirements: There are complex testing requirements for new products leading to longer go-to-market duration.	NEG	NEG	NEG
	Quality and industry reputation: Heat pump manufacturers have a strong preference for existing brands with a reputation for high quality and proven track record.	NEG	NEG	NEG
	Refrigerant as a driver: The type of refrigerant has a strong influence on the compressor design and with pressure to reduce the Global Warming Potential (GWP) and increase efficiency of heat pumps, there could be future uncertainties selecting the optimal compressor type.	NEU	NEU	NEU
	Strong demand: There is a growing demand for heat pumps and evidence from the market that heat pump manufacturers are actively seeking new compressor manufacturers.	POS	POS	POS
	Brexit: Potential tariffs and logistics challenges resulting from Brexit may make accessing European markets more challenging.	POS	NEU	NEU
	Overall assessment of market accessibility	Moderately accessible	Accessible	Low accessibility

Influence on market accessibility: **NEG** **NEU** **POS**

Market accessibility assessment: Low accessibility | Moderately accessible | Accessible | Very accessible

The markets of controls for heat pumps and networks see similar accessibility drivers and barriers

The accessibility of heat pump and network controls has been treated as one, as the drivers are the same.

	Description of drivers/barriers	Influence of driver on market accessibility		
		RoUK	DK	FR
	Low start-up costs for the equipment required to manufacture the different controls.	●	●	●
	Market competition: Market with existing manufacturers of controls (i.e. DK) can make it more difficult to enter.	●	●	●
	In-house manufacturing of components: Some heat network and heat pump manufacturers produce their controls in house.	●	●	●
	Flexible technology: Controls are flexible in both looks and capabilities for both heat pumps and networks. They are furthermore scalable across all sizes of heat pumps.	●	●	●
	Strong demand: There is growing demand for heat pumps and evidence from the market that heat pump and network manufacturers are actively seeking new controls manufacturers.	●	●	●
	Brexit: Potential tariffs and logistics challenges resulting from Brexit may make accessing European markets more challenging.	●	●	●
	Overall assessment of market accessibility	◕	◑	◑

Influence on market accessibility: **NEG** ● **NEU** ● **POS** ●

Market accessibility assessment: Low accessibility | Moderately accessible | Accessible | Very accessible

The pre-insulated steel pipe market faces several barriers to accessibility across the markets

	Description of drivers/barriers	Influence of driver on market accessibility		
		RoUK	DK	FR
	Medium start-up costs for the equipment required to manufacture the pre-insulated steel pipes.			
	Potential opportunity as the sustainable choice: The heat network market is starting to become more interested in sustainable products with potential demand for low-carbon/ circular economy offerings.			
	Quality and industry reputation: Heat network manufacturers have a strong preference for existing brands with a reputation for high quality and proven track record due to the high maintenance cost of repairing pipes.			
	Market competition: Market with existing manufacturers of pre-insulated steel pipes can make it more difficult to enter.			
	Strong demand: There is growing demand for heat networks, resulting in an increased demand for pre-insulated steel pipes.			
	Brexit: Potential tariffs and logistics challenges resulting from Brexit may make accessing European markets more challenging.			
	Overall assessment of market accessibility			

Influence on market accessibility: **NEG** **NEU** **POS**

Market accessibility assessment: Low accessibility | Moderately accessible | Accessible | Very accessible

Executive Summary

1. Introduction

2. Trends and Technology Assessment

3. Market Analysis

4. Company and Country Profiles

5. Conclusions

4. Company & Country profiles

The icons above provide guidance about when heat pumps or networks are the focus.

Introduction to report section

Trends and Technology | Market analysis | **Company & Country profiles** | Conclusions

The following section includes an analysis of the leading manufacturers of the key components identified for heat pumps and heat networks. The goal is to identify what competitive advantages the leading manufacturers have, and if they are benefitting from economic support schemes. The analysis consists of three main deliverables:

1. High level company profiles, and their perceived competitive advantages that they have in the market for heat pumps and heat networks.
2. Country profiles of the leading manufacturers' countries of origin, focusing on the types of economic support available – if any.
3. Overview of other metrics that may be assessed when selecting manufacturing site locations.

Methodology applied in report section

The assessment of the company & country profiles was conducted using the following method:

- Desktop research including the academic literature, annual reports, government reports, and private sector literature.
- Ramboll expert interviews, and Scottish, UK, and European industry expert interviews.

The breadth of the interview groups was designed to provide confidence in the research findings, allowing triangulation of perspectives across different actors.

Highlighted conclusions

Shared competitive advantages for market leaders

Market leaders have many of the same competitive advantages. The most relevant and competitive advantages identified was high quality products, good reputation, flexible solutions, and country of origin as it gives a stamp of quality.

All countries have some economic support for the leading manufacturers

The report investigates three types of economic support being *grants, loans, and others.* All three types of economic support were identified in the three investigated countries.

There are other factors that influence manufacturing site selection

When selecting new manufacturing sites, companies will look at a range of indicators to assess the attractiveness of certain sites. These may include t*rade conditions, market attractiveness, cost attractiveness, labour supply, and political and legal stability.*

The 8 market leaders within key components for heat pumps and heat network are mainly located in Denmark or Germany

Company	Component	Country
GEA	Compressor (Heat pump)	
Bitzer	Compressor (Heat pump)	
Danfoss	Control systems (Heat pump)	
Mitsubishi Electric	Control systems (Heat pump)	
Siemens	Electronic controls (Heat network)	
Danfoss	Electronic controls (Heat network)	
isoplus	Pre-insulated steel pipe (Heat network)	
Logstor*	Pre-insulated steel pipe (Heat network)	

Denmark is mainly focusing on heat networks, while Germany is mainly focusing on heat pumps.

The following section examines the companies identified as market leaders, which is followed by a section on the countries where they are headquartered.

*Now Irish Owned, but still manufacturing in Denmark

Company Profile (Heat pump - controls)
Danfoss

Company overview

Introduction	
General information	• Danfoss is a Danish Company founded in 1933. • They are considered an industry leader within control systems for heat pumps.
Organisation & Ownership	• Danfoss is an unlisted family and foundation-owned private company who is fully owned by Danfoss Group. • Danfoss has 40,000 employees.
Geographic presence	• Danfoss is present in 12 different countries through sales offices and has 95 production facilities in DK, DE, China, USA, Finland, England, India, and the Netherlands. • Their products are sold in more than 100 countries either through sales offices or local sales agents.
Financials	• Revenue of EUR 7.5 bn in 2021. • EBITDA of EUR 969 m in 2021, which was a 34% increase from 2020. • Profit margin up from 12.4% in 2020 to 12.8% in 2021.

Main Products

Programmable controllers – MCX
Danfoss' range of universal MCX programmable controllers offers the functionality and reliability to get the best out of heating, ventilation, air-conditioning and refrigeration (HVAC/R) equipment.

Electronic valve control - EKE 347
EKE 347 is used for regulation of the liquid level. The controller is connected with a level sensor that continuously measures the liquid level in the vessel/reservoir.

Evaporator and room control
The evaporator controls from Danfoss have functions for regulating/monitoring temperature, defrosting, doors, rail heating, light and fan operation.

Company Profile (Heat pump - controls)
Mitsubishi Electric

Company overview

Introduction	
General information	• Mitsubishi Electric is a Japanese company founded in 1921. • They are considered an industry leader within control systems for heat pumps.
Organisation & Ownership	• Mitsubishi Electric is a public listed company the stock exchange of Tokyo. • Mitsubishi Electric has 145,650 employees.
Geographic presence	• Mitsubishi Electric is present in 12 different countries through sales offices and has 95 production facilities in DK, DE, China, USA, Finland, England, India, and the Netherlands. • Their products are sold in more than 112 countries either through sales offices or local sales agents.
Financials	• Revenue of EUR 27.25 bn in 2021. • EBITDA of EUR 2.93 bn in 2021. • Profit margin of 10% in 2021.

Main Products

PAR-33MAA
The PAR-33MAA standard wired remote controller is used to control Mr Slim and City Multi indoor units. It is also compatible with M Series indoor units via MAC-397IF and is their most popular controller due to its user friendly backlit screen.

PAC-YT52CRA
To simplify operation of the system, the range of controls has been limited to On/Off, mode, room temperature, fan speed and additional vane control for hi-walls, cassettes, and under ceilings units.

PAR-U02MEDA
The controller is equipped with four built-in sensors (temperature, humidity, occupancy and brightness) for maximum comfort and increased energy savings. It also has the capability to control up to sixteen indoor units simultaneously.

Company Profile (Heat pump - compressor)
Bitzer

Company overview

Introduction	
General information	• Bitzer is a German company founded in 1934. • They are considered an industry leader within control systems for heat pumps. Bitzer is specialised in all sizes of compressors, but their main focus is on domestic and commercial size.
Organisation & Ownership	• 49% of Bitzer is owned by the Schaufler foundation and the rest by Bitzer Group. • Bitzer has 3,800 employees.
Geographic presence	• Bitzer is present in 72 different countries through sales offices and has 16 production facilities across the world. • Their products are sold in more than 90 countries either through sales offices or local sales agents.
Financials	• Revenue of EUR 808 m in 2020. • EBITDA EUR 79.7 m in 2020. • Profit margin of 9.2% in 2020.

Main Products

Semi-hermetic - Screw compressor
Universal and environmentally friendly: ECOLINE reciprocating compressors offer high cooling capacity with minimal energy requirements and are optimised for HFC, HFO and low-GWP refrigerants.

Hermetic – Scroll compressor
Hermetic scroll compressors are used particularly in air conditioning and heat pump applications. They offer high cooling capacity, reliability, exceptional energy efficiency, and low noise levels.

Semi-Hermetic Frequency - Screw compressor
The CSV series is optimised for maximum efficiency in liquid chillers and heat pumps with frequency-controlled capacity adjustment. The internal frequency inverter enables a large spectrum of applications and a broad range of control, which simplifies system integration.

Company Profile (Heat pump - compressor)
GEA

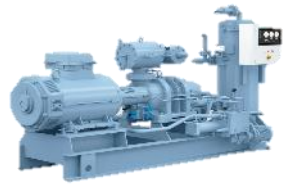
Company overview

Introduction	
General information	• GEA is a German company founded in 1881. • They are considered an industry leader within compressor systems for industrial heat pumps. GEA is mainly focusing on large scale compressors.
Organisation & Ownership	• GEA is a public listed company in the stock exchange of Frankfurt. • GEA has 18,143 employees.
Geographic presence	• GEA is present in 68 different countries through sales offices and has production facilities in USA, DE, China, Brazil, Italy, Poland, and Canada. • Their products are sold in more than 85 countries either through sales offices or local sales agents.
Financials	• Revenue of EUR 4.70 bn in 2021. • EBITDA of EUR 625 m in 2021. • Profit margin is up from 11.5% in 2020 to 13.3% in 2021.

Main Products

Grasso 5HP Series – Large scale heat pumps
The single-stage reciprocating compressor packages of the 5HP series include 4 sizes in direct drive execution for freezing applications with CO_2 (carbon dioxide) as well as heat pump applications with NH_3 (ammonia).

Grasso SP1 HP – Large scale heat pumps
Specifically designed for subcritical cooling applications with CO_2 or heat pump applications with NH_3 packages of the GEA Grasso SP1 HP series.



Grasso V HP – Large scale heat pumps
High pressure ammonia reciprocating compressor packages for heat pump applications.

Competitive advantages identified for heat pump components
Compressor and controls

Controls
Danfoss & Mitsubishi

1) Automatization of production

With Danfoss' and Mitsubishi Electric's aim of automating the production, it's possible to offer improved quality and reduced cost. They furthermore offer high flexibility to their products, making it possible to adjust their products to customer needs.

2) Many sales locations and high service level

With Danfoss' and Mitsubishi Electric's many sales locations, they can sell directly to many different customers. Boots on the ground make them more attractive and makes it possible to provide 24/7 service.

3) World-known reputation

The high reputation level makes it easier for Danfoss and Mitsubishi Electric to become the preferred manufacturer of control systems, as buyers tend to see them as a safe choice.

Compressors
Bitzer & GEA

1) High Quality

Despite making different size of compressors Bitzer and GEA are able to produce the compressors of high quality. High quality compressors are a key criteria for the heat pump manufacturers and more important than the price.

2) Good relationships with current clients

Bitzer and GEA have managed to keep good relationships with their clients resulting in a high customer loyalty. They have even managed to become an incorporated part of the supply chain for some of the heat pump manufacturers.

3) German industrial leaders

The German government has introduced the industrial development strategy "*Industrie 4.0*" giving the German manufacturing companies a well known reputation of being of high quality and digitalised. The reputation makes it easier for Bitzer and GEA to become the preferred manufacturer of compressors.

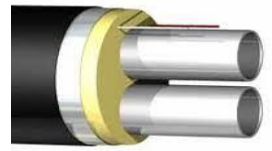
Company Profile (Heat network - pre-insulated pipes)
LOGSTOR

Company overview

Introduction	
General information	• Logstor is a Danish Company founded in 1960. • They are considered an industry leader within pre-insulated pipe systems for district heating transmission and distribution.
Organisation & Ownership	• Logstor is fully owned by Kingspan Group. • Kingspan Group is a building materials company based in Ireland trading in over 70 countries with 159 factories employing over 15,000 people. • Logstor has 1,200 employees.
Geographic presence	• Logstor is present in 12 different countries through sales offices and has eight production facilities in Denmark, Finland, Poland, and Sweden. • Their products are sold in more than 50 countries either through sales offices or local sales agents.
Financials	• Revenue of EUR 244 m in 2020. • EBIT of EUR 28 m in 2020. • Profit margin up from 6.6% in 2018 to 16.6% in 2019.

Main Products

TwinPipe
The TwinPipe system places both forward and return flow pipes within one single outer casing, encapsulated in the same kind of highly effective polyurethane foam insulation as used in single pipes.



FlextraPipe – Polymer pipes
FlextraPipe is the latest generation of the proven FlexPipe – flexible pre-insulated pipe systems. The main differences are that the flexibility is three times better, and the built-in diffusion barrier preserves the full insulation property (lambda of 0.023 W/mK) for the pipe's entire service life.

CuFlex – Copper pipes
Soft copper can be used in distribution systems for both heating and hot/cold water. The pipes are corrosion-free, and capable of withstanding high temperatures and pressures. At the same time, they are easy to lay because they can be straightened out, and remain straight once laid.

Company Profile (Heat network - pre-insulated pipes)
Isoplus

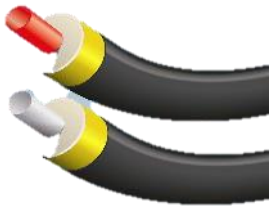
Company overview

Introduction	
General information	• Isoplus is a Danish Company founded in 1993. • They are considered an industry follower within pre-insulated pipe systems for district heating transmission and distribution.
Organisation & Ownership	• Isoplus is a part of The Isoplus Group. • The Isoplus group consists of fifteen independent production and sales companies operating all over Europe. • Isoplus has 100 employees and The Isoplus Group has 1,400 employees.
Geographic presence	• Isoplus is present in 4 different countries through sales offices and has nine production facilities located strategically close to their markets. • Their products are sold in more than 30 countries either through sales offices or local sales agents.
Financials	• Expected revenue of EUR 70.56 m in 2021. • Operational profit of EUR 6.36 m in 2020. • Profit margin up from 3.6% in 2019 to 4.3% in 2020.

Main Products

Steel pipe
pre-insulated steel pipes are bonded piping systems consisting of a steel carrier pipe, polyurethane insulation and impact-resistant and break-proof HDPE jacket pipes – bonded firmly together into a robust sandwich structure.

Isopex – Polymer pipes
isopex pipe is a fixed sandwich structure that consists of pex carrier pipe, flexible polyurethane insulation and a LLDPE jacket pipe. It provides maximum flexibility, low installation costs and smooth installation without major requirements to the fitter.



Isoalupex – Polymer pipes
Pre-insulated isoalupex is a bonded piping system. The pipe consists of a multi-layer pex-alupex carrier pipe and a LLDPE jacket pipe. A flexible layer of polyurethane foam bonds them together into a fixed sandwich structure.

Company Profile (Heat network - electronic controls)
Danfoss

Company overview

Introduction	
General information	• Danfoss is a Danish Company founded in 1933. • They are considered an industry leader within electronic controls for district heating transmission and distribution.
Organisation & Ownership	• Danfoss A/S is an unlisted family and foundation-owned private company who is fully owned by Danfoss Group. • Danfoss has 40,000 employees.
Geographic presence	• Danfoss is present in 12 different countries through sales offices and has 95 production facilities in DK, DE, China, USA, Finland, England, India, and the Netherlands. • Their products are sold in more than 100 countries either through sales offices or local sales agents.
Financials	• Revenue of EUR 7.5 bn in 2021. • EBITDA of EUR 969 m in 2021, which was a 34% increase from 2020. • Profit margin up from 12.4% in 2020 to 12.8% in 2021.

Main Products

ECL controllers
Electronic controllers (ECL) are intelligent temperature regulators for district heating and domestic hot water systems. The controllers can be adapted to a variety of district heating systems, ensuring a high level of comfort and optimum energy utilisation.

Weather compensation
The sensor registers the actual temperature and the electronic controller adjusts, if necessary, the heat supply (flow temperature) to reflect the new conditions.

Remote control
This enables room temperature monitoring and control, easy interfacing, and remote access for overriding all the functions of the ECL Comfort controller.

Company Profile (Heat network - electronic controls)
Siemens

Company overview

Introduction	
General information	• Siemens is a German Company founded in 1847. • They are considered an industry leader within electronic controls for district heating transmission and distribution.
Organisation & Ownership	• Siemens AG is a publicly listed company on the stock exchange of Frankfurt. • Siemens has 385,000 employees.
Geographic presence	• Siemens is present in 86 different countries through sales offices and has 285 production and manufacturing facilities. • Their products are sold in more than 140 countries either through sales offices or local sales agents.
Financials	• Revenue of EUR 62.3 bn in 2021. • Operational profit of EUR 6.7 bn in 2021. • Profit margin for their industrial business is between 11-15%.

Main Products

Climatix S300 – Configurable
Its compact design makes the S300 a particularly cost-effective solution for smaller applications. Its Modbus, Plug and Play, and Ethernet BACnet IP connections give it broad communication possibilities. Configurable means it is easy to use with other technologies.

Climatix C400 – Programmable
The Climatix C400 controller is a programmable solution that ensures maximum **flexibility** and modification possibilities. OEMs benefit from Siemens libraries of pre-tested applications that reduce their engineering efforts.

Climatix C600 – Programmable and scalable
The C600 is the most advanced Climatix controller in terms of application and size coverage. It is modular and scalable to cover the most demanding plants and applications. It also speaks any language, including Modbus, BACnet, PL-link, OPC, LON and M-Bus.

Competitive advantages identified for heat network components

Pre-insulated steel pipes and electronic controls

Pre-insulated steel pipes
Logstor and Isoplus

1) High quality – and high level of specification
The high repair costs for pre-insulated pipes drives quality demands and a reluctance of customers to switch to new suppliers. The market is also driven by specifications which can be set by designers (e.g. Ramboll), which can favour existing and known producers.

2) High experience in sector
Logstor and Isoplus have done many projects before and are highly valued by customers.

3) Danish company
Logstor and Isoplus both originated from Denmark where heat networks are well established. This gives an image of trust and high quality.

Electronic controls
Danfoss & Siemens

1) Economies of scale and flexibility
Danfoss and Siemens are able to produce the electronic controls cheaper than smaller companies, and at the same time ensure high quality products. They furthermore offer high flexibility to their products, making it possible to adjust their products to customer needs. They also offer long warranty on their products which is not seen at competitors.

2) Many sales locations and high service level
With Danfoss and Siemens' many sales locations, they can sell directly to many different customers. Boots on the ground make them more attractive and make it possible to provide 24/7 service.

3) World-known reputation
The high reputation level is making it easier for Danfoss and Siemens to become the preferred manufacturer of control systems, as buyers would see them as a safe choice.

The 8 market leaders within key components for heat pumps and heat network are mainly located in Denmark or Germany

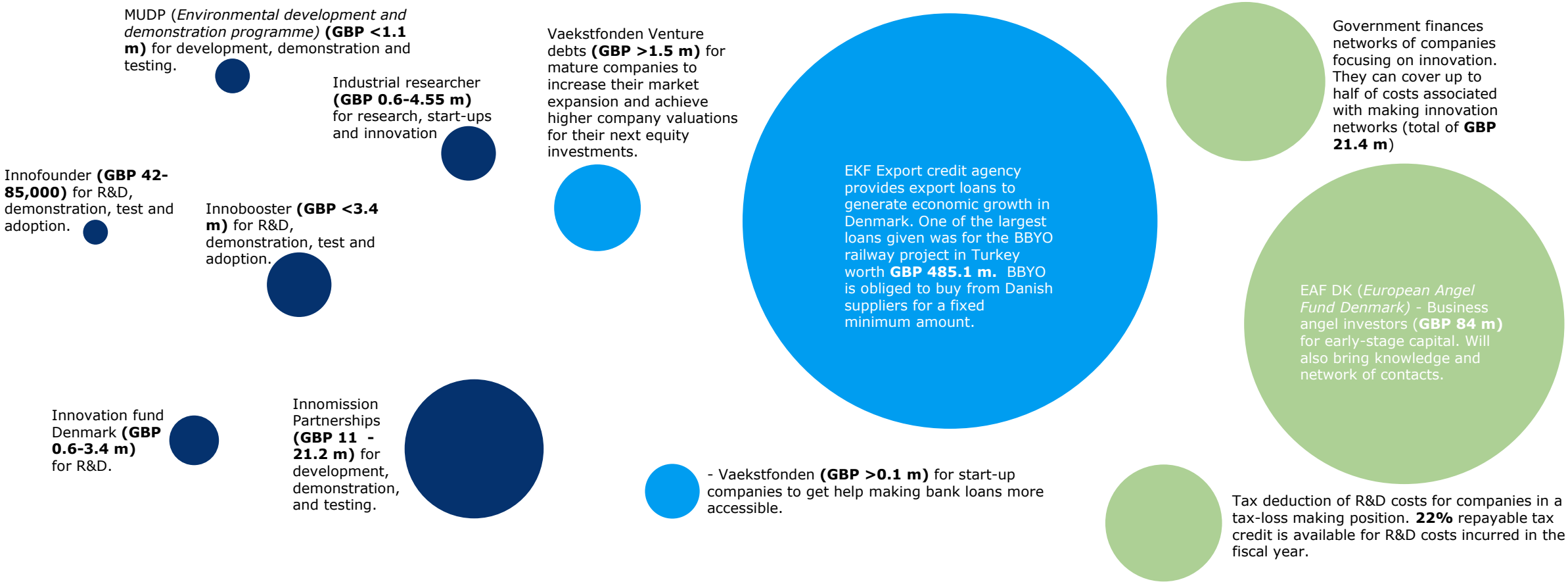
Company	Component	Country
GEA	Compressor (Heat pump)	
Bitzer	Compressor (Heat pump)	
Danfoss	Control systems (Heat pump)	
Mitsubishi Electric	Control systems (Heat pump)	
Siemens	Electronic controls (Heat network)	
Danfoss	Electronic controls (Heat network)	
isoplus	Pre-insulated steel pipe (Heat network)	
Logstor*	Pre-insulated steel pipe (Heat network)	

Denmark is mainly focusing on Heat networks, while Germany is mainly focusing on Heat pumps

The following slides show a selection of financial incentives that are available to manufacturers of different sizes producing heat pump and heat network components, as well as a high level assessment of the market attractiveness for both heat pumps and heat networks.

**Now Irish Owned, but still manufacturing in Denmark*

Country profile: Economic support available for manufacturers
Denmark



Source: Public funding scheme, TechfundingEU, 2021

Danish policies and regulatory support favour heat networks but still create attractive markets for both technologies

Category	Comment	Attractiveness
Policies and regulatory support in favour of heat pumps 	• Historically, Denmark has been a front runner when it comes to renewable energy, and were also the first to implement standardisation within the field of heat pumps. • Since 2017, Danish house owners with an oil boiler as their heating system and who are located outside district heating areas have been **able to order a heat pump on subscription without having to invest too much upfront**. The subscription solution entails a company – called the energy service provider – owning and being responsible for installation, operation and maintenance. The house owner pays a sign-on fee at the installation of the heat pump, a price for the heat supplied and a monthly fee for the subscription. • In June 2020, it was decided by the Danish parliament to end the use of fossil fuels for space heating, by **increasing the tax of fossil fuels** as financial support for replacing individual fossil fuel-based installations with either district heating or individual heat pumps. At the same time, the **tax on electricity for heating has been reduced**. It is expected that the lower electricity tax will **increase the demand for heat pumps** as heat networks no longer have the option of making connection to heat networks compulsory.	
Policies and regulatory support in favour of heat network 	• The Danish district heating sector provides 64 pct. of all Danish households with district heating **(38 TWh in 2016)**. This makes Denmark one of the countries in Europe with the most developed district heating supply network. There is a total of approx. **60,000 km of district heating network piping.** • Denmark has a goal of being 100% carbon neutral in 2050, and heat networks will be an important part for reaching that target. • As of 2021 taxes on excess (waste) heat will be cut and sold to heat networks, which will make it profitable and possible to heat almost 10% of Danish households which corresponds to about **200,000 households**. • In Denmark, the revenues generated by coal tax that charges different types of primary energy to different extents (fuels, electricity, heat) are almost totally allocated to support modernisation of the energy sector and the heating sector. • Until March 2018 it has in some regions been **obligated to connect** to the heating systems and pay a fixed fee even though the tenant was not using the heat.	

Overall attractiveness in relation to HP/HN

Low  High

Country profile: Economic support available for manufactures
Germany

Central Innovation Program for SMEs (up to **EUR 550,000**) to cover labor costs and R&D for enterprises with less than EUR 50 m annual turnover.

GRW cash grants (Up to **45%** of eligible expenditures for small enterprises and **20%** for large enterprises – depending on regional location).

Public loans with fixed interest-rates, long loan terms, repayment-free periods (up **to EUR 25 m** at national level, up to **EUR 10 m** at regional level).

In 2019, a total of approximately **EUR 36 bn** in new public loans was made available to enterprises in Germany by the national development bank KfW through a number of different programs.

Public guarantee for bank loans (Ease loans in case of insufficient collateral, covers up to **80%** of respective loan amount).

Coparion GmbH & Co. KG, with a fund volume of **EUR 225 m**. (Offers Co-investments of up to **EUR 10 m**).

High-Texh Gründer fonds, with a fund volume of EUR **900 m**. (Offers Seed financing of up to EUR 3 m).

Federal state venture capital companies, (Offers public equity of up to **EUR 10 m**) Investment focus on innovation in industry sectors.

Grants Loans Other

Source: Incentive programs, Germany Trade & Investment, 2021

German policies and regulation favour heat pumps over networks

Category	Comment	Attractiveness
Policies and regulatory support in favour of heat pumps	• Due to the high taxation and costs of electricity, individual heat pumps do not currently compete with natural gas. However, heat pumps are a **good solution in comparison to oil boilers and wood pellet burners**. • The construction of new buildings will only be permitted if they use energy generated from renewable sources for space and water heating such as efficient heat pumps. • The government has also endeavoured to make it more economical by allowing **the energy-efficient renovation of homes to be tax-deductible from 2020**. The government supports the installation of climate-friendly heating systems with an **investment grant of up to 35 %** of new construction and during renovation. If they replace a heating system fired by oil, the grant can even climb to **45 % (maximum EUR 25,000)**. • The German government plans to **abolish the Renewable Energy Act surcharge**, which is added to monthly electric bills, from January 2023 onwards. Further, in individual buildings, the grid operator can apply lower electricity fees if the operator is entitled to turn off the heat pump technology for a maximum 2 hours for three times a day during peak demand in the grid. The discount awarded by the operator can even reduce the variable cost of heating up to 20%	
Policies and regulatory support in favour of heat network	• In Germany, there are about 340 companies which provide heat energy via heating networks **(122.22 TWh in 2016).** A municipality may require investors to use a heating network in a given area for heating purposes. The German heating network had a **length of 21,300 km in 2017.** • Germany is a country heavily dependent on imported fuels for the energy sector and heating sector. Aiming at lower resource dependence Germany has been consistently implementing modernisation of the energy and heat supply sector since the 1970s. • In Germany, 100% of revenues from CO2 auctions are spent on power and pro-climate projects such as heat networks. • To improve air quality, subsidies for the construction of new heating networks were introduced, depending on its size **(between 30-40% of investment expenditures).** The maximum funding available for each project is EUR 20 m.	

Overall attractiveness in relation to HP/HN

Low  High

Country profile: Economic support available for manufactures

Japan

Subsidy program for industrial location and job creation in the areas recovering from the tsunami and nuclear disaster at Fukushima (up to **GBP 18.63 m** and **GBP 31.05 m** for highly valued projects).

Government of Japan (Japan has rolled out subsidies totalling over **GBP 2.5 bn** to move its enterprises out of China to Southeast Asia and beyond) There is a subsidy limit of **GBP 93.2 m** per company.

Female and young entrepreneurs (up to **GBP 4.58 m**) for new start ups with women and young people under 30 years.

Tax incentives for strengthening local business facilities (tax credit of up to **GBP 2.4 m** to cover capital investment costs when expanding/ building new buildings).

Japan finance corporation (up to **GBP 0.93 m**) to respond to the bankruptcy of trading partners.

Tax incentives for strengthening local business facilities (tax credit of up to **GBP 4,000** per new employee for establishing/ expanding headquarters in regional revitalization areas).

SME management strengthening fund (up to **GBP 4.58 m**) for new business activities.

Grants Loans Other

Source: Incentive programs, Japan External Trade organization, 2022

Japanese policies are targeting heat pump growth to displace the dominant gas heating in homes

Category	Comment	Attractiveness
Policies and regulatory support in favour of heat pumps	• Japan is currently offering government financed heat pump efficiency R&D - loans, tax incentives, grants, subsidies for building energy efficiency (including heat). • For homeowners, tax incentives were introduced in 2009 for energy efficient home renovation where 10% of renovation costs up to **JPY 2.5 m (approximately GBP 17,250)** can be deducted from that year's income tax. • Japan has an extensive natural gas grid with **28 m commercial and residential gas users**. 54% of dwellings are connected to the gas grid. • Japan is targeting a **total of 14 m heat pumps in 2030**. Industrial heat pumps have the potential to produce heat pump output as high as 440 TJ as replacements for industrial boilers, and have application examples in industries such as food, machinery, chemistry, electronics, agriculture/fisheries, and paper manufacturing. They are listed in the Ministry of Economy, Trade and Industry's energy conservation policy, and future growth can be expected.	
Policies and regulatory support in favour of heat network	• In Japan, 77 Japanese companies were operating 139 district heating or cooling systems throughout Japan in 2015 **(5.83 TWh in 2015**). The Japan heating network only had a **length of 672 km in 2014.** • Target of installing **22 Gigawatts (GW) by 2030.** • In Japan it is only **0.4%** of the total demand coming from heat networks **(2017).** • District heating plays only a minor role in Japan, and its consumption has been stagnant although its use is predicted to expand in the longer term in accordance with government targets for the energy system.	

Overall attractiveness in relation to HP/HN

Low  High

Country profile: Economic support available for manufacturers
France

PAT development grant (up to **GBP 15,000** per permanent job created, maintained or preserved).

Business development loans **(GBP 0.4 – 1.7 m)** interest-free loans. In certain cases the amount may not be repaid, in which case it becomes a grant.

Bpifrance Co-financing and guarantees covering for SME's for **more than 50%** of capital loaned.

The Heat fund - Current annual budget of **GBP 350 m** Total subsidies of **GBP 2.6 bn** given between 2009 and 2020.
- Produce renewable heat (biomass, solar thermal, geothermal, etc.)
- Heating networks

Up to GBP 100,000 for project support studies.

Bpifrance growth loan between **GBP 300,000 to GBP 5 m** at a fixed or variable rate limited by your business' equity capital and quasi equity capital

France's research tax credit gives businesses incurring R&D expenses a tax credit of **up to 30%** of R&D expenses up to **GBP 100 m.**

French Tech Community funding. *X-Wing and Millenium Falcon.* **(GBP 20-100,000)** grants.

Support from local authorities: grants, interest free loans, reduced purchased prices for real estate **up to GBP 200,000** over three years.

All employees in France will be credited with **GBP 500** per year to freely choose training courses through ***Compte personnel de formation***. Up to GBP 5,000 within 10 years.

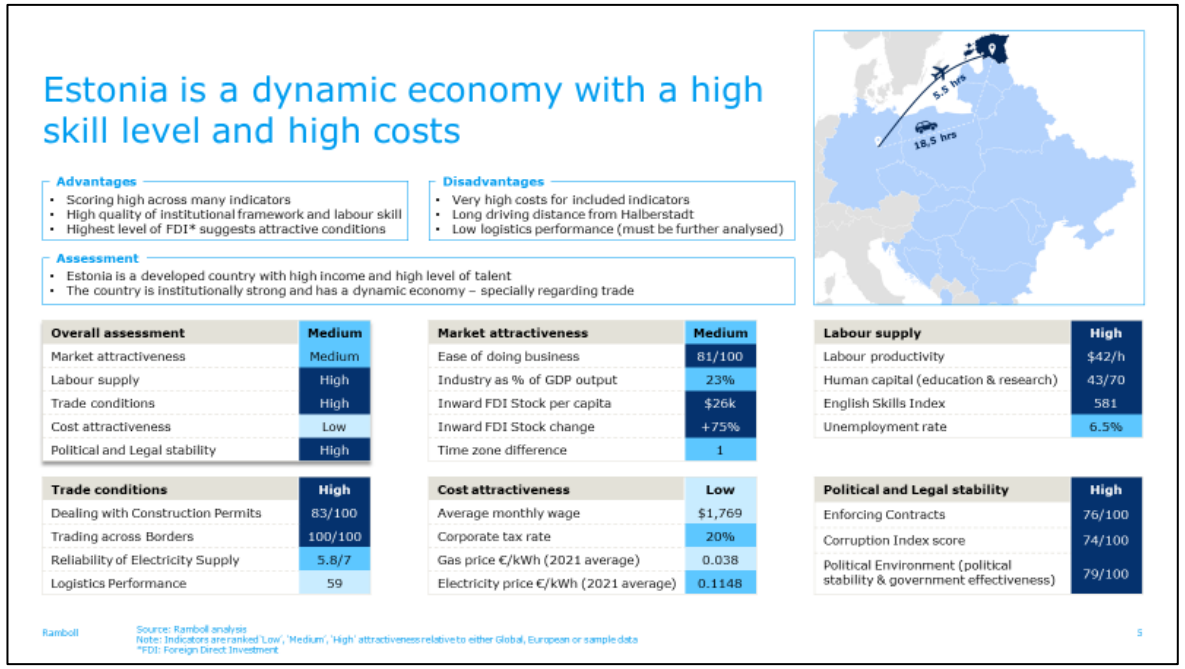
Grants Loans Other

Source: Government Support & Fínance – Doing business in France, BusinessFrance, 2020

Other metrics could be interesting to investigate when looking at a country's profile

Other metrics:
When assessing potential new manufacturing site locations, companies usually investigate a range of other metrics apart from economic support available. These metrics could include the following:

- **Corruption Index Score**
  (0-100 – the lower the worse)
- **Inward FDI Stock**
  GDP per capita
- **Political Environment score**
  (0-100 – the lower the worse)
- **Ease of doing Business**
  (0-100 – the lower the worse)
- **Trading across borders**
  (0-100 – the lower the worse)
- **Enforcing contracts**
  (0-100 – the lower the worse)
- **Logistics performance**
  6 indicators giving a final score
- **Labour productivity**
  GDP per hour worked



Example of how measures could be presented. The example was used as one of many to explain what country to place its production facilities in.

Source: World Bank; Global Innovation Index; Transparency International; UNCTAD; World of Economic Forum; International Labour Organization

Executive Summary

1. Introduction

2. Trends and Technology Assessment

3. Market Analysis

4. Company and Country Profiles

5. Conclusions

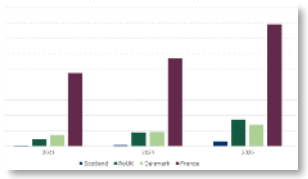
Key conclusions: Growing markets with barriers to entry

1. Key components are compressors, pre-insulated steel pipes, and controls…

Within heat pumps, compressors and controls were identified as two of the components with the most potential for Scotland. For heat networks, it was controls and pre-insulated steel pipes. These components were selected according to their value, existing expertise in Scotland, innovation potential, procurement difficulty, and potential for retrofits.

2. …and all show strong forecast market growth.

Across all geographies, there was a strong market growth forecast for the key components, but particularly for the UK and France, where predicted growth rates were highest. This is due to a combination of factors including macro trends towards decarbonisation and security of supply and local policy environments.



3. Compressors and pre-insulated steel pipes have a higher value but are harder-to-access markets.

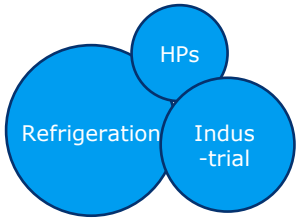
Up to 50% of value from a heat network comes from the pre-insulated steel pipes, but quality requirements and reputation are significant barriers to overcome for potential new entrants. Compressors face similar challenges in heat pumps, with high start-up costs and rigorous testing requirements making market entry challenging for new players.

4. Controls for heat pumps and networks have a lower market value but are more accessible markets…

The controls market for both networks and heat pumps have a total lower market value than for compressors and heat pumps but with lower barriers to entry, are considered more accessible for potential new entrants.

5. …however, this does not give the full picture.

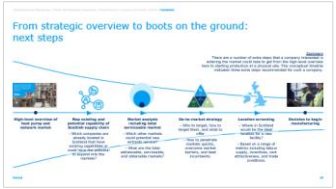
For all identified market leaders of the components, the heat pump market/network market was just one segment that they serviced. For example, refrigeration markets were a key segment for compressors. To give an indication of the total serviceable market for component manufacturers, other market segments should be analysed.



Example serviceable markets for compressor manufacturers

6. A number of further steps can be taken to mature the picture for potential Scottish entrants.

This report provides a high-level overview of the heat pump and network markets in several countries, but in order to get closer to recommending a company to set up manufacturing in Scotland, a number of additional analyses should be undertaken to improve likelihood of success.



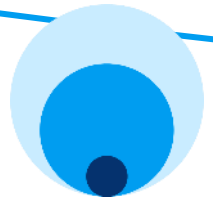
From strategic overview to boots on the ground: next steps

Summary
There are a number of extra steps that a company interested in entering the market could take to get from the high-level overview here to starting production at a physical site. This conceptual timeline indicates three extra steps recommended for such a company.

High-level overview of heat pump and network market

Map existing and potential capability of Scottish supply chain

- Which companies are already located in Scotland that have existing capabilities or could have the potential to expand into the markets?

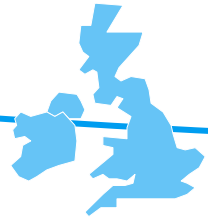


Market analysis including total serviceable market

- Which other markets could potential new entrants service?
- What are the total addressable, serviceable, and obtainable markets?

Go-to-market strategy

- Who to target, how to target them, and what to offer
- How to penetrate markets quickly, overcome market barriers, and beat incumbents.



Location screening

- Where in Scotland would be the ideal location for a new facility?
- Based on a range of metrics including labour supply, incentives, cost attractiveness, and trade conditions.

Decision to begin manufacturing

Thank you

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