Heat Pumps and Heating Systems Components Analysis

Final report

March 2023

RAMBOLL

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Scottish Enterprise

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Executive Summary

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Heat Pumps and Heating Systems Components Analysis

Project overview	• The market for heat pumps and their constituent components is expected to grow rapidly in the coming year, driven primarily by bold decarbonisation targets and energy security concerns. While the current value chain for heat pumps is largely based in continental Europe and Asia, there is an opportunity for Scottish-based stakeholders to capture a greater share of global heat pump markets as demand increases over the coming years. The European Heat Pump Association estimated that ~59,850 heat pump units were sold in the UK in 2022, which represent an increase of 40% compared to 2021. • Scottish Enterprise seeks to develop a better understanding of the components, activities and capabilities required to deliver a more localised heat pump system supply chain in Scotland. This will ultimately help Scottish stakeholders across the supply chain to determine where and how to enter the market, as well as guide Scottish Enterprises' efforts to maximise economic impact. This report seeks to contribute to this understanding. • Data collection involved a literature review and interviews with industry experts.
Domestic heat pump system and components analysis	• A technical analysis of domestic heat pumps was undertaken. First, a list of components was compiled. Second, technical drawings of a monobloc system and an exploded bill of materials are presented. Third, high-level costs are broken down across the heat pump system. • We found that heat pump systems share many elements with traditional boiler systems. However, there are also notable technical differences. For example, many of the components between the two systems vary in size, and heat pump systems require advanced controls for efficient optimisation. • The value of a typical heat pump unit was found to be approximately one third of the total system cost; installation and commissioning is one quarter of the project cost, although this is highly variable depending on the level of retrofit required. • The total market value for heat pump systems in Scotland is estimated to grow to £359 million in 2026. Manufacturing processes required to produce electrical components are scalable and can vary output with little change once established. However, other components such as compressors require specialist design and manufacture and are harder to set up without prior experience and infrastructure.
Value chain analysis	• Overall, it is less likely that upstream activities will constrain large-scale deployment in Scotland due to strong policy and forecast demand growth. Rather, the downstream value chain is where the more telling weaknesses and risks currently lie; it is therefore in this part of the value chain where Scottish Government and industry stakeholders need to inject greater confidence to strengthen the sector. • A major barrier to heat pump system development was found to be the lack of public understanding of heat pumps. A coordinated education campaign across all industry stakeholders, led by Scottish Government, is recommended. • Scotland's heat pump sector requires more high-quality technicians to reach its deployment targets. Increasing this labour pool will entail incentivising and enabling existing boiler installers to retrain (considered a short term solution), and attract new entrant through apprenticeships (a longer term solution, particularly important given the ageing demographic of the existing technician base). By tackling the skills gap quickly and decisively, Scotland's heat pump sector stands a better chance of not only meeting its deployment targets, but also creating economic opportunities as part a green and just transition.

1. Introduction

1. 1. Policy Context

Scotland’s decarbonisation ambitions present a challenging mandate, but also an economic opportunity

The Scottish Government has set a statutory climate change target to meet net zero emissions by 2045, as part of Scotland’s Climate Change Plan and green economic recovery. Progress in meeting this target over the past 30 years has mostly come through decarbonising electricity generation. Decarbonisation heat, however, is a core part of the solution, and heat pumps are regarded as a key ‘no/low regret’ technology in this regard.

The Scottish Government, set out in their Heat in Buildings Strategy, aims to reach installation levels of 200,000 heat pumps annually by 2030. Considering only some 3,000 heat pumps are currently installed each year, the required acceleration in heat pump deployment is immense (Scottish Government, 2021).

Despite this high target for sector grown, bridging the heat pump deployment gap also presents an economic opportunity. The market for heat pumps and their constituent components are expected to grow rapidly in the coming year. While the current value chain for heat pumps is largely based in continental Europe and Asia - with a local installer presence, there is an opportunity for Scottish-based stakeholders to capture a greater share of global heat pump markets as demand increases over the coming years.

To simultaneously meet the bold policy mandate and capture the economic opportunity, Scottish Government needs to build a robust understanding of how Scotland's heat pump supply chain can be fit for purpose.

1.2. Aims and objectives

This report aims to expand the understanding of how Scotland can capture the heat pump opportunity

Scottish Enterprise seeks to develop a better understanding of the components, activities and capabilities required to deliver a more localised heat pump system value chain in Scotland.

This will ultimately help Scottish stakeholders across the value chain to determine where and how to enter the market, as well as guide Scottish Enterprise's efforts to maximise economic impact.

This research is guided by the following **core aims**:

01

Understand the breakdown of all the **components across a heat pump system**. A domestic heat pump system is chosen for analysis.

02

Provide **technical specifications** of the heat pump system, including technical drawings, an exploded bill of materials, and a high-level cost analysis.

03

Understand the **capabilities** required to deliver the components.
This assessment is conducted across the entire heat pump system value chain*, and includes strategic insight relating to existing Scottish capabilities and installation targets.

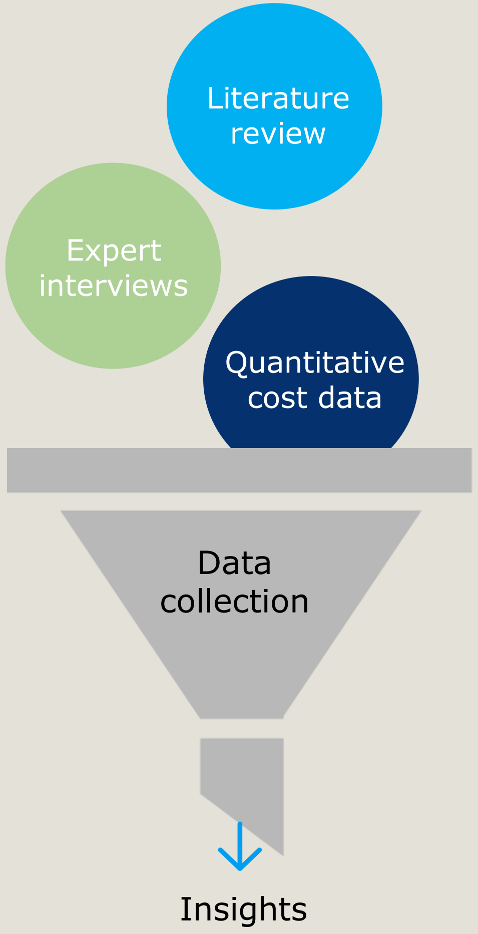
Examined in Section 2: Domestic heat pump system and componentry analysis (aims 01 and 02)

Examined in Section 3: Value chain analysis (aim 03)

*Note that 'supply chain' and 'value chain' can be used interchangeably in this report. Value chain is used to account for the value-adding process as the heat pump system progresses through each stage.

1.3. Methodology

Data collection involved a literature review and interviews with industry experts



This research was informed by an extensive literature review, including academic research and market intelligence from publicly available reports and databases. Ramboll's previous study, '[Heat Pumps and Heat Networks Assemblies and Key Component Analysis' (2022)](), was used as a starting point for the literature review.

In addition, 4 interviews were conducted with expert stakeholders from the following categories: heat pump manufacturers, heat pump installers, and Ramboll technical experts.

Heat pump manufacturers	Heat pump installers	Technical experts
Kensa Heat Pumps (A KENSA GROUP COMPANY); Vaillant	WARMWORKS	RAMBOLL

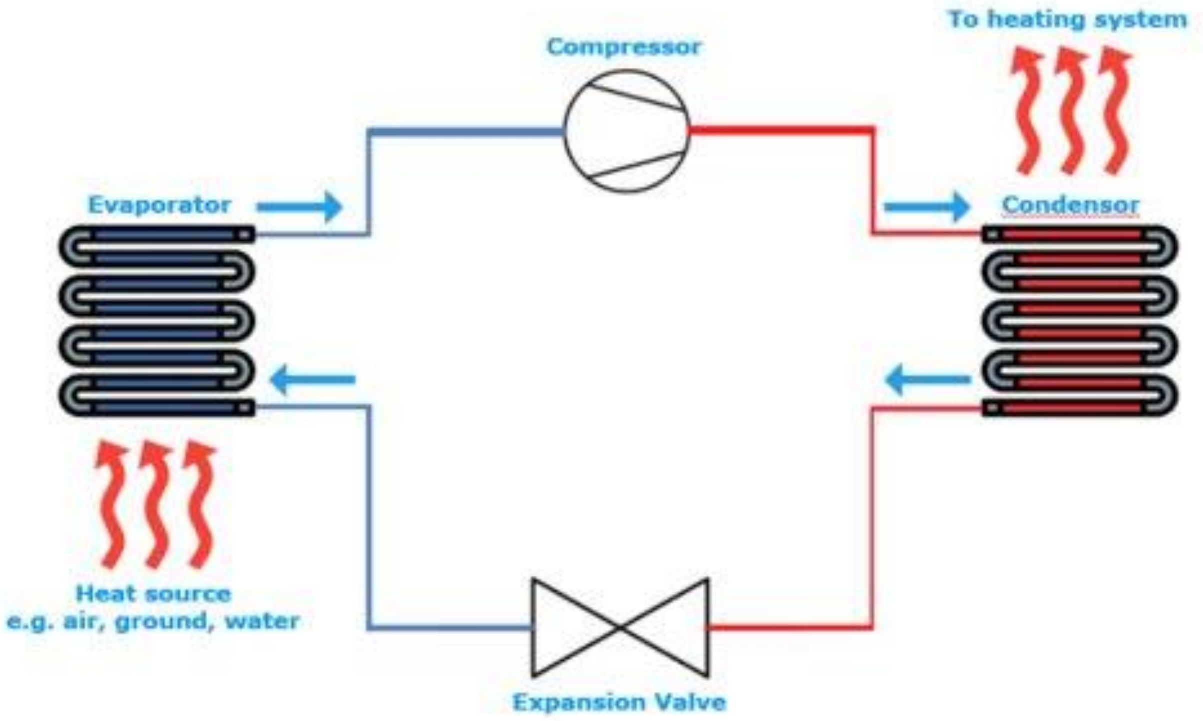
2. Domestic heat pump system and componentry analysis

2.1. Overview

Introduction to heat pumps

- Heat pumps use a refrigeration circuit, driven by an electrical compressor, to transport heat from a source to a demand. For domestic buildings this source can either be ambient air or heat from the ground and can be harnessed to supply heating (or cooling) without burning fossil fuels.
- All heat pumps operate using the same principles but can differ in their individual components, operation and size. Newer flats and small houses may only need a small air source heat pump due to higher fabric efficiencies, whereas larger older buildings may need larger air source heat pumps or ground source heat pumps in order to deliver the required heat supply.

The external system:
consists of a heat exchanger which recovers heat from a heat source, pipework, and the evaporator heat exchanger



The internal system:
The heat pump condenser is connected either to a low temperature hot water circuit or a water-air heat exchanger.

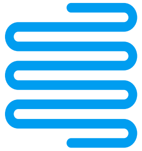
2.1. Overview

Types of heat pumps for domestic systems

Air Source Heat Pump (ASHP)

- ASHPs use a fan to force ambient air through a heat exchanger (evaporator) to recover heat.
- They are easy to install as the majority of the heat pump components are self contained
- Air temperature fluctuates both throughout the day and across different seasons. This means ASHP's efficiency is variable, decreasing when the air temperature is lower, especially in winter months

Ground Source Heat Pump (GSHP)



- GSHPs circulate water through pipes that are buried underground to recover heat.
- As the underground pipes need to be buried, trenching/drilling boreholes can add difficulty to installation depending on the geology of the area.
- The ground retains a much more constant level of temperature across the year than air. This means a GSHP can typically achieve higher efficiencies, especially in winter when the weather is colder above ground.

Monobloc and split system systems

Monobloc heat pumps are hermetically sealed units that generate hot water which is distributed directly from an external unit.

Split system heat pumps include both and internal and external unit connected by refrigerant pipework which also produce hot water (from the internal unit).

Many newer heat pumps are monobloc which simplifies their installation as it eliminates the need to handle any part of the refrigerant system.

2.1. Overview

Differences between traditional boiler and heat pump systems

Overview

The Scottish Government aim to install over 200,000 new heat pumps in domestic buildings by 2030, with further growth towards 2045. This role out will involve both new and existing heating systems and, while traditional boiler systems are similar to those used by heat pumps, there are some major differences that must be understood for the systems' effectiveness to be maximised. Several examples are given below:

Reduced operating temperature	Different operating conditions	Varying sizes of pipes and radiators	A need for thermal stores
Most heat pump systems generally operate at temperatures below 55ºC (typically around 20ºC less than boiler systems). This means that larger radiators are required to deliver the same amount of heat.	Traditional boiler systems can be ramped up and down in order to produce heat at the time it is needed. Heat pump systems, however, are most efficient when run at lower levels for longer periods of time.	The pipe and radiator sizes used for heat pump systems can be larger than those used for traditional boiler systems as a greater water flow rate is required to achieve the same heat supply.	Heat pump systems typically require a buffer vessel to work effectively whereas they are optional for traditional boiler systems. This increases the volume of water in the system, reducing the likelihood of inefficient cycling of the heat pump. This means that thermal stores are critical to heat pump systems.

2.2. List of components

List of components used in a domestic heat pump system

Heat pump components

Component	Category	Description	Manufacturing capability	Major materials
General valves	Connection	Various control and operating functions	Metal casting	Brass/cast iron
Heat pump pipework	Connection	Contains working fluid within the heat pump	Metal forming, welding	Copper/plastic
Communication interface	Electrical	Enables external sources to interact with the heat pump	Various (electric component)	Copper, PET, PVC, Silicon
Inverter	Electrical	Controls the speed of the compressor	Various (electric component)	Copper, PET, PVC, Silicon
Casing	Housing and frame	Protects internal elements	Metal forming-pressing etc (casing), powder coating	Aluminium/steel, plastic
Mounting brackets	Housing and frame	To mount the equipment/unit on a flat surface	Metal forming-pressing etc (casing), powder coating	Aluminium, steel
Casing insulation	Insulation	Reduces heat loss and noise levels	Various	Foam
Pressure sensor	Production	Monitors pressure for safety and efficient operation	CNC machining	Stainless steel/copper, plastic
Temperature sensor	Production	Monitors temperature for safety and efficient operation	Wire extrusion	Stainless steel/copper
Filter	Production	Prevents contaminants/damage in air flow and water flow	CNC machining, iron casting, annealing	Various
Control system	Production	Enables monitoring and advanced control of the system	Various (electric component)	Copper, PET, PVC, Silicon
Fan (including motor)	Production	Increases air flow, improving heat pump efficiency	Plastic forming	Plastic
Flow switch	Production	A sensor that monitors flow rate and pressure of a working fluid	Various (electric component)	Copper, PET, PVC, Silicon
Compressor	Refrigerant	Circulates refrigerant around the heat pump	CNC machining, iron casting, annealing,	Cast iron, stainless steel, aluminium
Reversing valve	Refrigerant	Reverses the refrigerant flow to enable heating and cooling modes	Metal casting	Brass/cast iron
Expansion valve	Refrigerant	Reduces the pressure and temperature of refrigerant	Metal casting	Brass/cast iron
Accumulator	Refrigerant	Prevents liquid refrigerant passing though the compressor	Metal forming, welding	Stainless steel
Refrigerant buffer	Refrigerant	Stores excess refrigerant when the system is not at full capacity	Metal forming, welding	Stainless steel
Evaporator	Refrigerant	Recovers heat from a heat source and deposits it to the refrigeration circuit	Tube bending, welding, metal forming, anti corrosion coating	Aluminium/Copper
Condenser	Refrigerant	Deposits heat from the refrigeration circuit to the end user	Tube bending, welding, metal forming, anti corrosion coating	Aluminium/Copper
Expansion vessel/device	Refrigerant	Maintains the desired pressure in the system	Metal forming, welding	Steel, insulation
Glycol	Refrigerant	Prevents inline water freezing	Various	N/A
Refrigerant	Refrigerant	A working fluid that is effective at transporting heat	Various	Various

List of components used in a domestic heat pump system

	Component	Description	Manufacturing capability	Major materials
Energy transport	**Pipework (refrigerant)**	Transports working fluid between split sections of a heat pump	Metal forming, welding	Copper
	Internal pipework (LTHW)	Transports LTHW inside a building	Metal forming, welding	Copper/plastic
	External pipework (LTHW)	Transports LTHW outside a building	Metal forming, welding	Copper
	Pipe insulation	A jacket of insulation that minimises heat loss while heat is transported	Various	Rubber, fibreglass, foam
	Valves (3 way/bypass valve etc)	Diverts flow from heat pump to either the space heating or DHW systems	Metal casting	Brass/cast iron
	Water pump	Drives LTHW around a heating system to deliver heat where needed	CNC machining, iron casting, annealing,	Cast iron, stainless steel, aluminium
	Water filter	Prevents impurities entering sections of a heating system	Varous	Various
Energy storage	**Expansion vessel**	Allows the increase in the volume of the working fluid when the system is hot to maintain acceptable working pressure	Metal forming, welding	Stainless steel
	Volumiser/Buffer vessel	Stores additional water to increase the volume of a heating system to prevent heat pump cycling	Metal forming, welding	Stainless steel
	Domestic thermal store (domestic hot water cylinder or PC battery etc)	An insulated vessel which stores LTHW or domestic hot water to decouple supply and demand of heat	Metal forming, pressure testing	Copper/Stainless steel
	Thermal store insulation	A jacket of insulation that minimises heat loss while heat is stored	Foam spray application	Polyurethane
Energy delivery	**User input (thermostat, timer etc)**	Electronic components which enable a user to set the operating parameters of a heating system	Various (electric component)	Copper, PET, PVC, Silicon
	Electrical wiring	To supply electricity to the electronic components of the system	Copper extrusion	Copper
	Connection to switchboard/existing electrical infrastructure	Provides a supply of electricity for the system	Various (electric component)	Copper, PET, PVC, Silicon
	Thermostatic valve	Controls the amount of heat supplied by each heat emitter	Metal casting	Brass/cast iron
	Radiators	Emits heat when supplied by LTHW. Installed on walls	Metal forming, brazing, iron casting, paint	Steel, Iron
	Underfloor heating pipework	Emits heat when supplied by LTHW. Installed under the floor	Plastic forming	Polyethylene or other plastic, aluminium

Example Monobloc Heating System

Generation

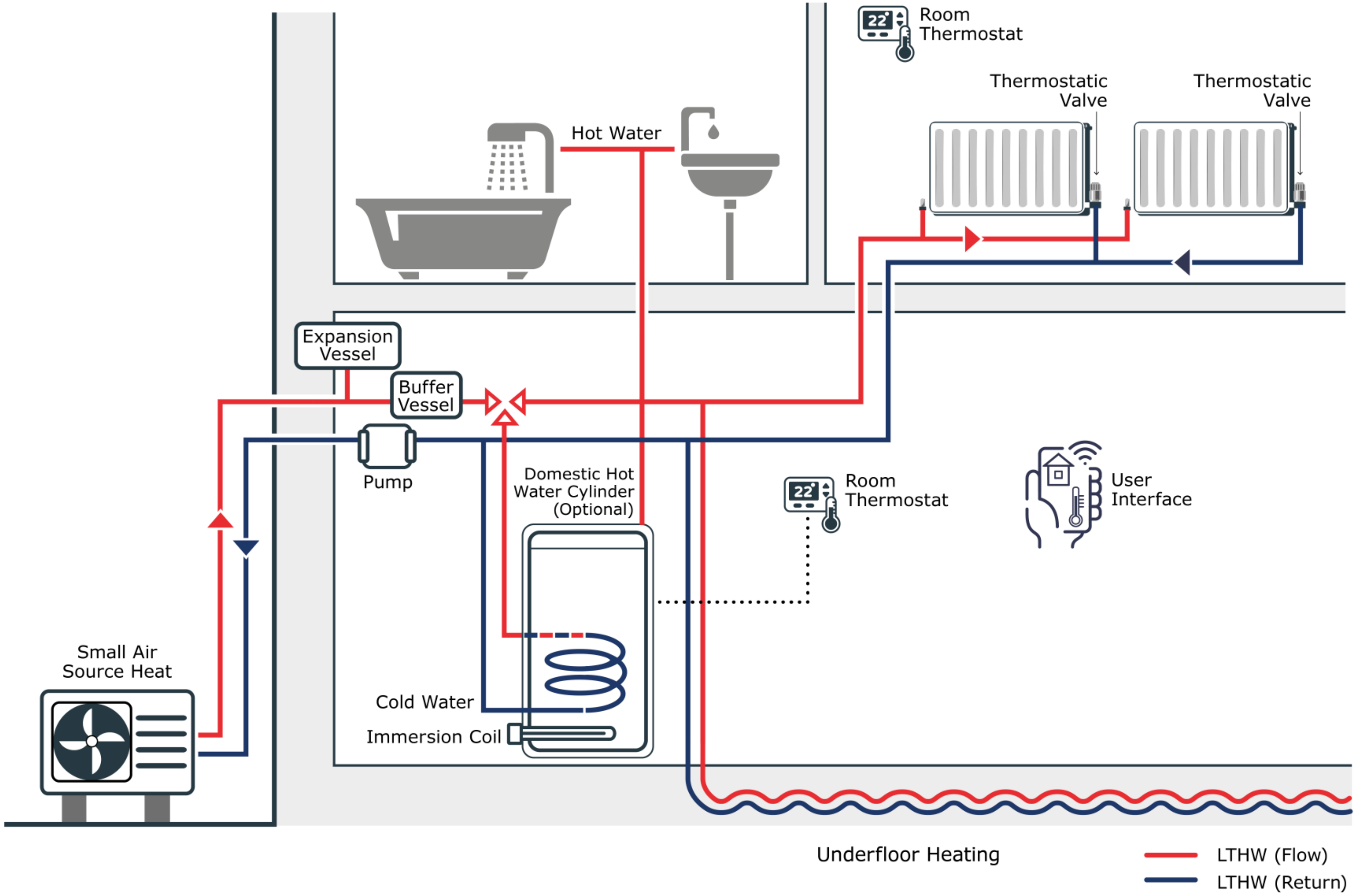
- A monobloc ASHP uses electricity to move heat from the ambient air into water in the heating system
- This water is circulated around the system using a pump

Transportation and storage

- LTHW is sent either directly to heat emitters or to charge a hot water cylinder to provide domestic hot water
- The hot water cylinder has an immersion coil to act as a top up when additional heat is needed and to achieve high enough temperatures to eliminate legionella
- An expansion vessel enables the water to expand when warm without pressuring the system
- A buffer vessel prevents the heat pump from switching on and off (cycling) by adding volume to the system (LTHW)

Delivery

- LTHW is circulated through radiators/underfloor heating to dissipate the heat where needed and then returns to the heat pump to recover more heat
- Domestic hot water is taken from the hot water cylinder and is used in taps/showers



2.3. Technical specifications

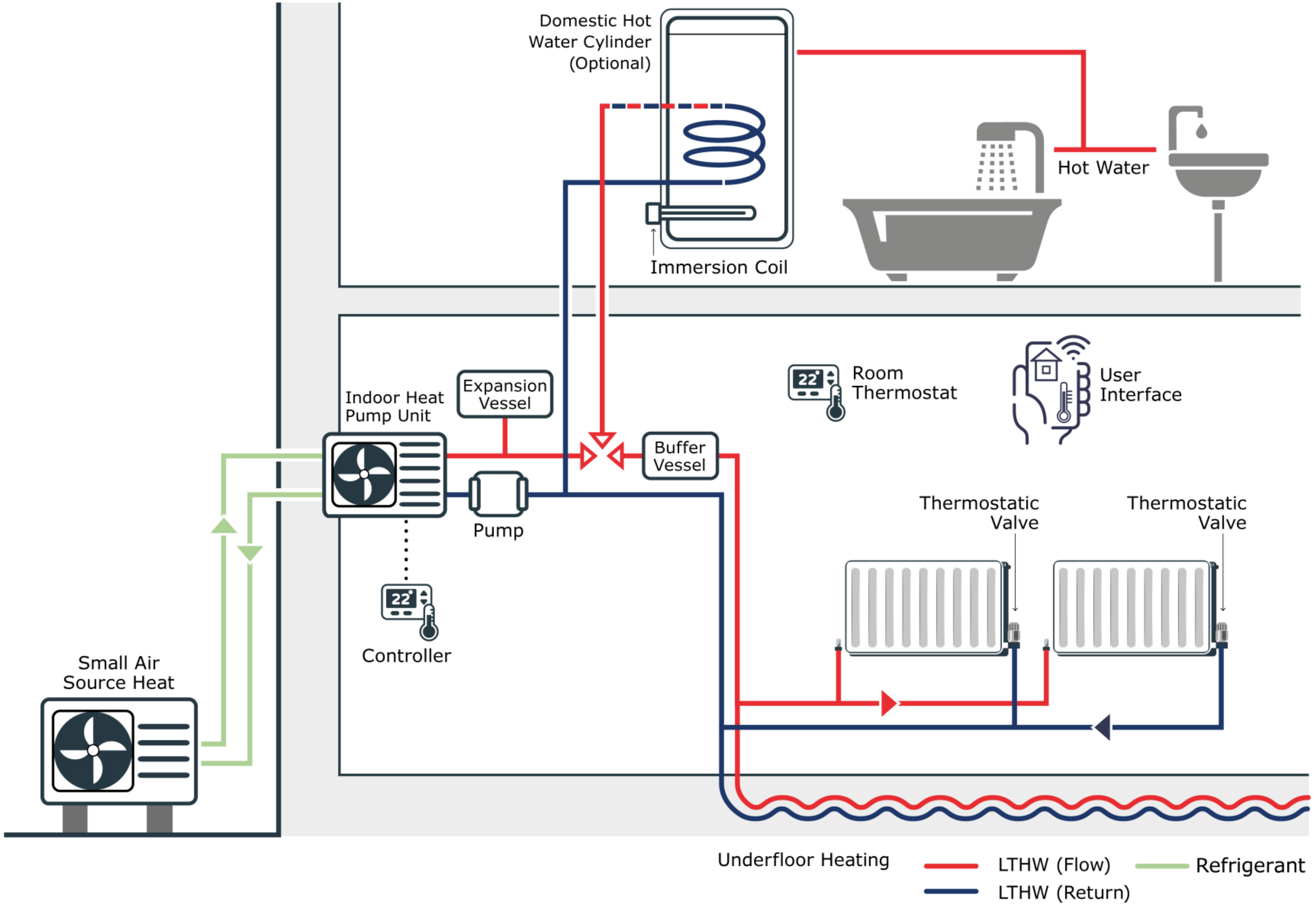
Example Split Heating System

Split system

This system operates similarly to a monobloc system except the heat pump is split into two different units. The outdoor unit houses the heat exchanger that removes heat from the air (evaporator) while the indoor unit houses the heat exchanger that imparts heat to the LTHW in the heating system (condenser).

Controls (monobloc and split systems)

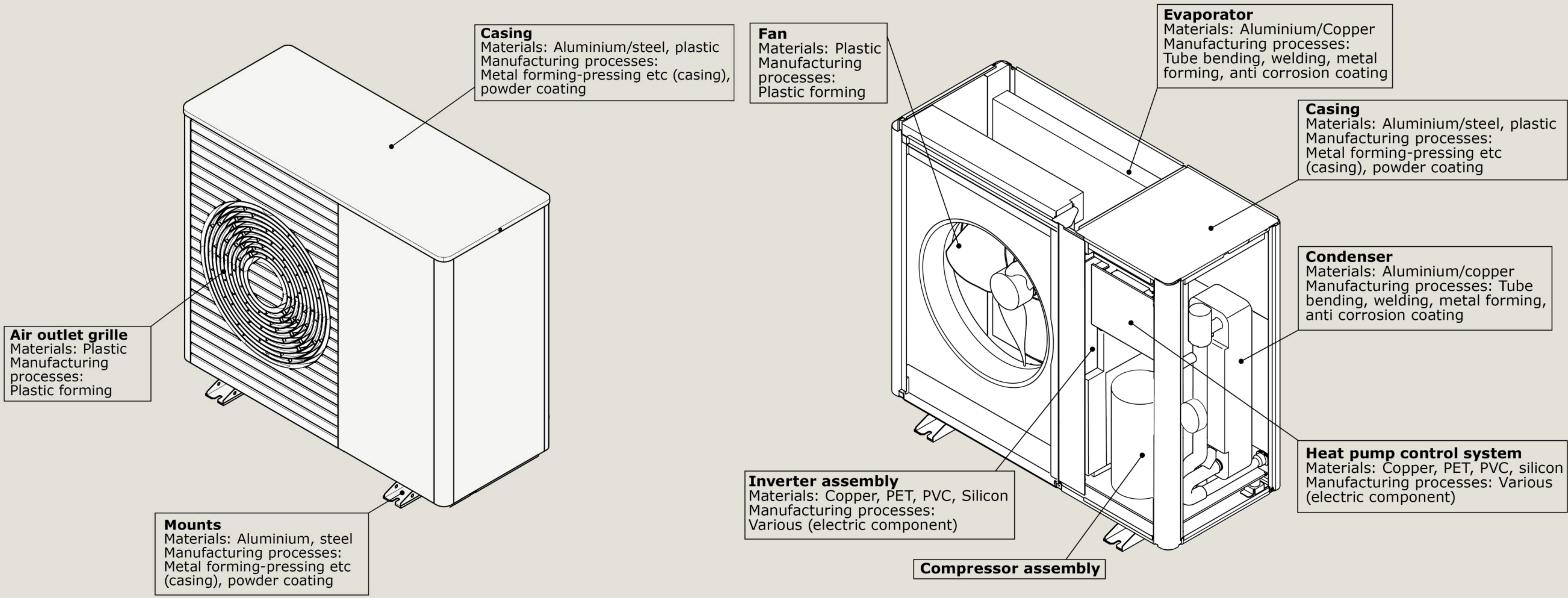
Heat pump systems can be highly efficient, if operated correctly, and therefore rely more heavily on their control systems than traditional boiler systems. This makes correct use of thermostats and other inputs such as user interfaces important, alongside effective use of hot water cylinders and other system components



2.3. Technical specifications

Technical specifications of a monobloc ASHP unit

These diagrams show the layout of a heat pump. A large proportion of the unit is used to maximise the surface area of the evaporator heat exchanger. The rest of the internal components are housed in a casing usually made from metal with an anti-corrosion coating.

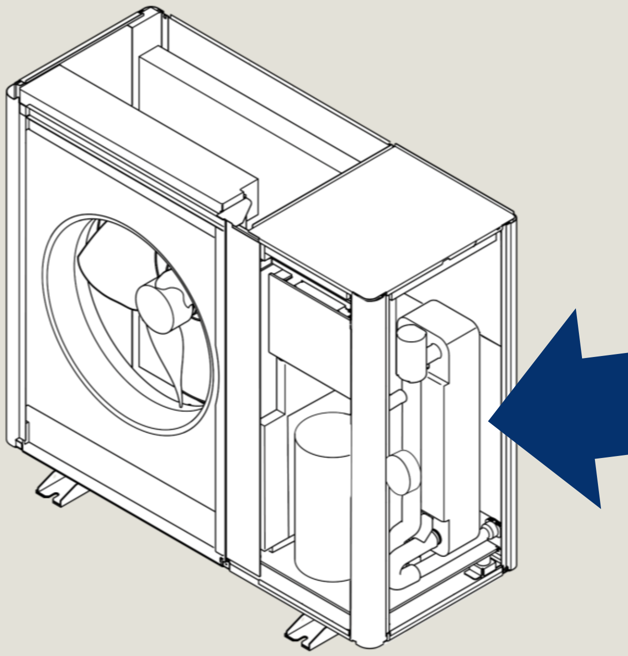


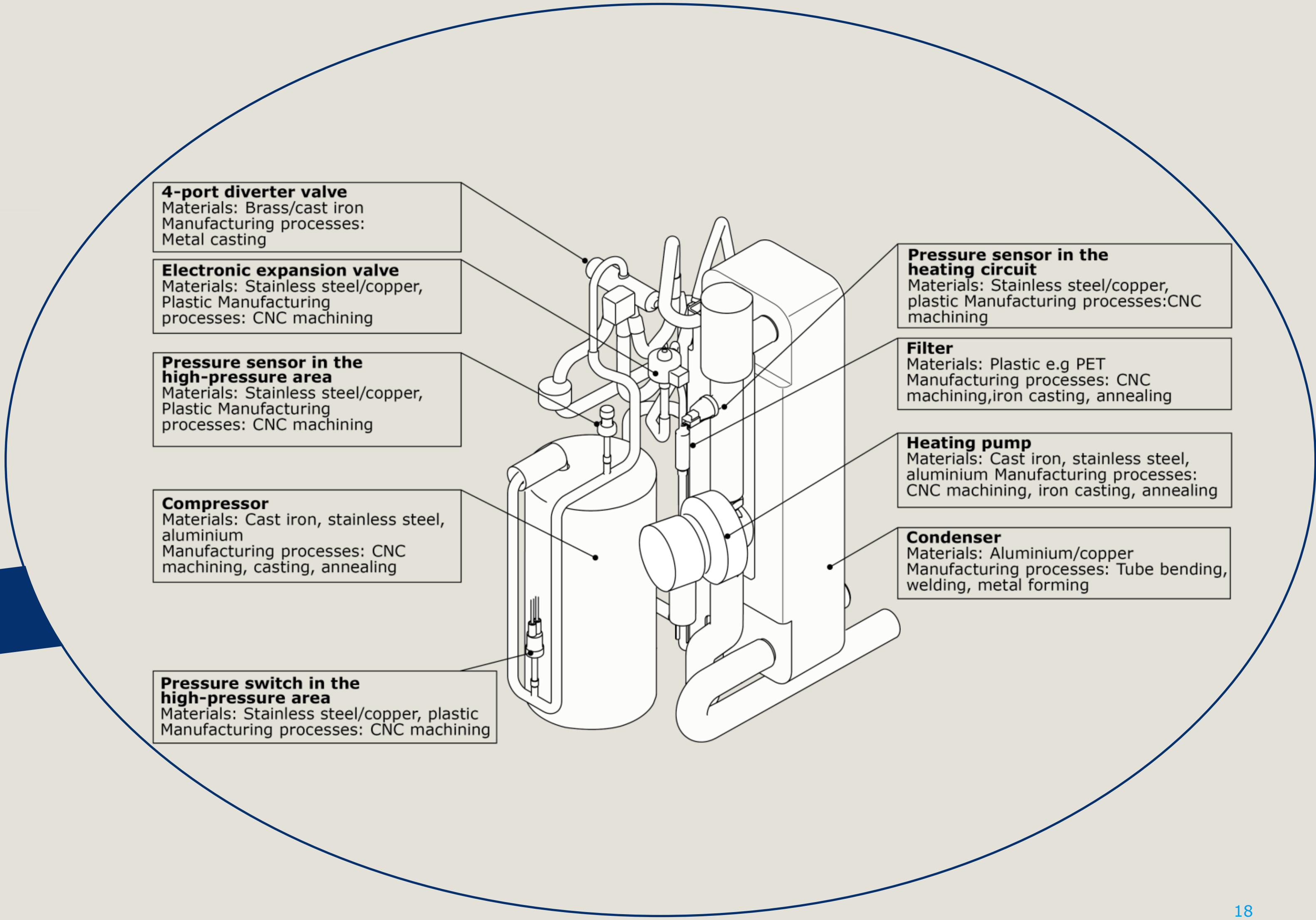
Technical specifications of a monobloc ASHP unit

The remaining space contains the next two largest components:

- Compressor
- Condenser heat exchanger

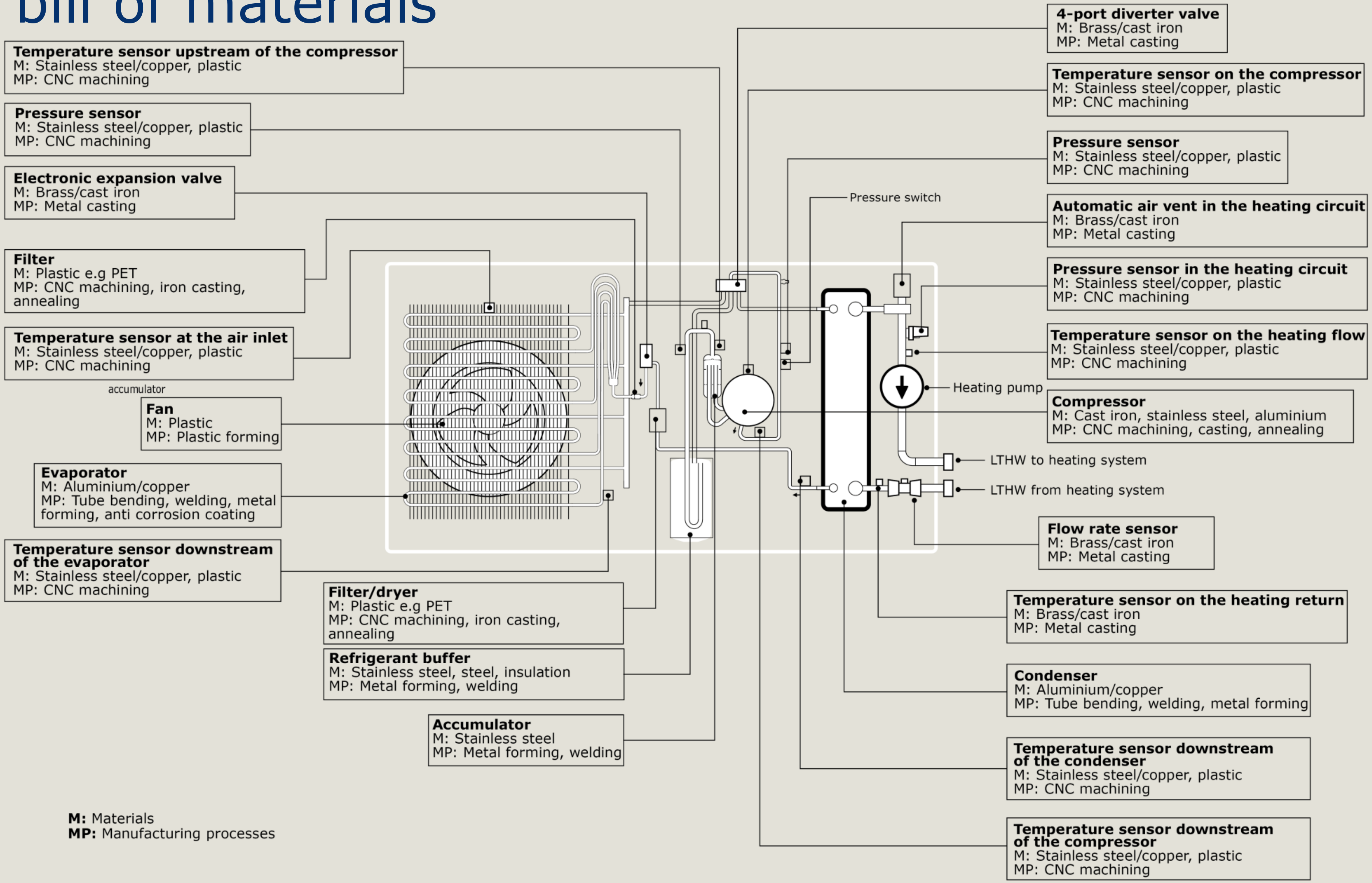
The remaining components are all relatively small in comparison.





2.3. Technical specifications

Exploded bill of materials

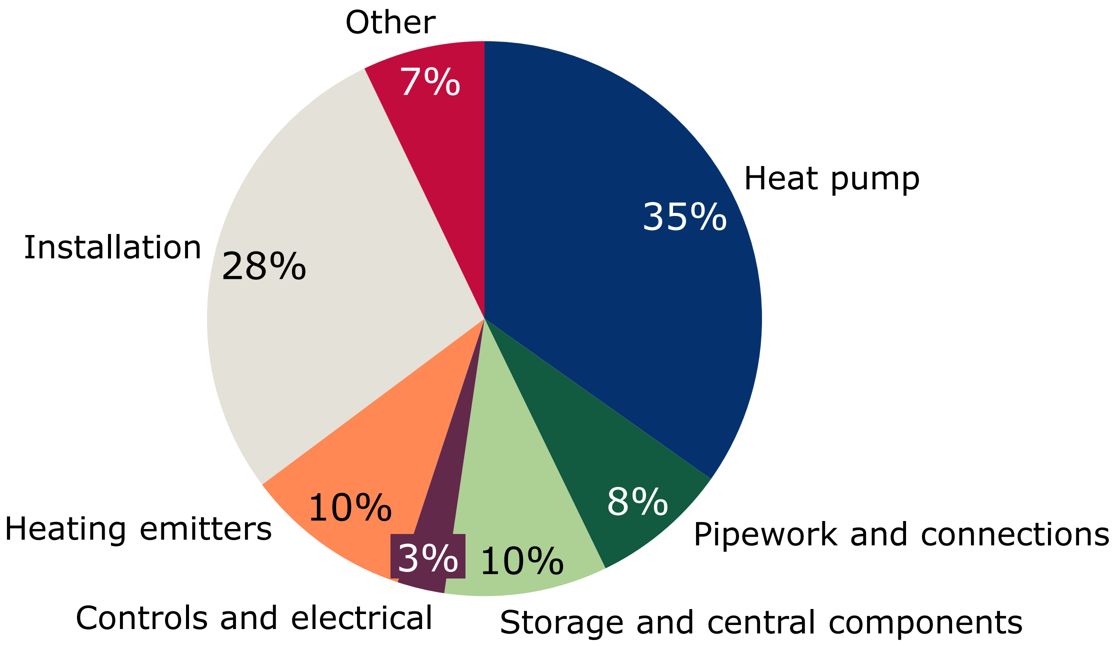


M: Materials
MP: Manufacturing processes

Heat pump heating system costs

This cost breakdown represents the share of costs for different groups of components in a new heating system with an ASHP and thermal store for a new medium domestic building.

- The **largest cost** is the heat pump at over **one third** of the overall project cost
- The **second largest cost**, by a significant amount is the cost of **installation**.
- The **cost of emitters can vary significantly** depending on the size of dwelling and type of emitter selected
- The **average system cost** used in the analysis was **£15,500**



Retrofit
While it may be possible to reuse some components in retrofit projects, the complexity of removing existing components and integrating new sections could add to the installation cost. Given the large share of the total cost that installation holds, any financial gain may be minimal depending on the individual case.

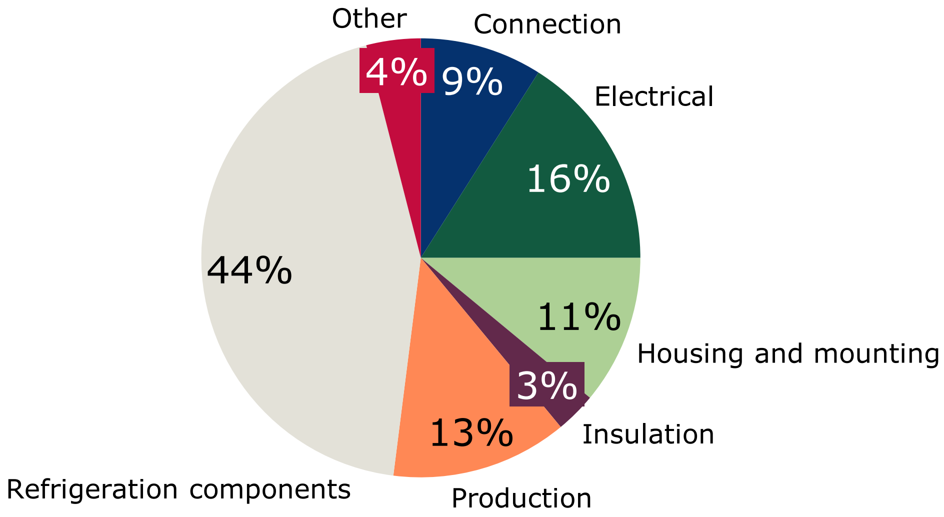
2.4. High-level cost analysis

Heat pump component costs

This cost breakdown represents the share of costs for different groups of components for a medium scale domestic ASHP.

- The **largest cost** in a heat pump can be attributed to the **refrigeration components**, including the compressor and heat exchangers
- Other **major costs** will include the **control system, user interface and LTHW pump**
- The **refrigerant cost** represents **less than 4%** of the overall heat pump cost

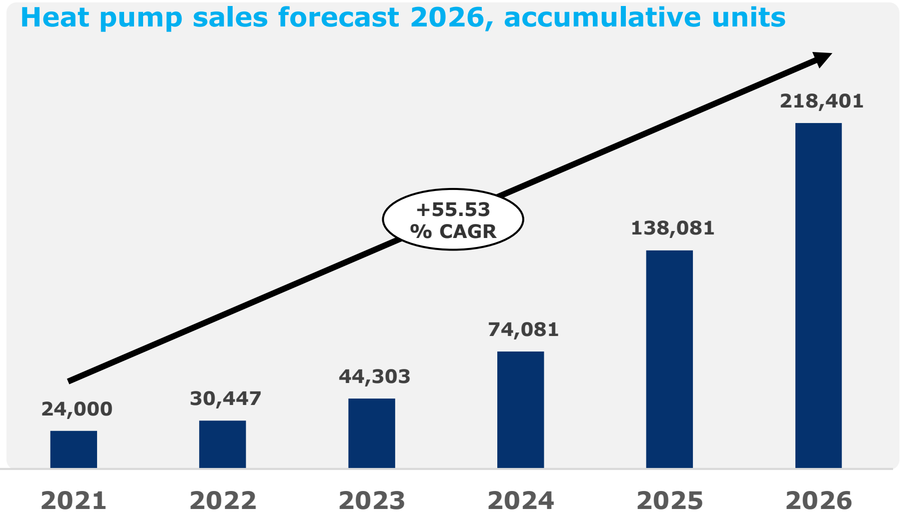
Category	Definition
Connection	Components used to connect system elements together e.g valves and pipework
Electrical	Electrical components e.g sensors and controls
Housing and frame	To keep internal components secure and protected from external conditions
Insulation	Components used to reduce energy losses and minimise operational noise
Production	Components used to handle LTHW through the heat pump
Refrigeration components	Components used to handle refrigerant through the heat pump
Other	Refrigerant, packaging, labels etc

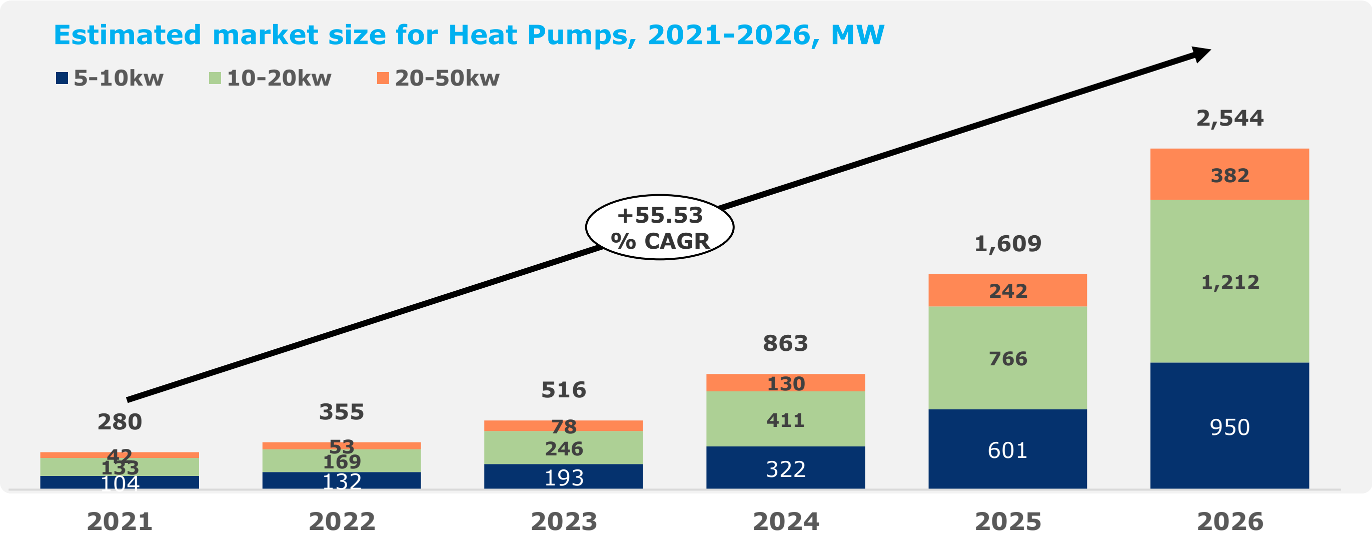


Note
The cost data shown above was obtained through stakeholder engagement and the use of several case studies. Due to the commercial sensitivity of the information, a full breakdown of costs cannot be disclosed. Therefore, several datasets were combined in order to give an overview of the overall heat pump system.

Cost analysis in the context of Scotland's heat pump market

In Ramboll's previous study, '[Heat Pumps and Heat Networks Assemblies and Key Component Analysis' (2022)], the market share for heat pumps was forecast. This was estimated to be £359 million in 2026 in Scotland, as below.





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 359 m**).
- Compressors are expected to hold **17%** of total market value (eq. **GBP 61 m** in 2026).
- Electronic controls are expected to hold **11%** of total market value (eq. **GBP 39 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*

2.4. High-level cost analysis

Cost analysis in the context of Scotland's heat pump market

By combining the heat pump component system cost breakdown and heat pump targets in Scotland, it is possible to forecast the market share for each component:

Sector	Market share in 2026 (£ million)
Heat pump	358.7
Pipework and connections	82.5
Storage and central components	97.9
Controls and electrical	28.3
Heating emitters	100.2
Installation	289.3
Other	73.4
Total	**1,024**

- The total heat pump system market – aggregating across all system components – is forecast to be approximately **£1 billion in 2026** with a third of the overall value associated to heat pumps specifically.
- The second largest sector of the market is **installation** at approximately **£300 million**.
- **Emitters** will also hold a large share of the market at **£100 million**
- Many of these sectors, including refrigeration and emitters, will be much larger in reality due to their **applicability across other markets** although may require some variances in design/manufacture.

3. Value chain analysis

3.1. Overview

Value chain analysis introduction

The heat pump system does not operate in isolation, but rather depends on various stakeholders and economic activities across its value chain. Uncovering strategic opportunities and risks for the heat pump sector requires understanding this broader value chain.

The value chain defined

According to Michael Porter in his book 'The Competitive Advantage: Creating and Sustaining Superior Performance', a value chain is a business model that describes the full range of activities needed to create a product or service from start to finish (Stobierski, 2020).

Value chain activities (or ‘stages’) can be split into two categories that contribute to competitive advantage: primary activities and support activities. Primary activities focus on taking inputs, converting them into outputs, and delivering a product or service to the customer. Support activities play an auxiliary role in primary activities.

Note that this assessment focuses on primary activities only.

The value chain analysis defined

Value chain analysis is a means of evaluating each of the activities in a value chain to understand where opportunities for improvement lie, and thereby realise some form of competitive advantage (e.g., cost reduction, product differentiation).

Aim

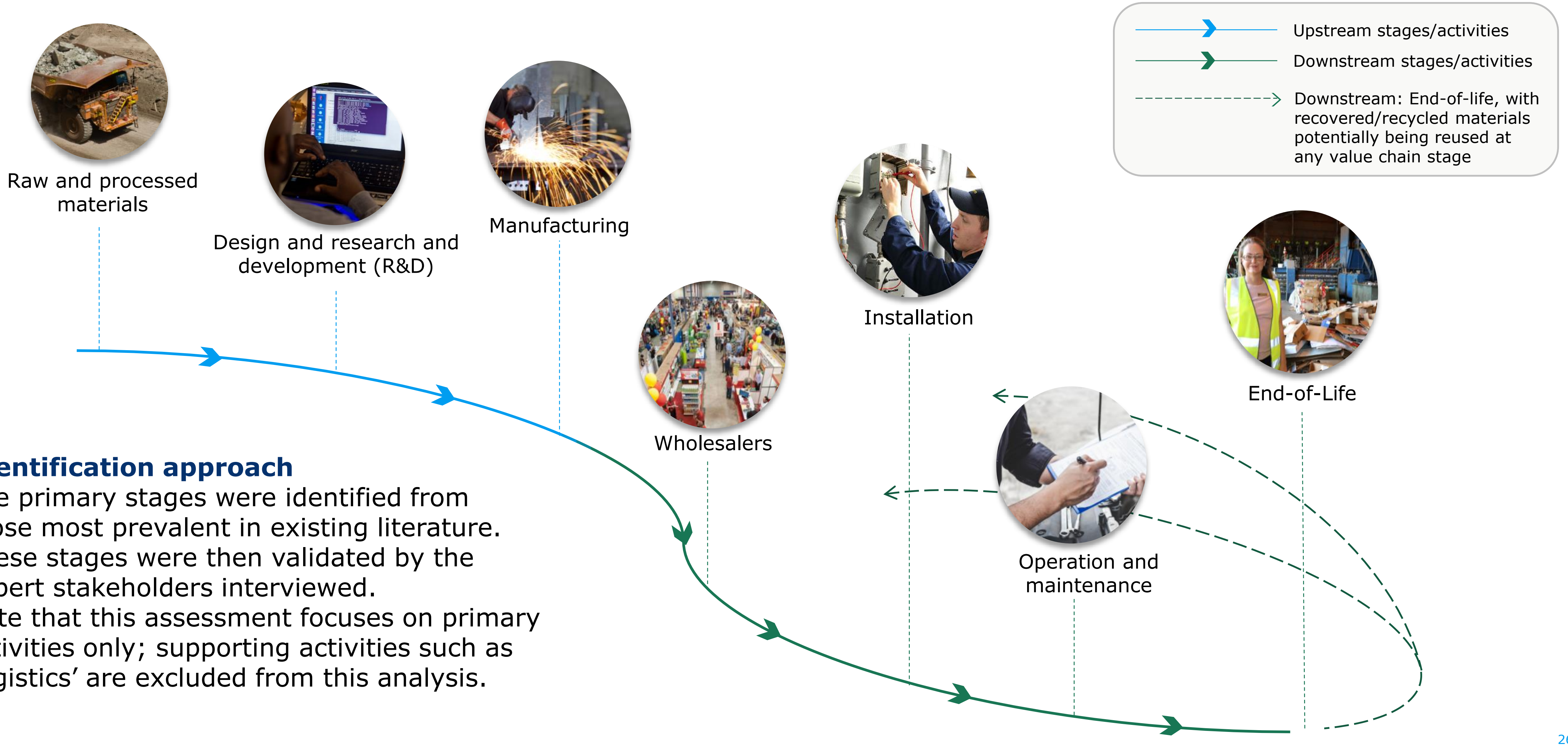
The value chain analysis seeks to identify aspects of the value chain where further focus could maximise long-term outcomes for the sector. It also provides an understanding of industry capabilities required across the value chain to deliver domestic heat pump systems.

Activities

1. Assess component costs and specifications, as identified in the previous section, across the value chain. This will provide relative values across the whole system, not just related to the heat pumps themselves. Consider the findings in light of annual installation targets.
2. Provide details of what types of capability – across all value chain stages – a company would need in order to deliver the components.

3.1. Overview

The heat pump value chain comprises seven primary stages



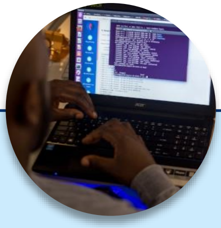
Identification approach

The primary stages were identified from those most prevalent in existing literature. These stages were then validated by the expert stakeholders interviewed.

Note that this assessment focuses on primary activities only; supporting activities such as 'logistics' are excluded from this analysis.

3.1. Overview

Summary of capabilities: upstream



	Raw and processed materials	Design and R&D	Manufacturing
Required capabilities	• Raw materials: specialised engineering capabilities in prospecting, site design and planning, construction, production (extraction processes) and reclamation. • Processed materials: specialised engineering capabilities in cleaning, chemical processing, metals coating etc.	• Research and Development Engineer; University researchers; Hardware and software engineering; Materials Engineer; Composite Engineer; Product Designer; Structural Engineer; Energy and building simulation engineers.	• F-gas (Category 1) qualified engineers; Production worker; Mechanical Engineer; Manufacturing Manager; Assembly Team Leader; Computer Numeric Controlled (CNC) Operator; Quality control assistant; Materials technician; Welder; Sheet metal worker; Metallurgical engineer; Boilermakers; Pipefitters; etc.
Current capabilities in Scotland	• Minimal existing mining operations in Scotland imply a lack of current capabilities for raw material extraction. • Scotland possesses several specialist engineering capabilities for processing (e.g., chemical processing, metals coating); however, there is limited competitive advantage when compared with other nations.	• Several universities in Scotland provide courses on Product Design and various types of engineering. However, very little R&D is done in Scotland due to the relatively smaller size and funding capabilities of companies (mainly done outside of the UK).	• Manufacturing processes such as the ones required to produce electrical components are scalable and can vary output with little change once established. Components such as compressors require specialist design and manufacture, however, and are harder to set up without prior experience/infrastructure.
Assessment relative to installation targets	• Rising commodity costs and geographical sourcing dependency (which implies logistical supply chain constraints) are the main drivers of risk at this stage, and threaten the significant heat pump system deployment targets.	• Innovation in design can upgrade features such as noise and aesthetics therefore improving customers' experience. Innovation can also make heat pump systems more energy efficient and low cost.	• Manufacturing local products would lower costs especially in delivery and imports. • Stimulating higher competition amongst manufacturers may reduce costs.
Opportunities in Scotland	• Scotland will likely depend on importing rather than producing raw materials. • Scottish value chain capability is more likely to lie in the materials *processing* side. • There is an opportunity to mitigate rising commodity costs by coordinating with other industrial sectors to bulk buy, thereby stimulating economies of scale.	• There is a gap in the market for R&D. Therefore Scotland has the opportunity to foster the development of new technologies and improve the existing processes through, for example, automation. • R&D in the refrigerant industry more specifically represents a valuable opportunity for Scotland.	• Scotland has the capacity to carry out pipe bashing and welding, and manufacture its own heat exchangers and heat storage/hot water cylinders. • There is an opportunity to upskill the current workforce on refrigerant handling. • Specialists in air conditioning or welders from the automotive industry can be upskilled to manufacture heat pumps.

3.1. Overview

Summary of capabilities: downstream

	 Wholesalers	 Installation	 Operation and maintenance	 End-of-Life
Required capabilities	• Trade negotiator; Tax specialist; Trading company; Wholesale merchandiser; Software developer; Web developer; Sales associate; Regional account handler; Warehouse operative; Mechanical Installation Manager; etc.	• Heat pump engineering expertise, including technical calculations, system design, drilling, joining and plumbing, refrigerant handling • General electrical knowledge and skills • Non-technical skills, including interpersonal and communication skills	• Similar specialised engineering skills as those for installation e.g., refrigerant handling, electrical work. • Software expertise e.g., analytics and optimisation software, predictive maintenance software and automated control systems	• Collectors • Waste separators (hand-pickers and automated trammel operators) • Waste material certification, auditing and planning • Technical qualifications working with F gas (applies to refrigerant recycling)
Current capabilities in Scotland	• Wholesalers of heat pump systems are widespread present in Scotland and the UK.	• Several sources have highlighted a skills gap in terms of the number and quality of heating engineers in Scotland. However, some stakeholders suggest the gap is overexaggerated; others suggest it is present more in system design rather than installation.	• The skills gap investigated as part of the installation stage also applies to operation and maintenance, although to a lesser extent (maintenance is less time and resource intensive).	• Scotland has adequate facilities and capabilities (and existing recycling companies) for industrial recycling in general. It is likely that these can be scaled for heat pump systems in Scotland.
Assessment relative to installation targets	• Wholesalers are able to sell their products for a lower price as they are selling in bulk. • Expert interviews revealed that wholesalers are commonly used in the heat pump sector in Scotland.	• Whether exaggerated or not, Scotland's heat pump system sector requires more high-quality technicians in order to deliver the projected numbers of heat pump systems.	• Effective operation and maintenance is important in that it helps to showcase heat pump systems as preferred heating choices to potential customers. Addressing perceived obstacles by customers is critical in this regard.	• End-of-life activities can improve cost recovery for manufacturers (in turn passed on to consumers). Given the perception of heat pump systems being prohibitively expensive, this may prove to be an effective lever to encourage consumer adoption.
Opportunities in Scotland	• Wholesalers often provide training to installers, thus helping to bridge the skills gap.	• By tackling the skills gap quickly and decisively, Scotland's heat pump sector stands a better chance of not only meeting its deployment targets, but also creating economic opportunities as part a green and just transition.	• Attracting and training skilled workers to undertake maintenance work is an economic opportunity to stimulate direct, indirect and induced employment benefits for the benefit of the local economy.	• There is little evidence of wide-spread recycling activities; there is much potential to scale this value chain stage. • Several policy packages can help in this regard, including the existing Recycling Improvement Fund and the proposed extended producer responsibility (EPR) schemes.

Raw materials and processed materials focus

Raw and processed materials

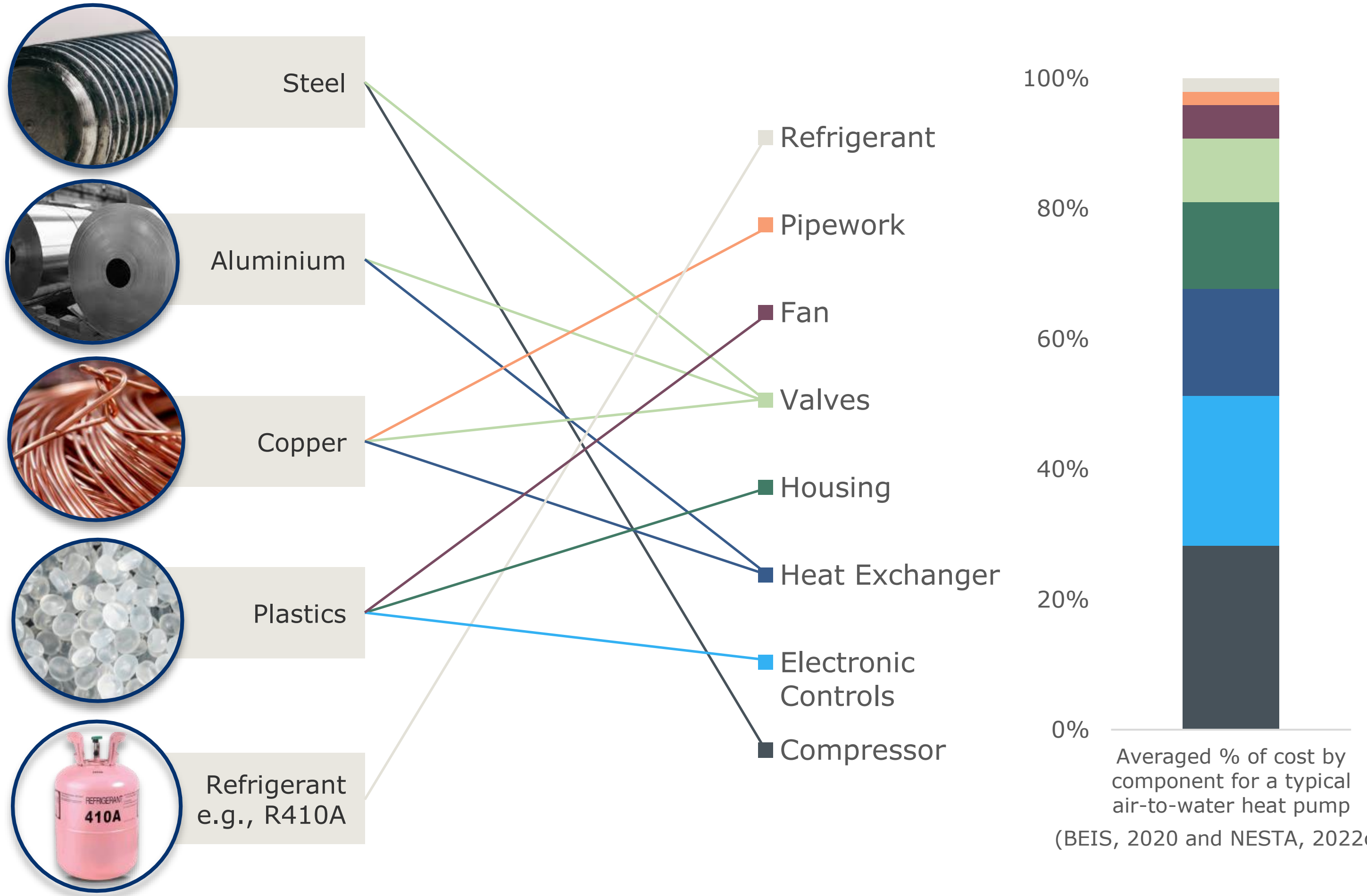
Raw and processed materials are the input goods needed to manufacture the heat pump components and unit.

Five raw and processed materials have been prioritised for assessment based on their high prevalence across the main heat pump components.

Scottish value chain capability is more likely to lie in the materials *processing* side, which would require specialist engineering capabilities such as metals coating and chemical processing.

Main raw and processed materials

Overview of the main costs generative components in a heat pump system



Averaged % of cost by component for a typical air-to-water heat pump

(BEIS, 2020 and NESTA, 2022c)*

*Note that this graph is taken from external studies as the values given earlier in this report are given in segments to protect commercial sensitivity and cannot be compared

Raw materials and processed materials focus

	Cost (commodity prices)	Main mining countries	Main processing countries	Key drivers of risk for Scottish HP industry
 **Steel**	• Demand is increasing (esp. for electrification assets), resulting in higher prices. • 'Green steel' demands higher cost premium (McKinsey, 2022).	• Scotland does not produce a significant amount of crude steel (University of Warwick, 2020). • China remains the largest crude steel producer, followed by India, Japan, United States and Russia.	• Three primary steel processors in Scotland: Liberty Steel Dalzell, Progress Rail, Valourec (Uni of Warwick, 2020). • International processers based in Korea, China, Sweden and the EU. • The 3 biggest steel manufacturers in the UK are Celsa, British Steel and Tata Steel.	• Price increases and overall volatility expected due to increased demand, as well as potential disruptions to global logistical supply chains. • Increasing energy costs threaten production and processing costs.
 **Aluminium**	• Demand is increasing resulting in higher prices, with a 10-year peak in 2022 (IEA, 2022a). A bearish outlook is expected in the short term.	• There is no commercial mining of bauxite ore in Scotland or in the UK. • Australia is the world's largest bauxite producer, followed by China, Guinea, Brazil and India (Statista, 2022).	• The only aluminium smelting facility in the UK, Lochaber Aluminium Smelter, is located in Fort William in Scotland, operated by GFG Alliance. • The largest producers are China (60% of global output), Russia, Australia, amongst others.	• While demand is expected to increase, there are opportunities for increasing global supply and recycling which will likely maintain equilibrium between supply and demand (McKinsey,2022) • Little opportunity to increase domestic supply
 **Copper**	• ASHP's contain ~15-20kgs of copper, making up ~10% of overall unit cost (IEA, 2022a). • Unprecedented increase in demand, resulting in price increases (Fitch Solutions, 2021)	• There is no commercial mining of copper in Scotland. • The leading countries in global copper production as of 2022 were Chile, Peru, the Democratic Republic of the Congo, China, the United State and Russia (Statista, 2022).	• n/a	• Price increases and overall volatility expected due to increased demand. • Likely near-term undersupply, although there are opportunities for reuse. • Scotland reliant on imports; increasingly challenging supply streams from South America.
 **Plastics**	• Polyethylene and polyvinyl (used as proxies for plastics in general) prices have decreased globally over the past 10 year (TradingEconomics, 2023)	• Plastics largely sourced from oil	• Dow Chemicals (USA), LyondellBasell (Netherlands), Ihne & Tesch GmbH (Germany), Exxonmobil (USA), Indorama Ventures (Thailand). • Ineos (largest plastic producer in the UK) situated in Grangemouth; numerous manufacturers based on Scotland.	• Regulatory and reputational pressures may demand that producers change processes to use alternative and recycled content (long term risk).
 **Refrigerant e.g., R410A**	• The refrigerant cost represents less than 4% of the overall heat pump cost. • Increasing demand is leading to rises in wholesale costs. • Metal container costs are increasing due to the rising price of metals.	• n/a	• Honeywell International Inc. (USA), Dupont (USA), Carrier Global Corp. (USA). Other major producers are based in China.	• Phase out of R-410A refrigerant in the USA may lead to price spikes as replacement refrigerants (e.g., R-32) are secured. • Temporary shortages in components that make up refrigerant. • Logistical constraints.

Legend: Drivers of risk — Volume shortage; Price volatility; Geographical -sourcing dependency; Long lead times; Material quality

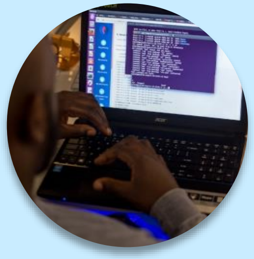
3.2. Findings by value chain stage

Design and Research & Development focus

Legend: Critical assessment

Internal factors
- Strength
- Weakness

External factors
- Opportunity
- Threat



Design and R&D

This stage of the value chain is about leading, performing, designing and analysing heat pump systems and components so that they efficiently generate the most power, are more reliable, and capable of withstanding environmental stresses.

Key activities

- Development of new concepts, products, equipment, or processes
- Preparation of technical reports for use by engineering or management personnel
- Identification of technical approaches for solving problems and meeting customer demands
- Market research and evaluation of similar products and their functions
- Redesign of existing products to enhance functionality or reduce costs
- Creation and testing of prototype products
- Improvements of the design, cost, feasibility of production and reliability of heat pumps
- Assurance that the production of components is feasible and cost effective
- Monitoring of how materials perform and evaluate how they deteriorate
- Evaluation of product safety

Required capabilities

- Research and Development Engineer
- University researchers
- Hardware and software engineering
- Materials Engineer
- Composite Engineer
- Product Designer
- Structural Engineer
- Energy and building simulation engineers

Critical assessment of Scotland's value chain stage

- The majority of R&D is currently undertaken overseas, therefore increased R&D in the Scotland and the UK is likely to be limited (BEIS, 2020).
- Scotland's research institutions are world-class and are effective test-beds for R&D research.
- Smaller companies may not have the expertise and financial resources to invest in R&D activities (BEIS, 2020).
- An expert stakeholder mentioned that designs are getting too complex and often poorly match with end user capabilities.
- There is a growing demand for the deployment of smart control systems, particularly where hybrid systems are in place (BEIS, 2020).
- R&D in natural refrigerants represents a valuable opportunity in the UK as highly polluting synthetic substances like fluorinated GHG (f-gases) with high GWP are being phased out in the EU and Northern Ireland and prices of natural refrigerants have proven low and stable compared to fluorinated refrigerants (Trevisan T. *et al.*, 2022).

Recommendations

- Foster the development of software tools, e.g. heat loss calculator, reduction in heat pump flow temperatures (Nesta, 2022a).
- Develop integrated solutions, e.g. combined heat pump and thermal storage management (IEA, 2022b)
- Develop systems to detect maintenance needs.
- Improve design features to reduce noise and aesthetics, thus easing customers' apprehensions (IEA, 2022b).
- Design processes to pre-assemble parts at the manufacturing site to reduce installation time.
- Seek end-of-life opportunities at the design stage.

Research and Development case study

The University of Glasgow develops a new flexible heat pump technology

What is it about?

Researchers at the University of Glasgow invented a flexible heat pump technology that integrates heat recovery and storage which is then used as a heat source to operate the heat pump (University of Glasgow, 2022).

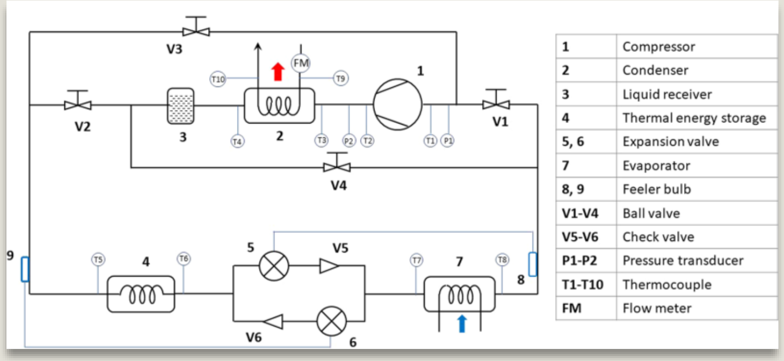
Why is it important?

This new patented technology theoretically saves up to 20% in compressor power consumption. Additionally, a practical 3.7% power saving at a heat production temperature of 35 °C was demonstrated based on the University's prototype. The researchers affirm that this new technology is a low-cost solution to current problems occurring in heat pump systems such as heating capacity and energy efficiency. The team's analysis predicts that, after optimisation, it could be up to 10% more efficient than current products when the heat supply temperature increases to 65 °C (Yu Z. et al., 2022).

An opportunity for Scotland

The Scottish Government can help develop heat pump technologies further and support the commercialisation of such advancements. Energy efficient technologies would alleviate energy costs for citizens and help the UK transition to Net Zero. The local development of such technologies could showcase Scotland as a leader in heat pump R&D.

Photograph of the flexible heat pump prototype



The schematic of the flexible heat pump prototype and instrumentation.
Charging mode: Open V1 and V2, close V3 and V4, feeler bulb 8 controls expansion valve V5. Discharging and defrosting mode: Close V1 and V2, open V3 and V4, feeler bulb 9 controls expansion valve V6.

3.2. Findings by value chain stage

Manufacturing focus

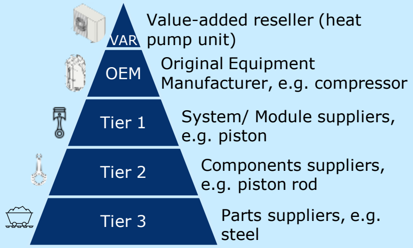
Legend: Critical assessment

Internal factors: Strength, Weakness

External factors: Opportunity, Threat

Manufacturing

This stage is about the fabrication of goods. Manufacturing can mean transforming raw materials into finished goods, or the creation of more complex items by selling basic goods to manufacturers for the production of heat pump systems.



	Key activities	Required capabilities
OEM & VAR	• Computer Numerical Control (CNC) machining • Wire extrusion • Tube bending and welding • Anti corrosion coating • Powder coating • Pressure testing • Production line equipment operations • Assembly of goods on a production line • Monitoring of production • Basic testing	• F-gas (Category 1) qualified engineers • Production worker • Mechanical Engineer • Manufacturing Manager • Assembly Team Leader • Information Technology Manager • Electrician • Service Technician • Computer Numeric Controlled (CNC) Operator • Quality control assistant
Tiers 1-3	• Metal casting and annealing • Metal and plastics forming • Metals welding and brazing • Computer Numerical Control (CNC) machining • Anti corrosion coating • Mechanical, physical, or chemical transformation of materials, substances, or components into new products • Operation of the production line equipment	• Materials technician • Welder • Sheet metal worker • Metallurgical engineer • Metallurgist • Foundry workers • Boilermakers • Pipefitters

Critical assessment of Scotland's value chain stage

- Expert stakeholder interviews revealed that key components are predominantly manufactured abroad (Expert interview, 2023).
- Competition is low, thereby creating a monopoly (Nesta, 2022).
- UK manufacturers have low automation factories (BEIS, 2022).
- The capital cost of components and heat pump systems may be an issue in the current context of economies of scale (Expert interview, 2023).
- There is a bottleneck with controls in the UK (Expert interview, 2023).
- Fans and valves are highly commoditized but inverters and electrical components may become a bottleneck (McKinsey, 2022).
- Scotland has the capacity to carry out pipe bashing and welding.
- There is a short-term need to upskill on refrigerant handling (BEIS, 2020).
- The Livingston Mitsubishi Electric and Glasgow Star Renewable Energy factories are the two main heat pump manufacturers in Scotland (Karpathy Z. *et al.*, 2022).

Recommendations

- Scotland could manufacture its own heat exchangers and heat storage/hot water cylinders.
- Specialists in air conditioning or welders from the automotive industry can be upskilled to manufacture heat pumps
- The government could support a 'centre of excellence' to provide training on heat pump skills which manufacturers could play an active role in (Energy and Climate Change Directorate, 2021).

Manufacturing case study

Mitsubishi Electric is developing a low carbon heat pump centre of excellence in Scotland with funding from Scottish Enterprise

What is it about?

Mitsubishi Electric Air Conditioning Systems Europe Ltd is developing a ‘smart factory’ to manufacture new heat pump products including ‘low global warming potential (GWP)’ refrigerants and materials with the financial support of Scottish Enterprise (Scottish Development International, 2021).

Why is it important?

The Livingston manufacturing facility is implementing robotics and automation which have been characterised as a gap in manufacturing by Ramboll experts. In addition, digitalisation such as IoT sensors and systems are expected to provide real time data.
In 2022, Mitsubishi Electric introduced its new Ecodan CAHV-R air source heat pump utilising low GWP refrigerant (Mitsubishi Electric, 2022).

An opportunity for Scotland

Upgrading Mitsubishi Electric’s manufacturing processes generates competition and fosters innovation in Scotland. This smart factory is expected to generate higher quality products, create 55 new technical and engineering job opportunities and help meet the increasing UK demand for low carbon heat pumps.

Staff working in Mitsubishi electric heat pump manufacturing facility in Livingston (Scottish Development International, 2021).

3.2. Findings by value chain stage

Wholesalers focus

Legend: Critical assessment

Internal factors
- Strength
- Weakness

External factors
- Opportunity
- Threat

Wholesalers

This phase refers to the purchase of heat pump systems in bulk and their sale/distribution to installers and merchants.
Ramboll experts have highlighted the prominence of wholesalers in the Sottish heat pump market, therefore they are assumed to represent an important value chain stage that links manufacture to installation.

Key activities

- Purchase of goods in bulk from manufacturers
- Sale of goods to retailers and merchants
- Marketing
- Storage of goods in warehouses (Luther D., 2022)
- Market research
- Building business relationships downstream and upstream
- Maximization of operational efficiency (Luther D., 2022)
- Delivery of final products
- Ability to provide a wide range of products and services
- Dealing with customer enquires and orders (Midsummer)
- Packing, lifting and handling of goods
- Heat Loss Calculation (Freedom)
- Installer training
- Remote tech support (Freedom)

Required capabilities

- Importer/Exporter
- Dealer (Luther D., 2022)
- Jobber
- Buying/selling group
- Trading company (Luther D., 2022)
- Wholesale merchandiser
- Wholesaler
- Software developer
- Web developer (Midsummer)
- Sales associate
- Regional account handler
- Merchant account handler
- Warehouse operative (Midsummer)
- Mechanical Installation Manager
- Projects Administration Assistant (Freedom Heat Pumps, 2023)
- Technical sale engineer
- Accountant
- Finance assistant
- Logistics administrator
- Delivery driver
- Customer service advisor (Freedom Heat Pumps, 2023)

Critical assessment of Scotland's value chain stage

- Wholesalers of heat pump systems are easily found in Scotland.
- 98% of wholesalers in Scotland are small businesses (Glover J., 2021). These businesses may not enjoy the economies of scale of other European wholesalers.
- Issues such as labour shortage impacts wholesalers, resulting in less competition due to forceful closure of small businesses (Glover J., 2021).
- Wholesalers can be an important source for technical knowledge and support. Some provide training for installers, thus helping to bridge the skills gap (mentioned in the Installation stage).

Recommendations

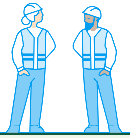
- A coordinated approach to knowledge sharing and support across all industry stakeholders is encouraged. Wholesalers' prominent position in the local industry suggests they can play an important role in this regard.

3.2. Findings by value chain stage

Installation focus

Legend: Critical assessment

Internal factors	*External factors*
🟢 Strength	🔵 Opportunity
🔴 Weakness	🟡 Threat



Installation

Installation comprises the actions of planning/ designing and installing the domestic heat pump system for the end user.

There are 702 ASHP and 310 Ground/Water SHP (UK-based) MCS-registered installers that operate in Scotland (MCS, 2023).
The market is dominated by small businesses and sole traders (Nesta, 2022b).

	Key activities*	Required capabilities	Critical assessment of Scotland's value chain stage	Recommendations
Planning (assessment and system design)	• Pre-sale information: energy performance estimation • Site suitability and risk assessment • Space heating design: heat loss calculations • General design considerations, including sizing heat emitters, pipework and materials • Post-design information • Equipment certification and listing	• Heat pump engineering expertise, including technical calculations and system design • Non-technical skills, including interpersonal and communication skills	🟡 Several sources have highlighted a skills gap in the number and quality of heating engineers in Scotland (Karpathy *et al*., 2022; Heat Pump Association, 2019a). 🔴 In a recent installer survey, 43% of installers said they had no experience at all in heat pumps (Heat Pumps Association, 2019b). 🟡 Gaps especially prevalent in refrigerant handling and drilling ground arrays. 🔴 Skills gap due to difficulties recruiting staff, high cost of training, and a lack of wage premium. 🔴 Some stakeholders suggest the skills gap is overexaggerated; others suggest the skills gap is present more in system design rather than installation (Expert interviews, 2023). 🔴 Lack of consumer demand and awareness of the benefits of installing heat pumps. 🔴 Costs perceived as prohibitively expensive compared with gas boilers. 🟢 The Home Energy Scotland Grant and Loan scheme offers up to £7,500 (£9,000 for household qualifying for the rural uplift) to homeowners for new heat pumps (Home Energy Scotland, 2023).	**Skills gap** • Increase number of high quality installers by attracting existing and new installers. • Incentivise existing installers to retrain (in the short term, the majority of installer are likely to come from the current boiler installer base). • Offer apprenticeship schemes for new/young entrants. Encourage partnerships between colleges and industry stakeholders. • Government to provide funding support and clear market signals e.g., National Transition Fund, Green Heat Installer Engagement Programme, Heat in Building Supply Chains Delivery Plan. **Consumer acceptability** • Promote competition in the market to bring down costs • Consumer education campaigns
Installation	• Ground array drilling (GSHP only) • Physical installation according to manufacturer's specifications: heat pump and auxiliary equipment • Metering and data communication security • Electrical work • Commissioning (documented procedure to ensure system is safe • Documentation and handover	• Heat pump engineering expertise, including trenching and drilling, pipe joining and plumbing, refrigerant handling. • Electrician: requires a qualified electrician with knowledge of configuring the heat pump, wiring and assessing electrical network capacity.		

*Key activities based on those required to comply with the MCS Standards (MIS-30050-D for planning/design and MIS-3005-I for installation)

3.2. Findings by value chain stage

Operation and maintenance focus

Legend: Critical assessment

Internal factors	*External factors*
Strength	Opportunity
Weakness	Threat

Operation and maintenance

Operation and maintenance (O&M) comprises the functions, duties and labour associated with:

- The daily operation of the heat pump system
- Normal repairs, replacement of structural components, and other activities needed to preserve the heat pump system so that it continues to provide acceptable services to the end of its expected life.

Key activities

Operation:

- general system usage and monitoring

Maintenance:

- Routine monitoring using integrated systems/software
- Routine maintenance, servicing and troubleshooting– most heat pump manufacturers stipulate that a heat pump service should be carried out once a year from year two following installation to maintain the Manufacturer's Warranty (*Heat Pump Assist, 2023). Includes heat pump check, filter check, control set-up check, glycol check, refrigerant top-up, service record entry.
- Breakdown and repair – includes diagnostic to locate fault, part repair or replacement, and service record entry

Required capabilities

Operation:

- n/a

Maintenance:

- Similar specialised engineering skills as those outlined in installation e.g., refrigerant handling, electrical work, plumbing.
- Software expertise, including analytics and optimisation software, predictive maintenance software and automated control systems (European Commission, 2021).

Critical assessment of Scotland's value chain stage

- The skills gap investigated as part of the installation stage also applies to operation and maintenance, although to a lesser extent (maintenance is less time and resource intensive).
- Running costs of heat pumps are perceived as being prohibitively expensive, owing to the relatively higher cost of electricity compared with gas. Compounding this is the poor insulation of much of the housing stock, as well as customer behaviours such as excessive on/off cycling of the compressor and window opening (both of which increases electricity consumption) (Bush., *et al.*, 2021).
- There is some evidence that customer dissatisfaction with heat pump performance and ease of use is associated with difficulties finding technical support and advice from suppliers (Bush *et al.*, 2021).

Recommendations

- Improve energy efficiency to lower running cost. This can be achieved through effective system design at the installation phase. Building regulations can also encourage insulation and minimum energy performance standards.
- Customer education: inform the owner about correct handling and operation and the need for thorough maintenance by qualified technicians. Installers need to offer a clear line of communication for technical support.
- Manufacturers and installers can further develop software tools to improve predictive maintenance, fault identification and heat loss calculators to improve efficiency. These developments are to be undertaken at the design/R&D stage.

Installation and operation & maintenance case study

Closing the skills gap: the Warmstart scheme

What is it about?
The Warmstart scheme, managed by Warmworks working with The Wise Group and the UK Government's Kickstart scheme, is an initiative to match young people with training and apprenticeship opportunities through members of Warmwork's supply chain.

Why is it important?
This skills support scheme directly addresses the skills gap observed in the heat pump system industry. Since the launch of the scheme in April 2021, 16 jobs and placements have been created. The long-term aim is for the holders of these placements, if successful, to be given longer-term apprenticeships or permanent roles in the Warmworks supply chain.

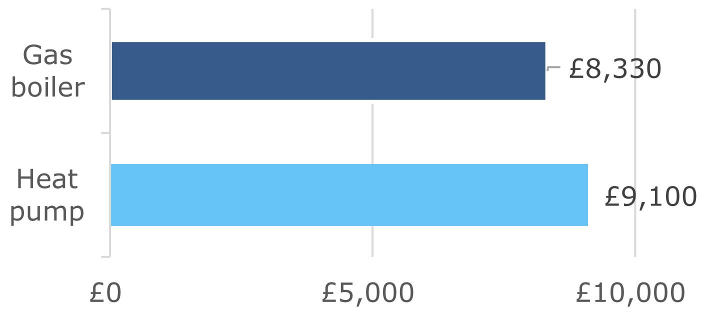
An opportunity for Scotland
The increase in the number of high-quality heat pump installers required to meet deployment targets is immense. While an immediate action is to retrain the existing boiler installer base for heat pump installations, a critical medium-to-long term goal is to expand the installer base with new entrants. This is particularly important since the high average age of the existing installer base means many will be retiring within the decade (Nesta, 2022b). If adopted widely by installers, such schemes have the potential to augment the heat pump workforce as part of a green recovery.

3.2. Findings by value chain stage

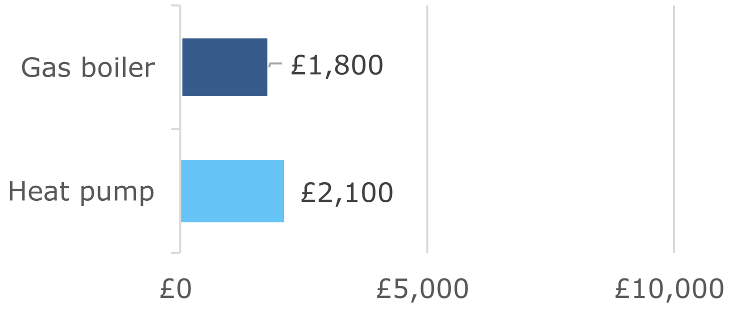
Downstream cost breakdown

The estimated costs for installing an ASHP in a small home post-1950 flat (50-100m2) of ~5kW are greater than that of a traditional gas boiler (Nesta, 2022d and 2022c)

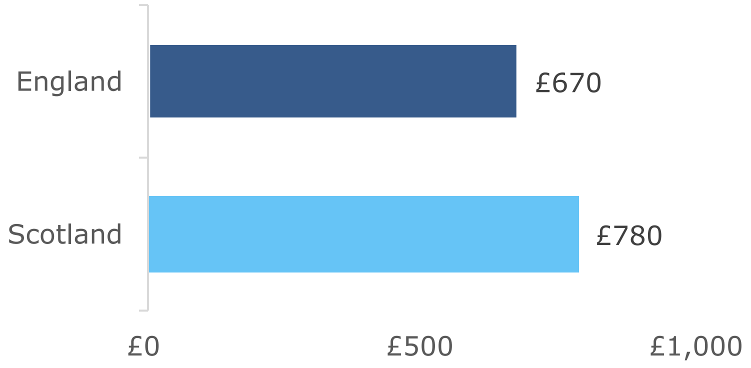
Upfront costs in Scotland (£ total in 02/2022)



Reduced upfront costs by 7,000£ (Home Energy Scotland loan) (£ total 02/2022)



Current whole life cost per year for an air-to-water heat pump relative to a gas boiler, including running costs



The upfront cost of installing a heat pump unit does not vary that much between smaller and larger properties, especially for monobloc systems. It should be noted that although upfront costs are rising, heat pumps are becoming slightly more efficient over time, resulting in lower running costs. The difficulty in understanding heat pump installation costs comes from the high variation associated with the rest of the heat pump system (Nesta, 2022c)*.

Whole life cost of a heat pump **£780 more per year**

* A 16kW heat pump package, for example, ranges from £4,000 to 8,500; however, the installed cost can vary from a few thousand pounds to over £30,000.
** Baseline energy rates used are based on the regional average of Ofgem's capped rates – using the expected increased rates of April 2022 from 2022-23, then a return to October 2021 rates from 2024-35

3.2. Findings by value chain stage

End-of-life focus

Legend: Critical assessment

Internal factors	*External factors*
Strength	Opportunity
Weakness	Threat

End-of-Life

End-of-life refers to activities that recycle or reuse the heat pump system or its constituent parts into new materials after the end of the anticipated product life.
Recycled and reused components can re-enter the value chain, thereby reducing waste and potentially input costs.

The expected life of a heat pump system is approximately 15-20 years, assuming regular maintenance is undertaken.

Key activities

- Decommissioning services
- Material collection
- Material sorting
- Material recovery and recycling processes (e.g., shredding, pressing)

Required capabilities

- Specialised engineering expertise
- Machine operators (e.g., shredders)
- Collectors
- Waste separators (hand-pickers and automated trammel operators)
- Waste material certification, auditing and planning
- Technical qualifications working with F gas (applies to refrigerant recycling)

Critical assessment of Scotland's value chain stage

- There is little evidence from existing literature and stakeholder interviews to show widespread end-of-life activities being undertaken in the heat pump system sector in Scotland. Given that nearly all heat pump system components can be recycled, this is a missed opportunity for Scotland.
- Recycling is mostly limited to small units and base materials.
- Scotland has adequate facilities and capabilities (and existing recycling companies) for industrial recycling in general. It is likely that these can be scaled for heat pump systems in Scotland.
- The life expectancy of a heat pump system is approximately 15-20 year.

Recommendations

- Encourage the sector to undertake research into end-of-life activities (e.g., to understand the economic benefits of recycling components). This is particularly relevant for the 'design and R&D' stage, since much of the end-of-life potential is determined at this value chain stage. It is best to anticipate this before the heat pump stock reaches the end of its life.
- Develop partnerships between manufacturers, wholesalers and installers to better define responsibilities and identify synergies.
- Implement the UK Government's extended producer responsibility (EPR) schemes, placing responsibility for the environmental impact of a product on the producer (Defra and EA, 2023)*.
- Support investment in commercial waste recycling infrastructure through the Recycling Improvement Fund (Scottish Government, 2022).
- Develop a digital waste tracking service.

* In Scotland is currently part of four UK EPR systems regarding Packaging, Waste Electrical and Electronic Equipment, Batteries and End of Life Vehicles (Zero Waste Scotland, 2019).

3.2. Findings by value chain stage

End-of-life case study

IVT Heat Pump Recycling Scheme

What is it about?

Ground source heat pump manufacturers IVT introduced a recycling scheme available across the UK in 2018 to encourages customers to trade in their old ITV heat pump and receive a discounted replacement system (Alto Energy, 2023). Up to £1,200 (roughly 10% of the heat pump system cost) can be saved for the purchasing customer. Recycled materials include the refrigerant as well as metals from the frame and casing, electrical components and mechanical components. Repurposed materials include the controller.

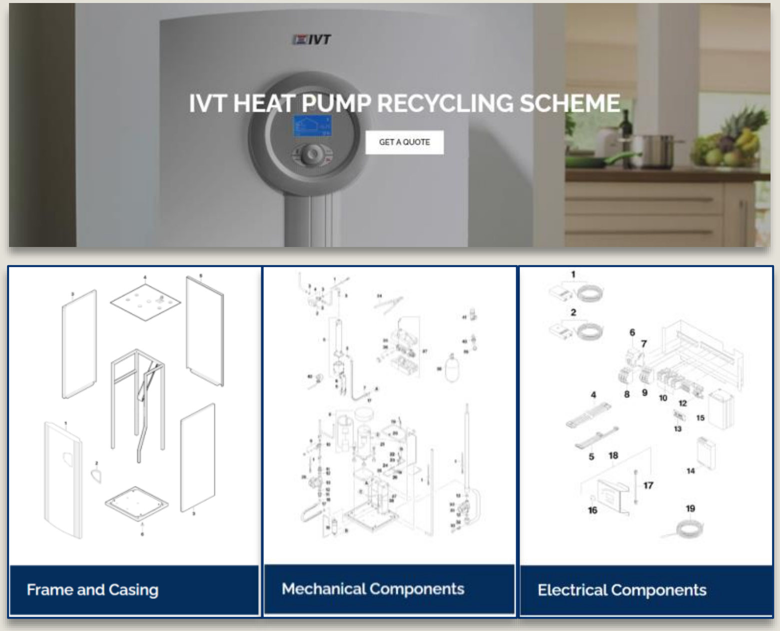
Why is it important?

The recycling scheme provides a case study of a recycling process that overcomes many of the obstacles facing end-of-life activities. For example,

- Framed as a cost saving scheme, it offers an effective economic incentive for the customer to participate.
- It is easy and convenient for the customer as participating stakeholders collect the heat pump, saving the customer a difficult disposal task. In turn, this ensures that the heat pump can be recycled as effectively as possible.
- There are environmental benefits from the materials recycled or repurposed.

An opportunity for Scotland

The limited evidence of end-of-life activities in Scotland in the literature examined and experts interviewed shows that this is an opportunity yet to be fully captured. The IVT Heat Pump Recycling Scheme is a case study of how a heat pump system business model can be structured to best recapture important materials and metals. This not only offers environmental benefits, but may reduce input costs for manufacturers which can then be passed on to consumers. Given the perception of heat pump systems as being prohibitively expensive, the cost recovery potential may prove to be an effective lever to encourage heat pump system adoption.



Recycled materials under the ITV Heat Pump Recycling Scheme, as shown by Alto Energy (a UK supplier and distributor offering the ITV scheme).

4. Conclusion

4. Conclusions

Key findings and recommendations

Heat pump heating systems share many elements with traditional boiler heating systems but require advanced controls for efficient optimisation

- Many components are shared between heat pump and traditional boiler heating systems.
- Notwithstanding, many of these vary in size between the two due to the lower temperatures and higher flow rates of heat pump systems.
- Heat pump systems require a buffer vessel or thermal store to prevent cycling. This is much less of an issue for domestic boiler systems, however, which can mean that heat pump systems require some additional equipment.

Heat pump system costs

- The project value of a heat pump was found to be approximately one third of the total system cost.
- The next largest cost was found to be upfront cost, including purchase, installation and commissioning. To be noted that installation costs were found to be highly variable.
- The total market value for heat pump systems is forecast to be around £359 million in 2026 in Scotland.

Materials and manufacturing

- Certain materials including stainless steel, aluminium, copper and plastic are required both in heat pump and heat pump system components. This links the cost of heat pump systems to these raw materials.
- Manufacturing processes such as the ones required to produce electrical components are scalable and can vary output with little change once established. Components such as compressors require specialist design and manufacture, however, and are harder to set up without prior experience/infrastructure.
- Scottish value chain capability is more likely to lie in the materials processing side rather than raw material extraction.
- Scotland has the capacity to carry out pipe bashing and welding, and manufacture its own heat exchangers and heat storage/hot water cylinders.

4. Conclusions

Key findings and recommendations

Several barriers to heat pump system deployment were identified across the value chain

- Overall, it is less likely that upstream activities will constrain large-scale deployment. Global supply chains are strong, and although there are obvious economic benefits to localised supply chain activities, the industry as a whole can respond to increasing demand from a manufacturing point of view. In contrast, the downstream value chain is where the more telling weaknesses and risks currently lie; it is therefore in this relatively weak downstream value chain where the Scottish Government and industry stakeholders need to inject greater confidence to strengthen the sector.
- Innovation is also required to improve system design that will optimise operational efficiency and uncover the cost-saving opportunities around end-of-life activities (which have yet to be demonstrated at scale).

A major barrier to heat pump system development was found to be the lack of public understanding of heat pumps

- Lack of understanding or trust by potential/existing users can lead to misinformation and improper use of heat pump systems and prevent efficient operation, further damaging public perception. A coordinated education campaign across all industry stakeholders, led by Scottish Government, is recommended.

Scotland’s heat pump sector requires more high-quality technicians to reach its deployment targets

- Several sources have highlighted a skills gap in terms of the number and quality of heating engineers in Scotland. However, some stakeholders engaged suggest the gap is perceived or overexaggerated, citing the similar installation capability requirements between gas boilers and heat pumps. In this regard, a lack of expertise in the proper installation and commissioning of heating systems generally applies and that this is less of an issue for boiler technologies.
- Notwithstanding this debate, what is clear is that a much higher *number* of qualified heat pump technicians are required if the ambitious deployment targets are to be met. Increasing this labour pool will entail incentivising and supporting existing boiler technicians to retrain (considered a short term solution), and attracting new entrant through apprenticeships (this is particularly important given the old age of the existing technician base).
- By tackling the skills gap quickly and decisively, Scotland’s heat pump sector stands a greater chance of not only meeting its deployment targets, but also creating economic opportunities as part of a green and just transition.

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Thank you

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