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Short Guide

AIR SOURCE HEAT PUMPS IN TRADITIONAL BUILDINGS

HISTORIC ENVIRONMENT SCOTLAND
ÀRAINNEACHD EACHDRAIDHEIL ALBA

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LIST OF ABBREVIATIONS

- **ASHP** – air source heat pump
- **COA** – compulsory owners' association
- **GHG** – greenhouse gas
- **GWP** – global warming potential
- **HEPS** – Historic Environment Policy for Scotland
- **HES** – Historic Environment Scotland
- **HLP** – heat loss parameter
- **LDP** – local development plan
- **MCS** – Microgeneration Certification Scheme
- **NPF4** – National Planning Framework 4
- **PDR** – Permitted Development Rights
- **SCOP** – seasonal coefficient of performance
- **UFH** – underfloor heating
- **WBA** – whole building assessment

Please refer to the Glossary for further explanation of some of these terms.

INTRODUCTION

This Short Guide provides information on the integration of air source heat pumps (ASHPs) in traditional buildings, commissioned by Historic Environment Scotland (HES). As the Scottish Government intensifies efforts to meet net zero carbon emissions targets by 2045, this document outlines the role of ASHPs in reducing greenhouse gas emissions from Scotland's traditional built environment. The guide emphasises the balance between preserving architectural heritage and adopting modern, sustainable heating technologies while demonstrating that ASHPs can work efficiently, even in buildings with high heat demand, when designed and specified well.

Key topics include policy frameworks, technological insights into ASHP operations, assessing heat demand in traditional structures, and the practicalities of fabric-first approaches to enhance building performance. The document also addresses design considerations, regulatory requirements and maintenance needs, and presents case studies illustrating successful ASHP installations in heritage contexts.

This document aims to equip stakeholders — including architects, planning officers and building owners — with the necessary knowledge to make informed decisions about implementing ASHPs in the context of Scotland's built heritage.

1. POLICY BACKGROUND

1.1 CLIMATE CHANGE AND GREENHOUSE GAS EMISSIONS

The primary driver of the uptake in air source heat pumps (ASHPS) is the overarching move by the Scottish Government to reduce greenhouse gas (GHG) emissions as set out in the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019. This set a legally binding target to achieve net zero GHG emissions by 2045.

A new Heat in Buildings Bill is due to be published by the Scottish Government. It builds upon previous iterations and reaffirms the central importance of phasing out polluting heating systems by 2045. It will set out the steps to be taken to reduce GHG emissions from Scotland's buildings and covers structures of all ages, construction methods and materials as well as a diverse range of uses. Emissions will be reduced through a range of energy efficiency improvements, as well as significant decarbonisation of heating systems.

ASHPs will be a critical part of this effort. Within the Heat in Buildings Strategy 2021 there is an interim target to decarbonise the heating systems of one million homes by 2030, with almost all homes and buildings using 'clean' heating systems by 2045.

The use of ASHPs, along with other clean heating technologies, will contribute to a number of the outcomes from the strategy as follows:

- 'Heating our buildings no longer contributes to climate change'
- 'Our indoor and outdoor spaces are filled with cleaner air'
- 'Our heating systems enable and efficiently use Scotland's renewable energy resources'
- 'Electricity [is] produced from sustainable sources in a way which is consistent with net zero emissions and biodiversity targets'
- 'Our heating systems enable the flexible and stable operation of our energy networks'

The last three of these points reinforce that while Scotland is decarbonising its electricity infrastructure, it is important that a market is developed in parallel to make the best use of this renewable energy as it arrives.

Four 'no and low regrets' strategic technologies are given special mention in the strategy, and two of these involve heat pumps: properties off the gas grid which currently use high carbon heating fuels, and buildings where heat pump deployment can be shown to be cost effective. Many of the case studies throughout the Heat in Buildings Strategy feature heat pump installations.

The strategy recognises the special place of traditional and heritage buildings. It acknowledges that bespoke approaches may be required and commits to working with HES to establish what these might be for listed buildings and those in conservation areas. However, no specific or detailed guidance is provided.

1.2 HISTORIC ENVIRONMENT POLICY & GUIDANCE

Scottish Government policy with regard to historic and traditional buildings is largely devolved to Historic Environment Scotland (HES). HES publishes the Historic Environment Policy for Scotland (HEPS), which supports and directs all decision-making that affects the historic environment. HEPS sets out a series of six principles and policies for the recognition, care and sustainable management of the historic environment. Among a range of challenges and opportunities facing the historic environment, it is acknowledged that climate change will have an impact and needs to be addressed. HES have also set out their approach to the climate and nature crises in the document, Pointing the Way to the Future. This relates to HES regulatory and advisory services in the planning and other consenting systems.

These principles and policies are then filtered down into a series of practical documents: 'Managing Change in the Historic Environment'. These identify the main issues which can arise in heritage buildings and offer guidance on how to best manage change. Importantly, they are intended to inform planning policies and the determination of applications relating to the historic environment, so carry considerable weight despite being non-statutory in nature.

These guides, including one on micro-renewables, offer practical guidance, such as:

- It is important to fully understand the specific significance of the building in each case.
- Energy efficiency should be addressed before considering micro-renewables.
- Any proposals should be carefully planned to minimise impact on the historic character of the building or context.
- Where possible, installations should avoid the main and visible elevations, for example being located on secondary parts of the building, adjacent outbuildings or on the ground nearby.
- Larger or communal systems can have visual and other impacts beyond one building, and the wider context should be assessed. The point is made that a single communal installation may be preferable to a larger number of individual installations.

- Physical impacts can include those affecting structure, archaeology, fabric and environmental aspects of a site and all interventions should be minimised.
- Impacts extend beyond visual and physical and can include vibration, emissions and noise, all of which need to be considered.
- Access to equipment may be required for maintenance and needs to be considered.
- Installation of ASHPs may affect the hygrothermal balance of a building (for example through a continuous cold air plume), which needs to be considered.
- Any fixtures (which might include parts of a renewables installation) should be sited to avoid detracting from the appearance of the roof, being seen from ground level or breaking the roof profile.
- It is important to carefully consider the routing of pipes and cables and notes.
- Painting unavoidable fixtures to match the surroundings can help to minimise their visual impact.

Conversion of Traditional Buildings – Guide for Practitioners (to be revised 2026) is an important document produced in partnership by the Scottish Government's Building Standards Division and HES, and intended to support practitioners in the appropriate application of the Scottish Building Standards in the context of traditionally constructed buildings. As such it offers a useful guide to the Technical Standards themselves, which are a critical part of the toolkit in enacting the wider policy drivers of the Scottish Government.

1.3 PLANNING POLICY

Scottish Government's National Planning Framework 4 (NPF4) was published in 2023 and comprehensively updated the highest-level planning guidance in the country. There are two parts. Part 1 comprises a spatial strategy for the country, while Part 2 presents the updated national planning policy. This is organised into three overall themes: Sustainable Places, Liveable Places and Productive Places.

Within these themes are 33 policies covering large-scale issues like climate change mitigation, sustainable transport, digital infrastructure and tourism.

While ASHPs are not mentioned by name, there is clear direct and indirect support throughout the document for renewables and clean heat installations, as part of the wider move to decarbonise our national infrastructure and address climate change.

Importantly, Policy 7 is focused on historic assets and places and is intended to 'protect and enhance historic environment assets and places, and to enable positive change'. The transition to net zero is specifically mentioned and while clean heating is not discussed, support for it is clearly implied. It remains the case, however, that 'development proposals for the reuse, alteration or extension of a listed building will only be supported where they will preserve its character, special architectural or historic interest and setting'. Meanwhile, 'development proposals in or affecting conservation areas will only be supported where the character and appearance of the conservation area and its setting is preserved or enhanced'.

While NPF4 sets out the high-level policy framework, these goals are supported and enabled through the local development plans (LDP) for each local authority. LDPs set out how places will change going forward, and they guide decisions on applications for planning permission.

1.4 SHARED OWNERSHIP

Following the publication of the Heat in Buildings Strategy, it was acknowledged that tenements represent a particular challenge to both energy efficiency and zero emissions heating solutions. One of the main reasons is that these buildings usually have owners, and co-ordinated or communal solutions are not always easy to organise.

As a result, the Tenements Short Life Working Group was set up to report on Energy Efficiency and Zero Emissions Heating, and its final report was published in late 2023. The report makes the important point that the existing condition of many properties is poor and that in any strategy, the priorities should be repair, maintenance, then energy efficiency and lastly clean heating technologies. It acknowledges the range of additional challenges faced by those within tenement and similar buildings and concludes with six recommendations:

- Owners will require funding from government and access to finance because of the very high costs often involved and the wide range of ability to afford these measures. It does note the considerable economic and cultural opportunities provided by the work needed.
- The Group supports the Scottish Government's proposals to take a phased approach to regulating tenement buildings as well as the proposal to establish compulsory owners' associations (COA).
- A whole building assessment (WBA) for energy efficiency and zero direct emissions heating should be developed for all properties.

- Current work streams by the Scottish Law Commission (including with regard to COAs) should be supported and properly aligned.
- The Tenements Act should be further amended to support energy efficiency and clean heating measures.
- Expert advice is required on traditional and protected buildings, as acknowledged in the Heat in Buildings Strategy.

2. ASHP TECHNOLOGY

ASHPs, while relatively new to homes in the UK, are a well-established technology, with Glasgow University's Lord Kelvin having described their operation as early as the 1850s (Zogg, 2008).

ASHPs use electrical energy to move heat from the outdoor air into a building, providing heating and hot water. This is achieved through a refrigeration cycle, the same technology that powers domestic fridges and freezers. An electrically driven **compressor** controls the pressure of a working fluid (known as refrigerant) in the refrigeration circuit. In the **evaporator** of the ASHP, the refrigerant pressure is reduced so that the refrigerant begins to boil at temperatures below the ambient air temperature. This means that heat is absorbed from the outdoor air, even when the air temperature is well below freezing. A **fan** is used to push outdoor air over the evaporator and increase the rate of heat transfer from the air into the refrigerant. The refrigerant is now a gas and travels to the **condenser**, where it is compressed. This causes the refrigerant to condense back into a liquid and release heat, usually into the radiator circuit or directly into the indoor air. The refrigerant then returns to the evaporator to repeat the cycle.

All domestic ASHPs operate using this basic refrigeration cycle, with the main differences between systems being in the type of refrigerant used and how heat is transferred from the condenser into the building.

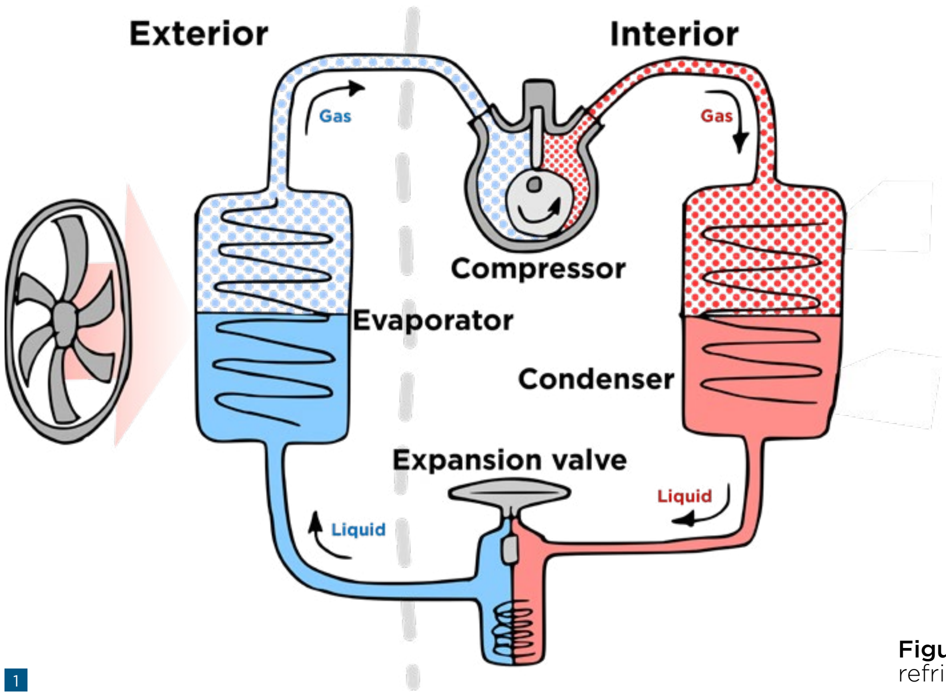

Figure 1. The basic refrigeration cycle.

2.1 AIR TO WATER SYSTEMS

In an air to water system, heat is extracted from the air in the evaporator and transferred from the condenser into a wet heating system. The wet system can then use traditional heat emitters such as radiators and underfloor heating to deliver heat throughout the building, as well as generating hot water in a storage cylinder. This can be particularly ideal for historic buildings that already have a wet heating system. When connected to an underfloor heating system, the internal visual impact is effectively eliminated.

In a **monobloc** air to water heat pump, the full refrigeration circuit is contained in the outdoor ASHP unit. Wet heating system pipework connects the external unit to the indoor wet heating system.

In a **split** air to water heat pump, the ASHP is split into two parts. The condenser is located indoors, separate from the external evaporator. Refrigerant pipework connects the external unit to the internal unit, which in turn interfaces with the wet heating system.

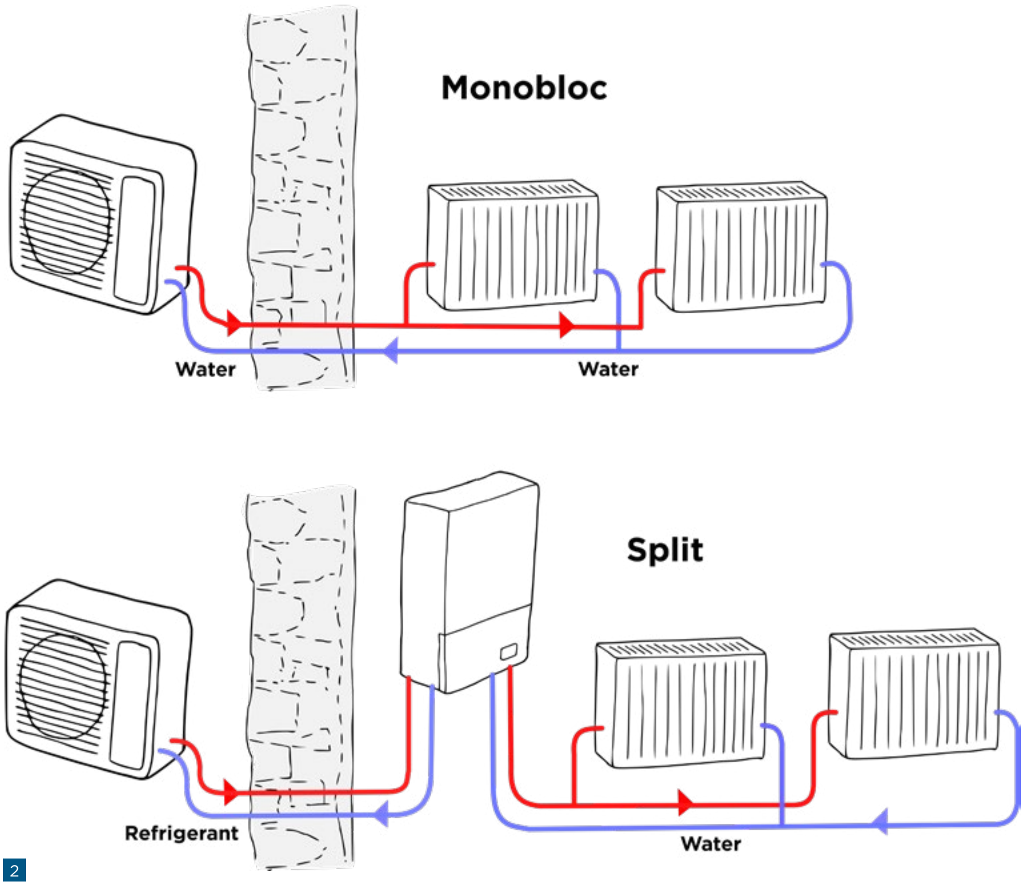

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Figure 2. Air to water systems can connect to existing heat emitters such as radiators. This can be achieved with a monobloc (top) or a split system (bottom).

The key advantage of a monobloc system is that the refrigeration circuit is sealed at the factory and does not need to be modified at installation. A split system requires the installer to be F-Gas qualified to work with refrigeration pipework. As a result, monobloc systems are the more commonly used type of air to water heat pump.

2.2 AIR TO AIR SYSTEMS

Air to air systems, commonly known as air conditioning units, bypass the need for a wet heating system by directly transferring heat from the condenser into the indoor air of the building. In domestic applications this is most commonly delivered with wall mounted indoor units and wall or floor mounted outdoor units.

Single-split air to air systems feature a single outdoor unit connected to a single indoor unit, suitable for when only one room of a building is required to be heated. **Multi-split** systems use a single outdoor unit connected to multiple indoor units, and so can be used to heat multiple rooms.

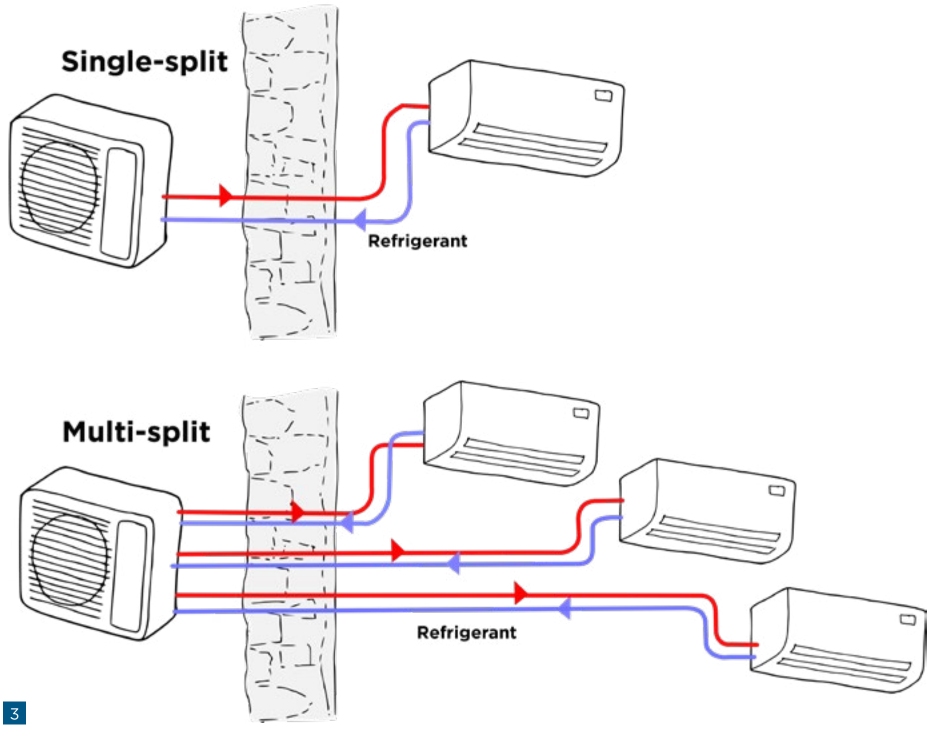

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Figure 3. Air to air systems connect refrigerant directly from the outdoor unit to the heat emitters. These are either connected in a single-split or in a multi-split system.

These wall-mounted air to air units are typically quite modern in appearance, and as such the visual impact on historic interiors needs to be considered. Additionally, the indoor units use fans to circulate air around the room, generating a small amount of noise. Air to air systems cannot generate hot water, and so a separate hot water system is required. Air to air systems can also be operated in reverse, to provide cooling in the summer.

2.3 REFRIGERANT CHOICE

A key characteristic of any ASHP is the type of refrigerant that it uses, as this can have a significant environmental impact.

It is important to look for refrigerants with a low global warming potential (GWP). GWP is a measure of the greenhouse warming effect of a refrigerant, compared to carbon dioxide. For example, R-410A, a popular refrigerant, has a GWP of 2,088. This means that one kilogram of R-410A released into the atmosphere has the same global warming effect as releasing 2,088 kilograms of CO_2, over a 100-year period.

While ASHPs are designed to minimise the possibility of refrigerant leakage, it remains a risk. Therefore, it is important to select a ASHP with a low GWP refrigerant to minimise environmental impact in the event of a leak.

In domestic ASHPs, common refrigerants include R-32, with a GWP of 675, and R-290 (propane), with a GWP of 3. R-290 is becoming increasingly popular due to its very low GWP, but its flammable nature means that ASHP manufacturers require some additional safety measures. These are discussed further in Section 5.

2.4 TECHNOLOGY SUMMARY

Type	Advantages	Disadvantages
Air to Water	• Connects directly with existing wet heating systems • Can generate stored hot water • Monobloc systems do not need an F-Gas engineer • Monobloc systems have reduced likelihood of refrigerant leaks • Generally lower GWP refrigerants available	• No or very limited cooling capacity • Performance highly dependent on design of heat emitter system • Radiators take up more wall space than air to air indoor units
Air to Air	• Indoor units take up less space than equivalent output radiators • Can be cost effective option for buildings without an existing wet heating system • Can provide cooling as well as heating	• Cannot generate hot water • Indoor unit fans generate noise • Indoor units generally less visually suited to historic buildings than radiators • F-Gas engineer required to install and maintain • Increased risk of refrigerant leaks • Generally only higher GWP refrigerants available

3. ASSESSING HEAT DEMAND

Understanding heat loss allows you to size your heating system correctly. Incorrect sizing could lead to inefficient systems, expensive systems, or overly complex systems, or it could lead you to conclude that your home is not suitable for an ASHP.

For a heating system to keep a building warm, it needs to be able to add heat to the building at the same rate that it is being lost to the outside. This rate of heat loss from the building, also known as the heat demand, will vary as the external temperature changes, reaching a peak on the coldest days. Heat loss is usually measured in kilowatts (kW).

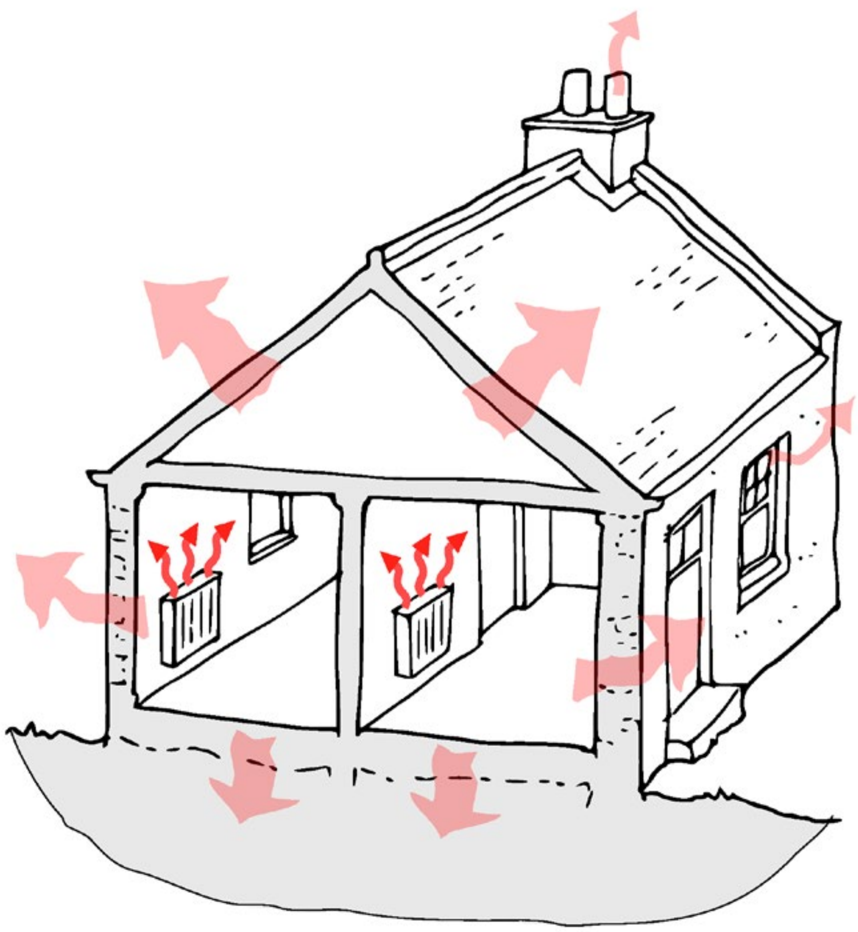

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Figure 4. To keep a building warm, the heating system must deliver heat at the same rate it is being lost to outside.

Heating systems are most efficient when the heat source, be that a gas boiler or an ASHP, can operate for long periods at optimum efficiency. This is achieved by correctly matching the heat source's power output to the building's heating demand. Too small, and the heat source cannot supply heat as fast as it is being lost to outside, and the building's internal target temperatures will not be achieved. However, larger is not always better. If the heat source is oversized, it may frequently cycle on and off to prevent overheating the space, which reduces the time the heat source operates at peak efficiency. This principle applies to both fossil fuel and ASHP systems; however, ASHP systems are more sensitive to cycling because the efficiency dramatically drops while the unit is starting up. ASHPs are at their most efficient when they can operate 'low and slow', constantly trickling heat into the space to keep it comfortable.

The higher unit cost of electricity than gas and oil makes an inefficient ASHP more expensive than an inefficient boiler. Most boiler systems are vastly oversized, but because gas and oil are still cheap relative to electricity, the cost impact to consumers is comparatively low (George Bennet, 2020).

3.1 THERMAL TESTING

To correctly size the ASHP and minimise running costs, it is essential to understand the building's heat demand. The most accurate method for determining this is through thermal testing of the building. In this process, a heat source with a known output is placed inside the building, and the effect on internal temperatures is monitored over time. This data is then compared with external weather conditions to calculate the building's heat loss. However, this method can be time-consuming and costly and requires the building to be unoccupied, making it unsuitable for many properties.

Some businesses offer an alternative method, using smart meter data, internal temperature loggers and external weather data in combination to establish the heat loss of a building. This has the advantage that the building can continue to be occupied during the test period.

3.2 HEAT LOSS CALCULATIONS

The next best option is to conduct a heat loss calculation. By using precise measurements of the building and making certain assumptions about the thermal transmittance of various elements of the building fabric, it is possible to calculate the theoretical heat demand for a specific design condition. For example, a design condition could involve maintaining an internal temperature of 21°C while the external air temperature is at -5°C.

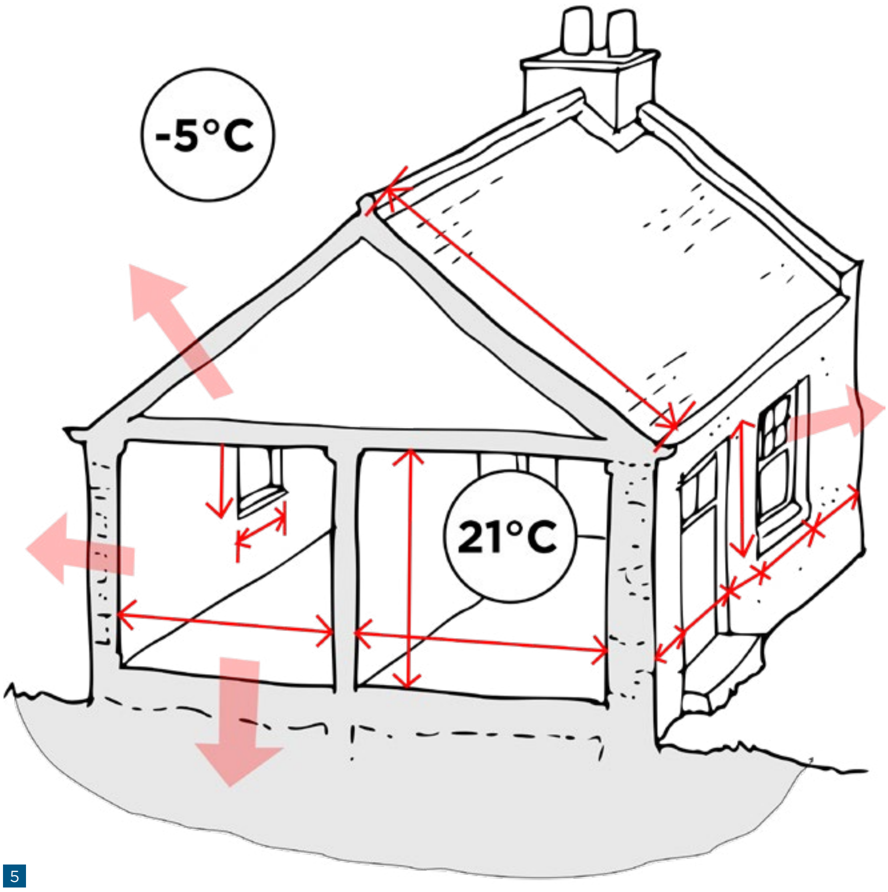

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Figure 5. An accurate heat loss calculation requires a detailed survey of the building.

Heat loss calculations are only as accurate as the assumptions entered into the calculation model. They must be carried out in alignment with established standards. In the UK, the relevant standard for domestic properties is the Microgeneration Certification Service (MCS) heat pump standard MIS 3005-D (MCS Charitable Foundation, 2024). This standard provides specific instructions for assessing heat demand, including design temperatures for different regions of the UK.

Due to the low cost of high-heat-output fossil fuel systems and the relatively inexpensive fuel associated with them, it has become common practice in the UK to forgo heat loss calculations and instead rely solely on rules of thumb when designing heating systems powered by fossil fuels. Consequently, there is considerable variation in how heating engineers understand these calculations. To ensure that a heating calculation is being carried out correctly, there are some key questions a client can ask:

- Has a measured survey of the building been carried out, including dimensions of all doors, windows and radiators?
- What u-values (thermal transmittance) have been assumed for the roofs, walls, floors, windows and doors? Are these appropriate for a traditionally constructed building?
- What internal and external design temperatures are used in the calculation? Are these temperatures suitable for the local weather and the building occupants' needs?
- What value of airtightness has been assumed? Is this appropriate to the age and condition of a traditionally constructed building?

Once the heating demand is determined, a heating engineer can choose an ASHP that meets the building's requirements.

3.3 HYBRID OR BIVALENT SYSTEMS

In some cases, ASHPs are installed alongside boilers to form a hybrid system. The ASHP is designed to cover the majority of the heating demand, with the boiler 'topping up' the heating on the coldest days. If the controls are not set up well, there is a risk that the boiler dominates the heating for most of the year, with the ASHP sitting idle. Modern ASHPs are more than capable of operating across the full range of UK winter temperatures and deliver temperatures close to that of a traditional fossil fuel system. In many cases, hybrid systems add unnecessary installation cost, complexity and carbon emissions without making a notable reduction in running costs.

A hybrid solution may be suitable for large homes where the heating demand exceeds 16kW, as this will often require upgrading the electricity supply to three phases. Such an upgrade can be costly, or prohibited by limitations on the local electrical network capacity. In these cases, it may not be possible to install an ASHP that can meet the peak heating demands. Therefore, a boiler could serve as an effective backup option.

4. FABRIC-FIRST AND ASHPS

4.1 THE FABRIC-FIRST APPROACH

Improving the thermal performance of a building prior to installing an ASHP is widely recognised as best practice. A well-insulated property should enable the specification of smaller, less expensive systems. This results in lower carbon emissions, reduced energy bills and enhanced comfort.

The first consideration around fabric when installing an ASHP should be basic repair and maintenance. A building should be in good repair, free from defects — such as blocked gutters, downpipes, or defects to roof coverings — before the ASHP is installed.

Once maintenance has been taken care of, then improvements to the thermal performance of fabric can be considered.

Figure 6. Floor insulation is one of the ways a building can be insulated before installing an ASHP.

The fabric-first approach prioritises reducing heat demand through measures like insulation and airtightness before addressing heating systems. However, practical limitations in traditional and historic buildings can complicate this process, for example in relation to overall budget and concerns about the impact on the buildings' significance.

4.2 BALANCING FABRIC IMPROVEMENTS VS SYSTEM EFFICIENCY

While an ASHP can technically be installed in any building regardless of its insulation levels, poor thermal performance can lead to higher running costs and the need for larger, more expensive systems. Striking a balance is crucial.

In many cases, undertaking 'low-hanging fruit' insulation measures, those that are cost-effective and minimally disruptive, can significantly improve building performance. Common examples include adding insulation to roofs or floors and improving airtightness, all of which can yield high returns on investment. These measures not only enhance comfort but also ensure the ASHP is appropriately sized, minimising upfront and operational costs.

Figure 7a and b. Upgrading windows and insulating roofs is an easy way building fabric can be prepared ahead of ASHP installation.

4.3 DETERMINING THE INFLECTION POINT

A key consideration is identifying the point at which additional insulation becomes less cost-effective than simply installing or upgrading an ASHP. This inflection point varies between buildings, depending on factors such as energy prices, tariffs and building characteristics.

Recent UK studies suggest that the inflection point occurs at a heat loss parameter (HLP) of around 2.5. For context:

- A typical uninsulated traditional building has an HLP of around 5.
- A highly insulated modern building achieves an HLP of about 0.5.

Another way to view this is through heat loss per square meter. Older homes are often designed with a heat loss of around $100W/m^2$, while Passivhaus standards aim for $10W/m^2$. For ASHPs, the economic threshold tends to align with a heat loss of approximately $50W/m^2$, a level achievable in many properties using straightforward insulation techniques.

4.4 STAGED RETROFIT AS A STRATEGY

For traditional and historic buildings, the concept of a staged retrofit is becoming increasingly valuable. This approach recognises that it may not be feasible to undertake all ideal measures simultaneously due to budgetary or practical constraints. A staged retrofit involves:

- implementing cost-effective, lower-impact fabric improvements up front;
- carefully designing initial measures to avoid compromising future interventions;
- creating a long-term plan that ensures compatibility with future upgrades and progress towards net-zero goals.

For instance, an initial retrofit stage might include insulating the roof and floor, improving airtightness, and installing an ASHP alongside appropriately sized radiators. Future stages could address more invasive measures, such as wall or window insulation, as funds and permissions allow.

What constitutes a 'well insulated' building?

It is important to note that well insulated does not just mean that each element of the building has been insulated. It also means that as far as possible, the insulation is continuous between those elements, and that there are no gaps. Gaps in the insulation are usually called 'thermal bridges' and avoiding them is not always straightforward to achieve in existing buildings. It is also important to note that in many buildings, air leakage can be responsible for up to 40% or so of heat loss, and so if this is not addressed, the efforts to insulate the building can be heavily compromised.

5. DESIGNING ASHP SYSTEMS FOR TRADITIONAL BUILDINGS

There are a number of key design areas that need to be carefully considered so that the ASHP system operates efficiently.

5.1 RADIATOR SIZING

The primary factor influencing ASHP operating costs is the flow temperature. Lower flow temperatures lead to greater efficiency in ASHPs. A good rule of thumb is that a 1°C reduction in radiator temperature can reduce running costs by 2.5%. The precise relationship between radiator temperature and running costs will depend on the specific equipment and system design.

However, as the flow temperature gets lower, the size of the radiators in a building must increase to deliver the correct amount of heat into the space, as illustrated in Figure 8. A standard 450x500mm double panel radiator can emit around 650W of heating power at a radiator temperature of 70°C. At a radiator temperature of 47.5°C (corresponding to a typical ASHP operating temperature of 50°C), the radiator would need to be about twice as long (1,000mm) to deliver the same heating power.

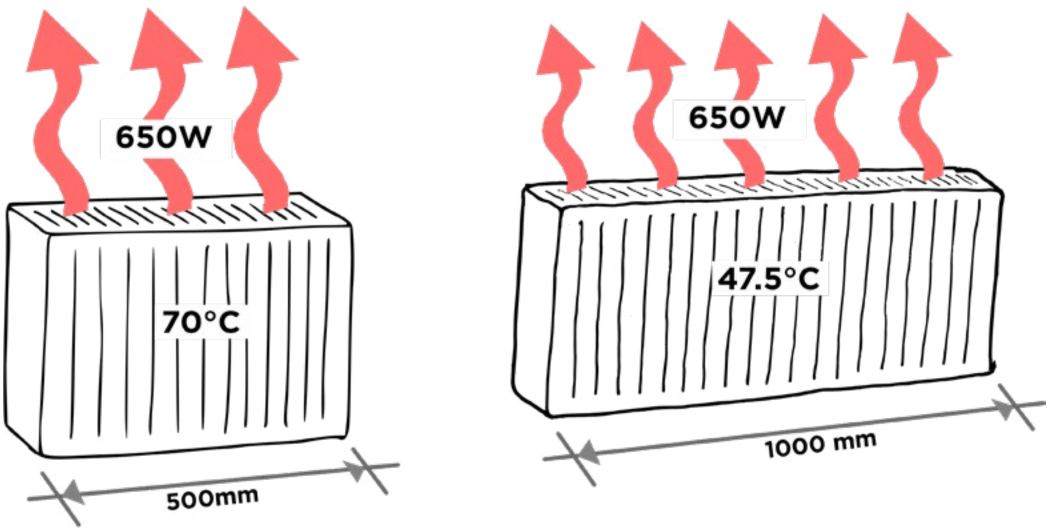

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Figure 8. Reducing the temperature of radiators means they need to be larger to deliver the same amount of heat.

Fortunately, in many existing gas or oil-fired systems, the radiators are typically oversized in order to quickly warm up a room from a cold state. However, as discussed later in this section, this rapid heating is not essential for an ASHP system, as rooms are kept at a stable temperature. Therefore, it is not always necessary for the output of the new ASHP system to exactly match the output of the previous, higher temperature system.

This means that if an ASHP is installed, the need to increase radiator sizes is reduced. The radiators' design needs to strike a balance between achieving the lowest possible flow temperature and keeping the size within reason. The acceptable size and quantity of radiators will be specific to each home. Some will be willing to give up more wall space for radiators in exchange for lower running costs, while others will prefer to limit radiator sizes and accept higher running costs. It is important that building owners are well informed about the impact on efficiency this decision has.

In some historic buildings there may be an aesthetic preference for cast iron column-style radiators. The reduced heat output of these older-style radiators compared to modern alternatives should be accounted for in the system design.

5.2 UNDERFLOOR HEATING

Underfloor heating (UFH) can be a good means of achieving a low system flow temperature (and associated low operating costs), as the whole surface area of the floor becomes a heat emitter. Unlike radiators, UFH does not use any wall space, minimising visual impact.

In a typical home with an estimated annual heating demand of 12,000kWh, the cost savings at current electricity prices between a radiator system designed to operate at a maximum temperature of 50°C and an UFH system designed to run at a maximum temperature of 35°C would be approximately £50 per year.

The installation of underfloor heating is more expensive and disruptive than that of radiators. While underfloor heating works well with an ASHP, it is not a prerequisite for low running costs, and the additional installation costs and disruption should be carefully considered.

5.3 PIPEWORK

When pairing an ASHP to an existing heating system, the size of the existing pipework needs to be assessed.

Domestic ASHPs generally operate with much higher flow rates than gas or oil boiler systems. If the existing pipework is not large enough for these higher flow rates, a number of issues can arise, such as:

- insufficient system flow rate (leading to higher running costs);
- noise from pipework;
- deterioration of pipework;
- increased wear on system pumps.

In many cases, the existing pipework can be reused without issue, but sometimes pipework will need to be upsized to handle the increased flow rates. 'Microbore' pipework with a diameter of 10mm or less can be a particular issue. Microbore is flexible, cost-effective and easy to install, making it ideal for installation in older properties, which explains its popularity since the 1970s. It is often recognisable by its diameter and may not be perfectly straight like standard lengths of pipe, as it has been installed from a roll and bent into shape.

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Figure 9. Microbore pipe connecting to radiator.

Existing microbore pipework can sometimes be compatible with ASHPs, but this depends on the assessment of the required flow rates by a heating engineer. In a traditional home, it is unlikely that microbore pipes can be reused unless some of the fabric improvements mentioned in Section 4 have been implemented first.

Some new ASHPs entering the market are designed to operate at lower flow rates, which may reduce the need to upgrade the existing heating system pipework.

When the system is installed, the engineer should measure the flow rate of the system in both heating and hot water mode and compare it to the manufacturer's recommendations. Operating within the correct range of flow rates is important to getting the best from an ASHP system.

5.4 BUFFER VESSELS

A buffer vessel is a tank of water installed in between the ASHP and the building heat emitters. It serves to separate the flow of water through the ASHP from the flow of water through the heat emitters. This allows the ASHP to run at a different flow rate from the radiators. Generally, buffer vessels are used in large buildings with multiple heating zones. As different heating zones open and close, the ASHP can continue to operate unaffected as the buffer vessel separates it from the heat emitter system. Most domestic heating systems in small to medium-size homes are single zone, so do not require a buffer vessel for this reason.

Buffer vessels also add volume to the heating system. This is important when the ASHP needs to operate in defrost mode. In cold weather, ice will build up on the ASHP external unit, reducing the heat transfer rate. Once the ice has built up to a level where air can no longer pass through it, the ASHP temporarily operates in reverse to melt the ice. When doing this, it will transfer heat from the heating system back into the external unit. It is important to have sufficient system volume to prevent this defrost mode from cooling down the radiators too much and subsequently reducing the temperature of the house. ASHP manufacturers will state a minimum system volume that must be met. Often, the volume of water in the pipework and radiators is enough to meet this requirement, but in some cases, additional volume will be required. While a buffer vessel can be used to increase system volume, a two-pipe 'volumiser' can add volume to the system without affecting the system arrangement.

If a buffer vessel is needed, internal space will be required to accommodate this. Some hot water cylinders are available with a small integrated buffer vessel, reducing the overall space requirements of the system.

For small domestic heating systems, buffer vessels are generally unnecessary and can sometimes decrease system efficiency. This is because it is challenging to design a buffer vessel that avoids mixing the flow from the ASHP with the return flow from the heating system. This unintended mixing can lead to a lower water temperature reaching the radiators, which forces the ASHP to operate at a higher temperature to overcome this mixing and provide the necessary heat to the radiator system.

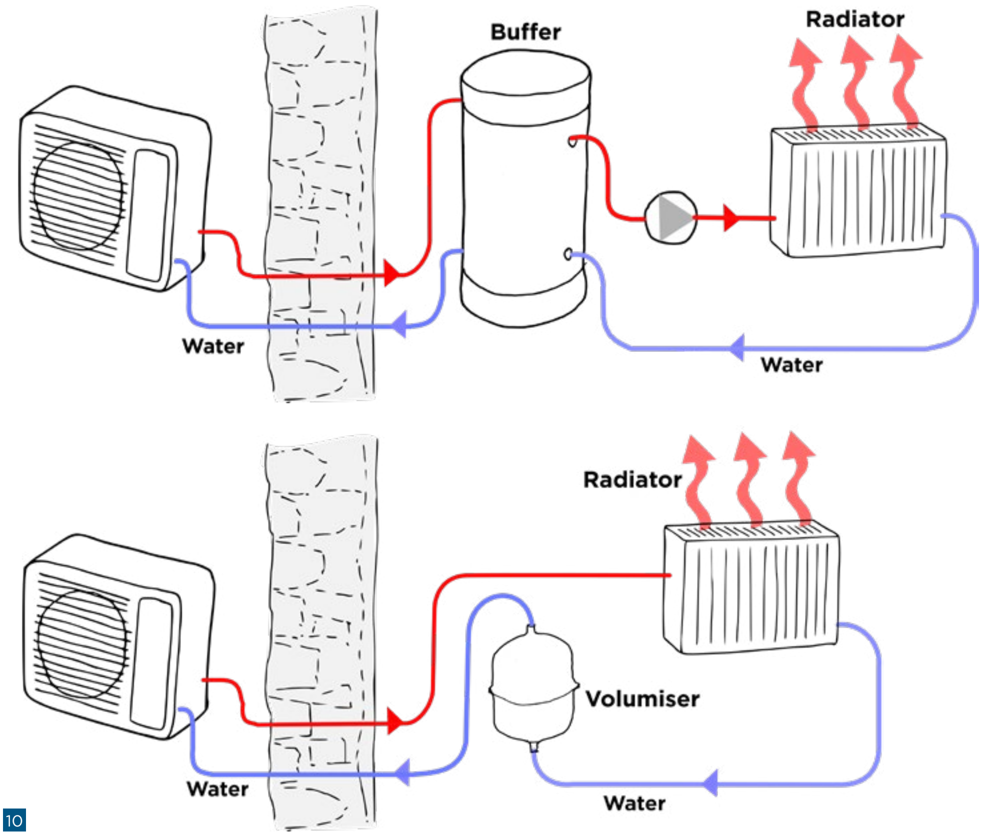

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Figure 10. The schematic difference between a buffer vessel (top) and a volumiser (bottom).

5.5 REFRIGERANT CHOICE

Refrigerants are essential for the operation of ASHPs, as they absorb heat from the outside environment and transfer it to the heating system. ASHPs utilise various types of refrigerants. From an operational perspective, the choice of refrigerant may not seem to affect homeowners directly. However, it can influence both the installation of the ASHP and the potential environmental impact in the event of an accidental refrigerant leak.

As also mentioned above, different refrigerants have varying levels of environmental impact. While legislation means that ozone-depleting refrigerants are no longer in use, some refrigerants have a high global warming potential (GWP). GWP is a measure of how much a gas contributes to global warming compared to carbon dioxide, which has a GWP of 1.

Previously, R410A was a popular refrigerant, but it has a GWP of 2,088. This means that leaking 1kg of R410A into the atmosphere is the equivalent of releasing 2,088kg of carbon dioxide. R32 was introduced as an alternative, with a lower GWP of around 675. However, many ASHPs now use R290, better known as propane. R290 has a very low GWP of just 3. Its flammability means that manufacturers have more stringent safety requirements. These often include an exclusion or safety zone around the ASHP, where there cannot be any openings, such as drains or windows, or ignition sources, such as electrical equipment. Each manufacturer provides detailed information regarding their specific exclusion zone requirements, but these are often not too difficult to comply with if considered at the early stages of ASHP positioning.

5.6 POSITIONING

There are a number of considerations when siting an ASHP, including:

- restrictions around the refrigerant choice (mentioned above);
- visual impact on historic buildings;
- the noise that the fans will generate.

Many modern domestic ASHPs run very quietly, especially under the low loads that they will operate at for much of the year. Still, when choosing a location for the ASHP, a suitable noise assessment should be carried out as per MCS requirements. Further guidance on this is provided in Section 6: Consents and Permissions.

In some very constrained sites, an acoustic enclosure may be required to limit the noise emitted from the ASHP. An enclosure may also be desired for visual reasons. It must be designed in consultation with the ASHP manufacturer. It is vital that the enclosure does not impede the flow of air through the ASHP, as this can severely limit efficiency.

Figure 11. An example acoustic enclosure constructed outside a historic building.

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Figure 12. It is important to maintain suitable clearance around the ASHP within the enclosure.

5.7 CONTROLS

Many building owners tend to associate the duration for which the heating is on directly with heating costs; the longer the heating runs, the more expensive it becomes. Consequently, people often try to limit their heating to the shortest run times possible. This typically involves turning the heating on for a few hours in the morning and evening while allowing the building to cool down in between, when the heating is turned off. This practice is referred to as 'pulse heating'. It is likely the most cost-effective way to operate a fossil fuel heating system, as these systems can quickly raise the temperature from cold to comfortable.

Most ASHPs cannot operate at the same high temperatures as a fossil fuel system and so are generally not well suited to pulse heating. Instead of turning the heating 'on' or 'off', ASHPs can be programmed to maintain target temperatures over a 24-hour period. The heating system is enabled continuously, but whether the ASHP is actively heating the building depends on the current heating needs.

It is often more cost-effective to set the desired temperature for the building during different periods of the day and let the ASHP controls determine the amount of heat that needs to be added. The temperatures that are designated are referred to as set-point temperatures. Whenever no set-point temperature has been set, the system heats/defaults to a predetermined setback temperature. Typically, the setback temperature is about 2°C lower than your preferred set-point temperature. An example of a set-point schedule could be established for a home that is occupied throughout the day and for a home where the occupants are away at work all day.

Period	Set-Point Temperature
00:00-05:00	Setback (18°C)
05:00-22:00	20°C
22:00-24:00	Setback (18°C)

Table 1. An example ASHP heating setting for a home that is generally occupied all day.

Period	Set-Point Temperature
00:00-05:00	Setback (18°C)
05:00-07:00	20°C
07:00-16:00	Setback (18°C)
16:00-22:00	20°C
22:00-24:00	Setback (18°C)

Table 2. An example ASHP heating setting for a home where the occupants are generally out at work during the day.

5.8 WEATHER-COMPENSATED CONTROL

To optimise efficiency, it is essential to minimise the temperature of water circulating around the heating system. Weather-compensated control was designed to do exactly this by monitoring the outdoor temperature and adjusting the ASHP flow temperature to precisely match the building's heating needs. This allows the ASHP to run at the lowest possible flow temperature for the weather conditions while maintaining internal comfort. In practice this means that the radiators will be warmest on the coldest days and cooler on mild days, all while maintaining the same internal temperature. This function can achieve a significant reduction in running costs.

5.9 SEASONAL COEFFICIENT OF PERFORMANCE

The seasonal coefficient of performance (SCOP) is a measurement of the efficiency of ASHPs over an entire heating season. This indicates how much heat an ASHP produces on average for each unit of electricity consumed throughout the season. SCOP is another consideration when planning the use of an ASHP in a traditional building.

6. CONSENTS AND PERMISSIONS

A number of different bodies contribute to the landscape of consents and permissions in Scotland:

- The Scottish Government sets the overarching policies and drivers, balancing both the need to protect the historic environment and the need to decarbonise Scotland's built environment more widely.
- Planning authorities are the decision makers for planning permission, listed building consent and conservation area consent.
- Local authorities also manage building control departments and environmental health departments, who may be required to scrutinise and consent to any installations.
- The Microgeneration Certification Scheme (MCS) as an organisation creates and maintains (largely technical) standards relating to low carbon equipment. They also provide an accreditation scheme that provides confidence in the quality of the products, and installation design and workmanship.

In most cases in Scotland, planning permission is not required for ASHPs because they fall under 'Permitted Development Rights' (PDR). However, there are several important caveats to this.

Under guidance issued in May 2024 in relation to PDRs for microgeneration technologies, ASHPs are described as Class 6H, which permits 'the installation, alteration or replacement of an air source heat pump on a dwelling or within the curtilage of a dwelling. In both cases, this means a dwellinghouse, a building containing one or more flats or a flat contained within such a building.'

Several limitations are generally imposed in order to manage potential adverse effects on neighbours and amenity:

- No more than one ASHP is permitted on the same building or within the curtilage of a building.
- The ASHP must not protrude by more than 1 metre from the outer surface of an external wall, roof plane, roof ridge or chimney of a dwelling.
- No part of the installation should be forward of a wall forming part of the principal or side elevation of a building where that elevation fronts a road.
- No part of the ASHP structure may exceed 3 metres in height.
- Development is not generally permitted on a dwelling within a conservation area unless the ASHP is located at ground floor level and on the rear elevation of the dwelling.

- Development is not generally permitted in a World Heritage Site or within the curtilage of a listed building.

In addition, some conditions apply:

- The ASHP must comply with MCS 020 Planning Standards or equivalent standards.
- The ASHP must only be used for domestic heating and hot water.
- The equipment must be removed if it no longer required, or if it is not being used for the above purposes.

As noted above, there may be increased constraints on the use of ASHPs in conservation areas, World Heritage Sites or within the curtilage of listed buildings. However, as the case studies at the end of this Short Guide show, permission has been granted for ASHPs on a variety of projects in just these situations. In addition to the points raised above, the following should be considered when approaching any such project:

- Procedurally, it is worth engaging early with planning officers, along with submitting detailed designs to enable proper scrutiny of any proposals. Along with detailed drawings, a typical submission might include photos, a noise assessment and heritage assessment to demonstrate sensitivity to its setting. It is also helpful to include a decommissioning plan to show how the installation can be removed if no longer required, or if non-compliant.
- Regardless of whether planning or listed building consent is required, it is important to check whether building control is required.
- Consultation with the local authority Environmental Health Service in relation to statutory nuisance legislation is also important.
- When designing or preparing the submission, existing landscaping or architectural features should be used where possible to screen the equipment for both visual and potentially acoustic reasons.
- Ensure that all visible elements harmonise with the building's materials and colour palette.
- Under MCS standards, noise levels for an ASHP must remain at or below 42 decibels at 1m distance from any habitable room. It would be wise in all cases to establish this in advance via manufacturer's guidance or testing.
- Refer also to the HES guidance noted in Section 1.

7. MAINTAINING ASHP SYSTEMS

Generally, ASHPs have low maintenance requirements, akin to those of a gas boiler. Many general maintenance tasks for the exterior of the ASHP or heating system can be performed by anyone. However, the refrigerant circuit in an ASHP contains gases that can be harmful to the environment if leaked. Additionally, these gases may be under high pressure or flammable, which poses a risk of injury. Therefore, any work on the internal components of an ASHP should be performed only by a qualified engineer who is compliant with F-Gas regulations.

Systems must be designed with adequate maintenance access in mind. When proper access is not provided, maintenance tasks can become expensive, as safe working platforms need to be set up. The lack of access may also lead to maintenance being performed using less safe but quicker methods, which can decrease the likelihood of maintenance being carried out altogether, ultimately harming the system's life expectancy.

For example, ASHPs are sometimes wall mounted high on the elevation of a building, meaning that maintenance access is only possible with the risks of working at height. The risks associated with maintenance must be assessed if this approach is to be taken.

7.1 COMMON AREAS OF MAINTENANCE

It is important to consult with the ASHP manufacturer's specific maintenance requirements. Some aspects of general maintenance are listed below.

7.1.1 Cleaning external debris

ASHP fans can suck debris into the back of the unit, where it can become trapped in the coil. This restricts airflow and can reduce the efficiency of the ASHP. It is a good idea to regularly check the unit for debris, particularly in autumn when there can be heavy leaf fall.

Only easily accessible debris should be removed. Do not be tempted to reach into the unit using tools to extend your reach. ASHPs are designed not to allow you to touch the moving parts through the casing. Using any type of tool may either damage the ASHP or, worse, cause injury.

In addition to clearing internal debris, regular cleaning of the external casing can also help prevent discoloration and corrosion later in the life of the ASHP.

7.1.2 Checking external insulation

External pipework connecting the ASHP to the indoor system should be insulated to prevent heat losses. Pipework insulation is vulnerable to damage, which can affect its performance. When damage is observed, the insulation should be replaced with a product that is suitable for external use. If damage is persistent, a form of mechanical protection to the insulation, such as aluminium cladding, may be appropriate.

Figure 13. Damaged insulation increases heat losses from the system and should be repaired.

7.1.3 System pressure

As with boilers, ASHPs require the heating system water to be maintained at a suitable pressure to operate correctly. If the pressure is low, air can become trapped in the system, preventing some radiators from heating up. If the pressure drops very low, the ASHP will stop operating and display a low-pressure fault on the control unit to protect the unit from damage.

Consult the manufacturer for advice on the required operating pressures. Generally, the system pressure should be between 1 and 1.5 bar when cold.

It is common for wet heating systems to slowly lose pressure over time through tiny leaks. The system pressure can be easily topped up using the filling loop in such cases. Opening the isolation valves allows the heating system to be topped up with mains water to increase the pressure.

If the heating system experiences a sudden drop in pressure, this is a sign of a more significant leak somewhere in the installation. It is important that this is repaired by a heating engineer to prevent possible damage to the building fabric.

When topping up the system after a large drop in pressure, it is important to add back the necessary system additives, such as glycol antifreeze and corrosion inhibitors, to ensure the correct concentrations are maintained.

7.1.4 System filtration

All ASHP manufacturers require installing some form of heating system strainer and magnetic filters between the heating system and the ASHP; this is also common for any new gas boiler installation. If these are not installed, the warranties will be invalidated. If debris from a heating system is allowed to enter the ASHP, it could block the narrow channels of the integrated heat exchanger, causing the unit to stop operating. If permanent damage is caused to the heat exchanger, it can be an expensive part to replace.

When retaining existing heating systems to work with a new ASHP, it’s important to consider that deposits may have built up in the pipework over time. Therefore, when installing the ASHP, it is advisable to flush the existing radiators and pipework system. Even if an existing system is flushed, filters will likely require cleaning on occasion to keep the system operating correctly. As debris builds up in strainers and magnetic filters, the amount of water circulating around the heating system will reduce. When the flow rate falls below the ASHP’s minimum flow level, the ASHP will cease operation and display a low flow error code. Correct flow rate should have been measured as part of the installation of the system.

7.2 THINGS TO ASK YOUR ENGINEER

To ensure that the end user is best equipped to keep the system running effectively, there are some key questions to ask the engineer installing the system:

- Where are the system filters located? When should these be cleaned, and how?
- Where is the system filling loop located? How can the user top up the pressure of the system?
- Where in the ASHP manual can I find the ongoing maintenance requirements?
- How do I adjust the heating set temperature and timer?
- How do I adjust the hot water cylinder temperature and timer?
- How can I adjust the radiator temperature?
- What are the predicted running costs of the system?

8. CASE STUDIES

We have collated some case studies of ASHP installations in traditional buildings. These were managed and completed by independent companies, and they represent some of the options available in terms of design and installation. Each case study describes their unique circumstances and challenges and shows how these have been addressed.

8.1 1 DANUBE STREET TENEMENT FLAT, EDINBURGH

This 165m^2 top floor tenement flat in Edinburgh was comprehensively retrofitted in 2022, including extensive insulation and the installation of a roof-mounted Mitsubishi Ecodan ASHP. Heat is delivered through a zoned underfloor heating system, rather than installing larger radiators to work with the low flow temperatures of the ASHP. Instead, the existing radiators were removed, which means that the property is now closer to its original appearance when first built.

Figure 14. Interior of Danube Street Flat (© John Jeffery).

Although the size of the ASHP was minimised through thermal improvements, an upgraded electrical supply was still required in order to power the new heating system.

As the ASHP was to be roof-mounted, care was taken to ensure that the unit would not be visible from street level. This involved calculating the level of additional building insulation that would be required in order to allow a smaller, single-fan ASHP to be used. Mounting the ASHP to the roof was a particular challenge. The unit was initially intended to be mounted to the chimney stack, but concerns about structural integrity meant that this was not possible. Instead, a bespoke frame was installed to transfer the weight of the ASHP down into the structure of the roof.


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Figure 15. ASHP discreetly sited on roof (© John Jeffery).

8.2 107 NIDDRIE ROAD TENEMENT, GLASGOW

This 1900 tenement of eight small flats in Glasgow was comprehensively upgraded in 2021-22 to the EnerPHit standard, which is the Passivhaus standard for retrofit. The street elevation was retained as stone with internal insulation, while the rear was externally insulated. The planning department noted that they would treat the building as if it was in a conservation area although it was just outside the boundary.

Figure 16a and b. The completed street façade of the tenement building (left) and the rear of the same building (right) with ASHPs just visible bottom left and right.

As a project associated with COP26 climate summit, which took place in Glasgow, there was interest in demonstrating low carbon technologies. As a result, ASHPs were proposed. After extended discussion with the Glasgow Council Planning department, it was agreed that the four ground and first floor flats could be supplied by external units located on the ground in the rear court. Locating units on the ground and taking the warm water pipework any further up than the first floor was considered inefficient. Units were not allowed to be located at high levels on the walls. Therefore, it was decided to retain the existing gas boilers on the two upper floors.

In the four lower flats, the upgrade included the installation of new radiators and pipework along with the creation of a new cupboard in the rear-facing bedrooms, and the installation of an internal cylinder. The ASHP was a Mitsubishi Ecodan Monobloc unit sited externally, as seen in Figure 17, with an associated packaged cylinder internally.

Figure 17. Closer view of the external units with rudimentary timber screening for protection.

8.3 GANNOCHY TRUST COTTAGES, PERTH

The cottages at the Gannochy Trust in Perth are all detached and have sizeable gardens, meaning it was relatively simple to locate an ASHP to the side and rear of the buildings in an acceptable way.

Figure 18. The front elevation of one of the Gannochy Trust Cottages in Perth.

Figure 19. The ASHP was discretely positioned to the side of the property as part of a wider refurbishment project.

The circa 75m^2 cottages underwent a comprehensive internal upgrade. This included new wall, ceiling and ground floor insulation. Part of the upgrades was the installation of ASHP heating systems. Due to this existing disruption to the interior fabrics, installing new radiators posed no issue. The system consisted of a Vaillant 'Arotherm' external unit and a 200 litre cylinder. The cylinder was installed in existing external sheds adjacent to the cottages. These were insulated as part of the upgrade, ensuring that no heat was lost and the system efficiency was maintained.

Figure 20. Image showing the internal cylinder and pipework within the shed, which was insulated as part of the works.

9. CHECKLIST

Checklist for achieving a good-quality ASHP installations in traditional buildings:

9.1 PRE-INSTALLATION ASSESSMENT

- Conduct a whole building assessment (WBA): Evaluate the building's energy efficiency, structure and heritage value.
- Heat demand calculation: Accurately assess the heating demand using detailed surveys and established standards (eg, MCS Heat Pump Standard MIS 3005-D).
- Identify any repair and maintenance work that needs to be completed.
- Identify insulation opportunities. Prioritise fabric improvements like roof, floor and airtightness enhancements.

9.2 SYSTEM DESIGN

- Select the right ASHP: Choose an ASHP suitable for the building's size and heat demand, considering monobloc vs. split systems.
- Optimise heat emitters: Ensure radiators or underfloor heating are appropriately sized for low flow temperatures.
- Assess existing pipework: Check if the existing pipework can handle the higher flow rates required by ASHPs, and upgrade if necessary.

9.3 INSTALLATION CONSIDERATIONS

- Site the ASHP carefully: Place the ASHP to minimise visual impact and noise, especially in conservation areas. Use acoustic enclosures if needed.
- Ensure adequate airflow: Maintain clearance around the ASHP for efficient operation.
- Follow regulatory requirements: Obtain necessary consents, including planning permission, listed building consent and compliance with MCS standards.

9.4 ENVIRONMENTAL AND HERITAGE CONSIDERATIONS

- Choose low-GWP refrigerants: Select refrigerants with minimal environmental impact, like R290 (propane).

- Minimise interventions: Avoid major alterations to the building's historic fabric. Place units on secondary elevations or outbuildings where possible.

9.5 CONTROLS AND EFFICIENCY

- Implement weather-compensated controls: Use controls that adjust the ASHP's output based on outdoor temperatures to maximise efficiency.
- Utilise temperature set-point schedules: Optimise heating schedules with appropriate setback temperatures for energy savings.

9.6 MAINTENANCE AND LONGEVITY

- Plan for maintenance access: Ensure ASHPs are accessible for routine checks and servicing.
- Regularly clean and inspect: Keep the external unit free from debris, check insulation on external pipes and maintain system pressure.
- Install system filters: Use strainers and magnetic filters to protect the ASHP from debris and prolong its lifespan.

9.7 USER ENGAGEMENT

- Educate occupants: Provide clear guidance on using and maintaining the ASHP, emphasising the importance of regular maintenance and proper operation.

By following this checklist, building owners and installers can ensure a high-quality, efficient and sympathetic ASHP installation that aligns with both environmental goals and heritage conservation principles.

10. CONCLUSION

This guide has provided an introduction to some of the factors that should be considered when seeking to install ASHPs to traditionally constructed buildings. It has included technical considerations around assessing heat demand, different heat emitters and maintenance. An important part of this is considering the extent to which building fabric needs to be improved prior to installing an ASHP, and this guide has sought to provided a balanced approach.

Planning and consent in the context of ASHPs has also been discussed, and it is hoped the guide has shown what is possible with careful consideration.

Scotland is committed to lowering carbon emissions from buildings with ambitious net zero targets. Traditionally constructed buildings are an inherently sustainable and durable resource and a key part of Scotland's net zero future. The way we heat such buildings does need to evolve to meet these targets, and ASHPs will be part of this.

11. GLOSSARY

A glossary of technical terms used in this document.

Air source heat pump (ASHP): A heating system that transfers heat from the outside air into a building, even at low external temperatures, using a refrigeration cycle.

Buffer vessel: A tank used in heating systems to separate the flow of water through the ASHP from the flow of water through the heat emitters.

Compulsory owners' association (COA): A legal framework for managing jointly owned properties, often used in tenements and other shared buildings.

Fabric-first approach: A strategy that prioritises improving the building's insulation and airtightness before upgrading its heating system to maximise efficiency.

Greenhouse gas (GHG): Gases that trap heat in the atmosphere, contributing to climate change. Common examples include carbon dioxide (CO_2) and methane (CH_4).

Heat loss calculation: A method to estimate the amount of heat a building loses, used to size heating systems appropriately.

Heat loss parameter (HLP): A measure of how much heat a building loses per square meter, used to assess insulation and heating system efficiency.

Hybrid/bivalent system: A heating system that combines an ASHP with a conventional boiler, providing flexibility and backup heating on very cold days.

Microbore pipework: Small-diameter pipes used in heating systems, which may require assessment for compatibility with ASHPs due to potential flow rate issues.

Microgeneration Certification Scheme (MCS): A certification scheme that sets standards for microgeneration technologies, including ASHPs, ensuring quality and compliance.

National Planning Framework 4 (NPF4): Scotland's long-term plan for development and investment, which includes policies on sustainability and the historic environment.

Permitted Development Rights (PDR): Regulations that allow certain types of work to be carried out without needing full planning permission, subject to specific criteria.

Refrigerant: A substance used in ASHPs and refrigeration systems to transfer heat. The choice of refrigerant impacts the system's efficiency and environmental footprint.

Seasonal coefficient of performance (SCOP): A measure of the efficiency of an ASHP over a year, indicating the ratio of heat output to electricity input.

Set-point temperature: The target temperature that a heating system aims to maintain. A setback temperature is set during unoccupied periods, which is typically lower to save energy.

Thermal performance: The ability of a building to retain heat, influenced by factors such as insulation, airtightness and materials used.

Underfloor heating (UFH): A heating system that circulates warm water through pipes beneath the floor, providing even low flow temperature heat distribution.

Volumiser: A device that increases the volume of water in a heating system, helping to maintain efficient ASHP operation during defrost cycles.

Weather-compensated control: A control system that adjusts the ASHP's flow temperature based on outdoor temperature to optimise efficiency.

Whole building assessment (WBA): A comprehensive evaluation of a building's energy efficiency and environmental impact, considering all aspects of its structure and systems.

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