Heat Pumps - Implementation Guide

Heat Pumps Implementation Guide

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Sustainable Energy Authority of Ireland
SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with Government, homeowners, businesses and communities to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies.

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Contents

1. Introduction

Ireland has a long-term vision for a low-carbon energy system. It aims at reducing greenhouse gas emissions from the energy sector by between 80% and 90% (compared with 1990 levels) before 2050. Achieving this target will require a radical transformation of Ireland's energy system, a reduction in energy demand, and a move away from fossil fuels to zero- or low-carbon fuels and energy sources.

Air, ground and water-source heat pumps extract naturally occurring, renewable heat and upgrade it to a temperature at which it can be used for heating or cooling loads. Heat pumps use some electricity to operate, usually between 25% and 40% of the heat output, which means that efficiencies of 250% to 400% can be achieved. In other words, up to four units of heat are delivered for every unit of electricity used. Properly designed and installed heat pumps are cheaper, and have lower emissions, than fossil fuel or electric heating. Compared to other renewable heat solutions such as biomass, they also offer advantages such as significantly lower maintenance requirements and freedom from delivery charges.

Correct preparation at the design, installation and operational stages, helps to ensure that a heat pump system achieves the anticipated seasonal performance factor (SPF), is efficient and reliable, with optimised value for cost, and low emissions. The heat pump, the system to extract the renewable heat produced, and the heat distribution system must be designed and installed correctly.

1.1. Purpose of the guide

This guide is principally intended for site or facility owners who are interested in installing a heat pump system, it:

- Sets out good practice in implementing a heat pump system; and
- Lists sources with more detailed information on specific aspects of the technology.

This guide and its two companion guides are intended as a comprehensive starting point for those wishing to better understand the technology, its implementation and management.

1.2. Scope

This is one of three guides:

- This **Implementation Guide** focuses on the decisions associated with each stage of a heat pump project;
- The **Technology Guide** describes in more detail the different parts of a heat pump system; and
- The **Operation & Maintenance Guide** gives information on operating a heat pump system.

These guides focus on heat pump systems for non-domestic premises, using packaged heat pumps with an installed capacity of 45 kW to 1 MW of heat output. Much of the guidance will also apply to smaller scale systems. Large bespoke heat pump systems and direct air heating systems are not within the scope of this guide. This guide focuses on heat pump systems that distribute heat through water-based systems for use in non-domestic space, water and process heating. You should read the whole guide before implementing a heat pump system.

2. Overview of heat pumps

Heat pumps work differently from other heat sources, such as gas or oil boilers, and have different implications for the rest of the heating system.

Boilers generate heat by burning fuel and converting the chemical energy in the boiler fuel into heat. Heat pumps use a refrigerant cycle to extract very low-grade heat (usually under 25 °C) and upgrade it to a higher temperature. In short, heat pumps move heat. This section explains the operating principles of this process.

At its most basic, a heat pump system consists of three linked systems:

- The source (air, ground or water), from which heat is extracted,
- The heat pump, which extracts heat from the source and upgrades the heat to a higher temperature, and
- The heat distribution system, which brings the heat to the points of use.

Properly commissioned, heat pumps require very little maintenance. Heat pumps are sealed refrigeration systems, there is no combustion taking place, and no fuel delivery mechanism. Therefore, there are few moving parts. However, since the whole system depends upon three separate systems working together, there are quite a number of design elements to get right.

2.1. Principles

Heat pumps use the principle that changing the pressure of a gas changes its temperature. Compressing a gas causes its temperature to increase, and expanding a gas causes its temperature to reduce. The gases used in refrigerant cycles are known as refrigerant gases.

Heat pumps also use the principle of latent heat absorption: evaporating a liquid to a gas requires it to absorb energy and conversely, condensing it from a gas to a liquid, releases energy.

These principles are important for understanding why heat pumps systems are designed differently from boiler systems.

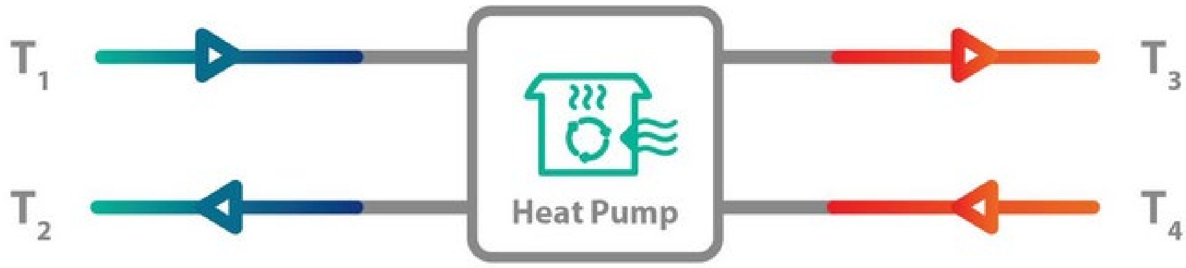
2.2. How to achieve an efficient heat pump installation

One of the main factors in heat pump efficiency is the difference between the mean temperature in the heat source system, and the mean temperature supplied to the heating system. It is desirable to reduce the temperature difference by:

- Maximising the temperature of the heat source, and
- Minimising the temperature of the heat distribution system.

Heat pumps are also very sensitive to the difference in temperature between the flow and the return in each system. It is vital to remember this when designing the heat distribution system.

Figure 1: Heat pump temperatures



The heat pump system performance depends on the four temperatures shown in Figure 1 above: the flow and return temperature on the heat source (T_1, T_2), and the flow and return temperature on the heat distribution system (T_3, T_4). If these temperatures stay within the range required, the heat pump is likely to achieve a seasonal performance factor (SPF), be reliable and require very little maintenance.

That's why a lot of the requirements for the design, supply and installation of heat pump systems are to do with keeping these four temperatures within acceptable limits.

For example, compared to other heating sources (and for the reasons set out in Sections 4.4. and 4.5.), the insulation of the building being heated and the design of the heat distribution system are much more important in a heat pump system. Designing and installing a heat pump system correctly is more complex than for many other renewable heat sources. Heat pump systems are more sensitive to design errors.

Many other renewable heat sources (such as biomass boilers) need more maintenance and manual intervention but are much less sensitive to the temperatures of the heat distribution system.

2.3. Heat pump energy efficiency

There are different terms used to describe how energy efficient a heat pump system is. All of these terms compare the units of heat output by the heat pump (in kWhth) to the units of electricity consumed (kWe) by the heat pump, but under different circumstances.

- The **coefficient of performance (COP)** is the ratio of heat output to electricity input at a specified set of operating temperatures for the flow and return in the heat source system, and the flow and return in the heating system. These temperatures are all defined in Standard EN1411, which sets out how the COP is determined. In reality, these four temperatures vary throughout the year, so in a real system the efficiency constantly changes.
- The **seasonal performance factor** (**SPF**) is the ratio of the units of heat delivered in kWhth over one full year to the units of electricity consumed over that period. This can only be determined after one full year of operation, and where heat and electricity meters are installed. It is a measure of the heat pump system's performance in the real world.
- The **seasonal coefficient of performance** (**SCOP**) is an estimate made, according to Standard EN14825, of what the SPF is likely to be, by taking into account the various circumstances during a full year of operation.

An SPF of 4 means that, on average over the year, 4 kWh of heat is supplied for every kWh of electricity used by the heat pump. This can also be thought of in the following way: the electricity input is 25% of the heat output of the heat pump. So the higher the SPF, the less electricity it will consume per unit of heat output.

European legislation[1] specifies that for the heat produced by a heat pump to count as renewable heat, the heat pump must have an SPF of 2.5 or above. Financial support schemes for heat pumps may set requirements for a minimum SPF. The conditions of the scheme should be checked in order to ensure compliance.

A heat pump system with a higher SPF will consume less electricity in order to meet the heating requirements of a building/facility over a year. Therefore, SPF is one of the main factors for operational cost and lower emissions considerations.

Working out the target SPF for the desired operational costs (and emissions reductions) can help to assess which system configuration is most suitable. For more information on SPF, see the accompanying Technology Guide.

[1] Renewable Energy Directive (2009/28/EU)

3. Energy efficiency first

Key messages

- **Before installing a heat pump system, the thermal efficiency of the building (or process) must be as high as possible. Existing buildings are likely to need changes, such as more insulation, for the heat pump system to be a feasible option.**
- **Improving air tightness as well as increasing thermal insulation is important. An air tightness test should be conducted.**
- **Improving the thermal efficiency is likely to reduce the cost of a heat pump system.**
- **Improving the thermal efficiency of a building greatly reduces running costs. A well-insulated building means that the heat pump can run at lower flow and return temperatures, resulting in a higher seasonal performance factor.**

All viable actions to minimise heat demand should be taken before installing a heat pump system. Assistance in improving energy efficiency may be available through the SEAI EXEED Programme.

The heat pump system itself should be designed to be energy efficient, and include measures such as effective system controls, a hydraulic design which minimises energy requirements for pumps, high efficiency pumps and good practice levels of insulation for distribution system pipework and heat storage vessels.

3.1. Energy hierarchy

When developing any low-carbon energy system, it is good practice to follow the energy hierarchy (see Figure 2). This identifies ways to minimise the total energy demand in a cost and resource efficient manner. The energy hierarchy indicates the order in which energy efficient measures should be implemented, as follows:

1. End-use demand is limited to what is necessary.
2. Measures that increase the efficiency of supplying the total demand are installed (these are usually of moderate cost), helping to ensure that demand is met in the most cost-effective way.
3. Renewable and low-carbon technologies are sized and installed (these tend to be more expensive compared to the measures associated with 1 and 2).

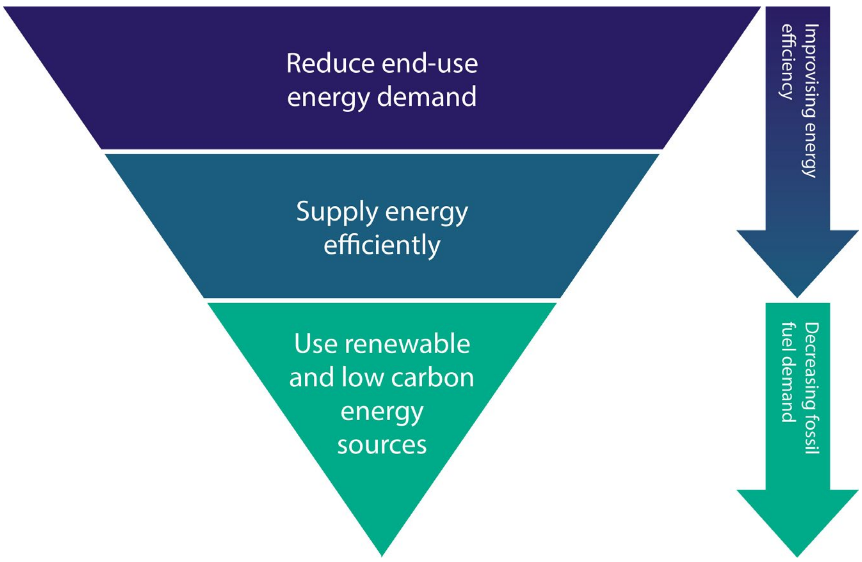


Figure 2: Energy hierarchy

Reduce end-use energy demand

This can be done through end-use energy efficiency technologies and measures (also known as 'energy performance improvement actions'), such as:

- Insulating (walls, attic, etc.) and draught-proofing buildings,
- Improving windows to reduce heat loss,[2]
- Replacing external doors to improve thermal insulation and air tightness,
- Optimising time and temperature settings,
- Behaviour modification of building users,
- Zoning or improving heating controls so that heat is used only when needed, and
- Improving the energy efficiency of heat-using processes.

It is important to consider a building's ventilation requirement as part of any upgrade work. Increasing the air tightness of a building improves thermal efficiency, but may mean that a ventilation system is then needed to meet minimum air change rates and ensure suitable air quality. Using a mechanical heat recovery ventilation system can further reduce heating requirements by recovering heat from warm air being expelled and using it to pre-heat incoming fresh air. A mechanical heat recovery ventilation system should be considered for a building that has been made as air tight as possible (normally this is below ≤ 5 m3/hr/m2). When insulating a building, it is essential that the insulation is installed in such a way that the building fabric is protected (for example, by ensuring that condensation is not allowed to form in unventilated cavities).

The SEAI EXEED Programme can help to identify thermal efficiency measures for a building or process.

SEAI EXEED Programme

Excellence in Energy Efficiency Design (EXEED) enables organisations to establish a systematic approach to design, construction and commissioning processes for new investments and upgrades to existing assets. The SEAI EXEED Programme aims at influencing and delivering new best practices in energy efficient design management. SEAI EXEED designs, verifies and manages optimum energy performance and management at the earliest stages of a project's lifecycle. There is also a grant scheme worth up to €500,000 per year per project.

For further information, please visit www.seai.ie.

Supply energy efficiently

This includes measures improving heat distribution system insulation, and the efficiency of circulating pumps, etc.

The heat pump performance is highly dependent on the design of the heat distribution system. Therefore, upgrades to the heat distribution system (e.g. radiators and hot water storage tanks) should always be considered as part of the upgrade works at the same time as the heat pump system is being designed and costed.

Use renewable and low-carbon energy sources

As well as heat pump systems, this could include biomass boilers, combined heat and power systems, and solar thermal technologies.

[2] Building Regulations 2017 – Technical Guidance Document L

The energy hierarchy should be followed before installing any renewable energy system. Importantly, it is particularly important to reduce heat demand when considering installing a heat pump.

A lower heat demand (for example, as a result of additional wall insulation) means a lower peak heat demand and reduces the total amount of heat that must be delivered in a year. A building with lower heat demand means a less expensive/lower capacity heat pump system can be specified. This is because:

- A smaller size heat pump can be used, lowering capital costs and potentially reducing the amount of input energy required;
- Heat emitters (e.g. radiators) can operate at a lower temperature, which improves the SPF. Usually, any reduction in flow and return temperatures of the distribution system results in an improvement in the SPF achieved by the heat pump system when in heating mode); and
- The size of the heat source system required can be reduced (for ground- and water-source heat pumps).

4. Feasibility study

Key messages

- **It is vital to first undertake a feasibility study to establish whether a heat pump system is physically, practically and financially viable. Different heat pump technologies (air-source, ground-source or water-source) may be assessed.**
- **The potential savings are directly linked to the seasonal performance factor. This will influence the choice of technology.**
- **For a heat pump system to be technically feasible, the heat source system and heat distribution systems must be assessed.**
- **The heat load of the building/facility must be calculated. The result of the calculation determines whether a low temperature heat emitter system is feasible, and if improvements to the building fabric and process pipework are required.**
- **Options for improving the building fabric should be considered. This in turn will affect the low temperature heat emitter design, and therefore seasonal performance factor.**
- **It is important to identify which heat sources are technically feasible for a specific site.**
- **Ground-source heat pumps using horizontal trenches will generally require a ground area that is several times larger than the footprint of the building.**
- **Vertical boreholes require an appropriate rock/soil type and are capital-intensive.**
- **Sites with a productive aquifer or surface water source may have the option of using water-source heat pumps.**
- **Air-source heat pumps are on option for most sites.**
- **Sources of waste heat, such as low-grade heat from an industrial process, should be included in the feasibility study.**
- **There must be an adequate electricity connection available on the site to power a heat pump of the necessary capacity. This may require an existing connection to be upgraded.**

It is best to carry out a detailed feasibility study before purchasing a heat pump. The aim of a feasibility study is to establish if a heat pump system is physically, practically and financially viable, and to outline provisional high-level system designs and system criteria. The study should cover the areas discussed in this section. The depth of the feasibility study will be dictated by the size and complexity of the project, with larger more complicated projects requiring a more detailed feasibility study.

Heat pumps can be sensitive to flocculating temperatures, for example:

- The external air temperature which is used to extract heat in a typical air-to-water heat pump as the source of their heat; and
- The source temperatures required on the secondary side of the heat pump in a heat-to-heat emitter and/or process pipework.

The exact temperatures will depend on the SPF to be achieved, the size of the heat load, and the source temperature.

For a low temperature heat emitter system to supply the required amount of heat using water at a low temperature, the building fabric and heat emitters must all be considered in detail. Upgrading the building fabric is often an essential part of preparing for a heat pump installation. This is also applicable for process heat, where process pipework insulation may need to be upgraded. The temperatures required for the system should be considered and augmented where necessary.

It is highly unlikely that it will be feasible to install a reliable heat pump system that achieves an acceptable SPF without upgrading the heat emitter system and the building fabric.

4.1. How to conduct a feasibility study

4.1.1. Who should conduct the feasibility study?

You should make sure that a site assessment is carried out by sufficiently competent professionals, to ascertain what types of heating system would be most suited to the site. The assessor should be impartial, and be able to draw unbiased conclusions. The assessment may need to include a feasibility study in order to ascertain the best solution for the site.

Competency is defined as a mix of theoretical and practical knowledge of the subject, including:

- Knowledge of the tasks to be undertaken and the risks involved, and
- The experience and ability to carry out the task.

Table 1 summarises the pros, cons and risks of carrying out the study in-house or contracting it out to a consultant or, installer or supplier.

Table 1: Summary of pros, cons and risks of feasibility study options

	In-house	Consultant	Installer/supplier
Pros	Likely to be the lowest cost solution.	An experienced and competent consultant would have the necessary level of skills and provide and unbiased assessment.	Should have a high level of knowledge of heat pump systems. May do the study at low or no additional cost.
Cons	Individual(s) may not have the competency to conduct the study.	Likely to be the most expensive option.	Lacks independence.
Risks	Key costs or considerations may be overlooked or miscalculated resulting in an inappropriate system being put forward.	Engaging a consultant who does not have sufficient experience of heat pump systems would result in an inappropriate system being put forward.	Knowledge may be limited to heat pump components and not cover integration with other technologies.

4.1.2. Initial site assessment

At the start of the feasibility study, a site visit should establish the specifics of the site. The site visit should include and review of:

- The objectives of the heat pump system, for example reducing cost or emissions;
- The existing heating systems;
- All factors affecting suitability of a heat pump system;
- The future uses of the site that could affect heat demand;
- The heat loads to be served, i.e. how much heat is required, when and where it is required;
- The existing heat sources, i.e. fuel used, heat medium, condition and whether they are to be retained;
- The heat distribution system(s), i.e. type, operating temperatures and condition;
- The presence and scope of a building energy management system (BEMS), supervisory control, and data acquisition systems;
- The availability of electrical power;
- The site layout, i.e. scale drawings (if available) showing the entire site and the types of ground cover (e.g. access roads, hardstanding and grass);
- The buildings in question, i.e. scale drawings of buildings to be heated (plans and elevations), location of plant rooms and existing equipment;
- The location and size of existing plant rooms and space for external heat pump components;
- All available information on the ground conditions of the site (test boreholes, trial pits, etc.);
- The availability of heat sources, such as a river or lake for water-source heat pumps or ground space for ground-source heat pump systems;
- Access for delivery of the system;
- All potential environmental issues;
- An asbestos report for the site;
- Any works that are planned and information on them (e.g. drawings); and
- The level of ongoing operational input that site staff can provide.

4.2. Permissions and environmental constraints

It is important at the feasibility stage to look at what permits are required, and the likelihood of these being granted. These could include permissions from:

- **Planning authority**

Check whether exemptions are in place for the planned system.

- **Building control**
- **Environmental Protection Authority (EPA)**

Whether permission is required from the EPA will depend not only on the type of system, but the other site requirements. For example, drilling boreholes on a site with contaminated land may require EPA approval.

- **National Parks & Wildlife Service**

This could be necessary if a protected species will be disturbed by works, for example.

Early engagement with the relevant authorities means that the time, cost and requirements associated with an application can be identified and included in the feasibility study.

4.3. System priorities

It is important to set clear targets for the envisaged heat pump system and to prioritise these. This means that different solutions can be compared according to these targets. The targets could include lowering operating costs, minimising net overall costs (i.e. capital and operating costs) or reducing emissions. On a remote site, one important reason for implementing a new heating system could be to minimise fuel deliveries.

Because heat pump systems have different characteristics, the best choice of system depends on the chosen targets. For example, air-source heat pumps are likely to cost less upfront than ground- or water-source systems. However, the SPF will probably be lower than that of a ground- or water-source heat pump, so air-source might not be the best solution if minimising carbon emissions is the main goal.

The three graphs below compare the cost of heat (fuel only) from three different heat sources. These are only for illustrative purposes, and take into account only the fuel cost and the heat source efficiency. In reality, the other costs (not included here) are: operation and maintenance contracts, capital repayments and depreciation.

Figure 3: Cost of heat from a heat pump compared to electric heating (example only)

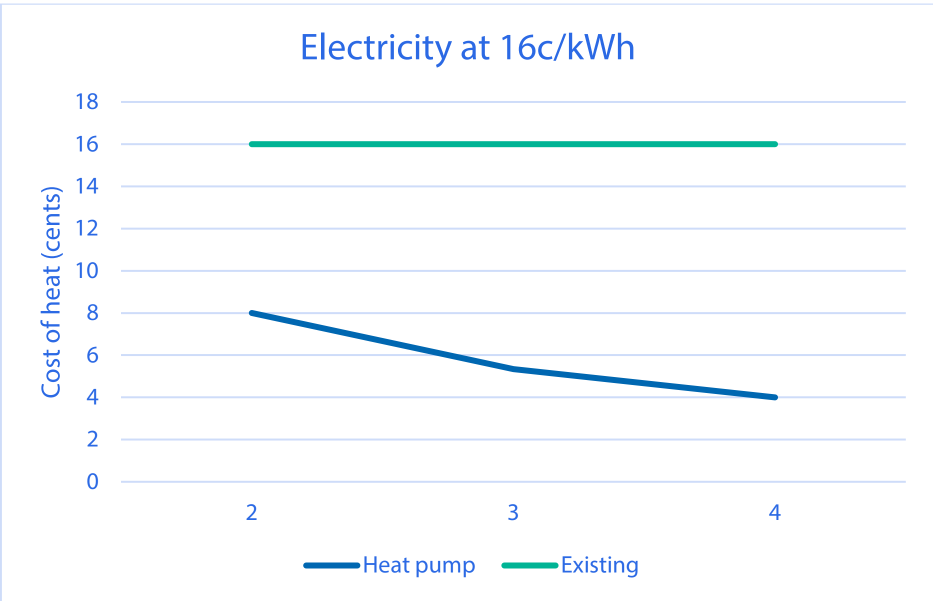


Figure 4: Cost of heat from a heat pump compared to oil heating (example only)

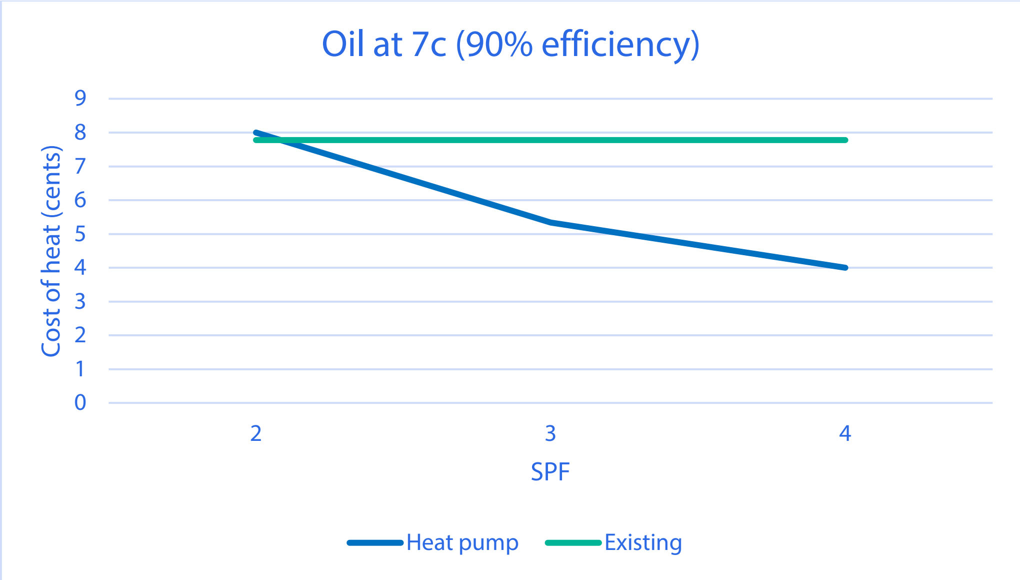
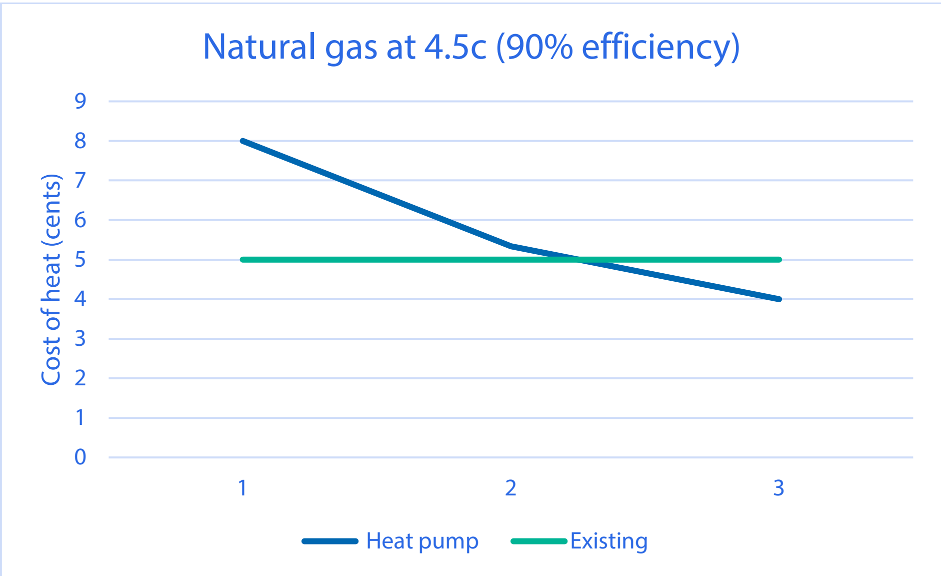


Figure 5: Cost of heat from a heat pump compared to natural gas (example only)



These graphs show that where electric heating, using electricity at a cost of 16 c/kWh, is substituted by a heat pump using electricity at the same price, the cost of heat is lower at all SPF ranges from 2 upwards.

As the cost of fuel decreases (i.e. for oil in Figure 4, and gas in Figure 5), the heat pump must have a higher SPF in order to provide competitively priced heat. Figure 5 details a comparison in savings relative to the cost of fuel, for example a heat pump should have an SPF of 2 if you are replacing the fuel source from natural gas to electricity or greater savings

For a specific project, the SPF matched to the desired operational cost savings must be determined as early as possible. The target SPF can then be used to assess the feasibility of different options. Establishing targets at the beginning of the project increases the likelihood of achieving them.

4.4. Heat load and characteristics

An important stage in a feasibility study is to determine the performance requirements for the heating system. This means not only determining the heat load, but also other parameters such as:

- For a heating system, it's important to know the space heating temperature requirements. Are there specific circumstances which mean standard design temperatures are not suitable? For example, a residential care facility may require higher space heat temperatures.
- Must the space, hot water and process be maintained at a constant temperature, or does the temperature requirement fluctuate?
- If it fluctuates, how rapidly does the heating system need to reach optimum temperature?

These parameters influence the system design, so it is important to identify them at the beginning of the design process.

4.4.1. Heat demand

The main aspects to consider are:

1. **Peak heat demand** the maximum rate at which a system uses heat or the maximum estimated demand, in kilowatts (kW). This should be established for space heating, hot water, and other processes separately, and used to calculate an overall peak load. This will give a complete picture of the demand and, where appropriate, allows different loads to be met by different technologies.
2. **Total annual heat requirement** the quantity of heat consumed over a whole year (expressed in kWh).
3. **Load profile** the variation of the heat load over a day, a week, or a year. Monitoring equipment can help to determine the load profile.
4. **Future changes** ways in which the heat requirement is likely to change in the future (e.g. expansion of the site or varied throughput of processes) so the new system can be future-proofed.

The way in which these factors are determined depends on the type of project.

For new build properties[3] or processes, or for a major retrofit, the heating requirements are solely determined by calculation. This should be done by a suitably qualified person.

For existing properties, the most accurate way to determine the peak heat demand and total annual requirement is from heat meter data for the loads being met. As these data are often unavailable, alternative approaches are discussed in Section 4.4.1.1. and Section 4.4.1.2.

Accurately determining the peak heat load and the total annual heat usage is essential for selecting a suitable system. If a building heated by a gas boiler uses more heat than it is designed for, then the only drawback is likely to be for it to use more gas. However, if a building heated by a ground-source heat pump uses significantly more heat than it has been designed for, the heat pump may freeze the ground-source area and in turn deplete the source, lowering the SPF and causing the system to fail.

A heat pump operating at a lower seasonal performance factor (SPF, see Section 4.5. for more information) also uses more electricity. If the electrical load of the heat pump exceeds the connection capacity, it is possible that the site will exceed the maximum import capacity, which could result in extra costs.

[3] IS EN 12831-1 : 2017 ENERGY PERFORMANCE OF BUILDINGS - METHOD FOR CALCULATION OF THE DESIGN HEAT LOAD - PART 1: SPACE HEATING LOAD, MODULE M3-3

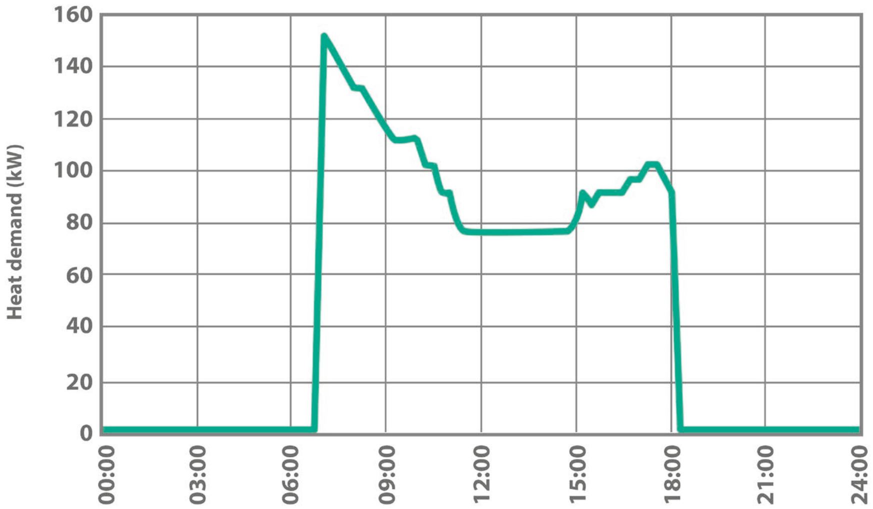
Similarly, if the estimated heating requirement of a space is not accurate, the heat emitters (radiators) used for that room will not be the correct size. This could mean that the room will not be heated adequately. Often, the only solution is to use bigger radiators.

The load profile data available varies a lot between sites. Half-hourly or quarter-hourly metering is ideal because the heat load profile can then be determined quickly and accurately. In practice, this data is often unavailable. The heat demand profile might have to be estimated based on the data available and typical load profiles. For new builds, the load profile is necessarily a theoretical calculation. It is important to ensure that it is as accurate as possible, as it influence the choice and design of the system.

It is important to discuss with the client what future changes should be allowed for. A system can be designed to allow easy integration of extra capacity at a later date. Where the additional capacity is known in advance, it should be accommodated in the initial design to minimise work and costs later.

Peak heat demand

Figure 6: Example of a daily heat demand profile



The peak heat demand can be extrapolated from the capacity of existing heat sources (for example, a gas boiler). However, this is often highly inaccurate. The peak heat load may not have been established accurately, and the boiler may have been oversized. Also, the peak heat demand could have changed since the boiler was installed.

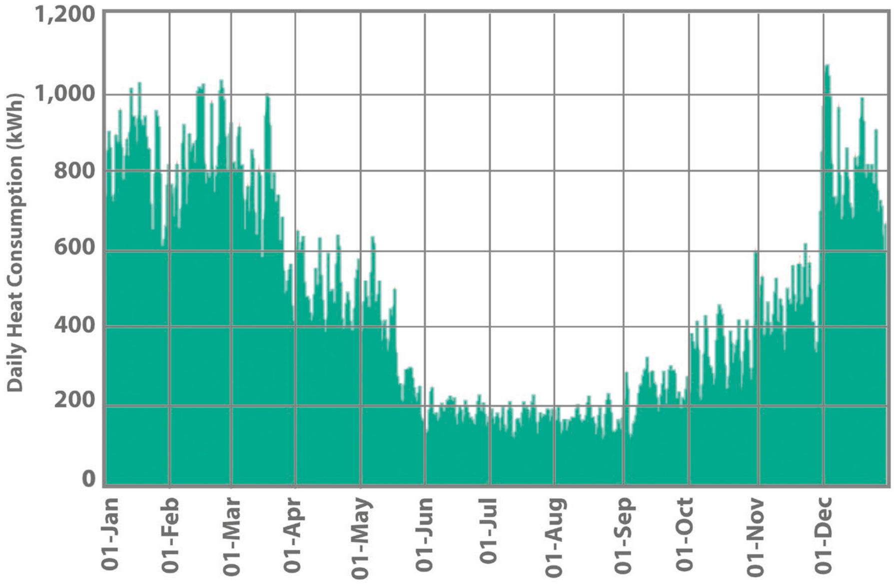
The capacity of existing heat sources may provide a rough estimate of maximum heat demand, but it should not be used to size the heat pump. Peak heat demand is calculated using a combination of metering records over a suitable period of time (including the period at which the peak heat load is expected to occur) to ascertain the size of the load (or loads) being met.

As discussed in Section 2.3, it is important to lower heat demand before installing a heat pump. It is often necessary to insulate a building for a low-temperature heat distribution system to be feasible.

Therefore, heat pump installation is often part of a larger retrofit. Better insulation reduces the peak heat demand and the total annual heat demand. Calculations should take account of proposed measures and be updated if changes are made to the industrial process equipment and building fabric throughout the design or construction process.

4.4.1.1. Total annual heat requirement

Figure 7: Example of an annual heat requirement profile



There are several methods for estimating the total heating requirement of a building, each with different levels of complexity and accuracy. Whichever method is used, a calculation of the total heat used by a building in a year is always a simulation based on the expected use of the building. The real heat usage fluctuates based on weather and operating patterns.

For an established heat load, fuel invoices for a full year and an estimate of boiler efficiency are used to estimate the total annual heat requirement. However, as discussed previously, care needs to be taken to allow for the impact of planned heat demand reduction measures.

By comparing the results of software simulation with metered data and fuel bills, it is possible to 'sense check' each analysis. The theoretical consumption is often different to the real consumption. A combination of approaches is a stronger basis for heat pump sizing and system design, than any single method.

4.4.2. Cooling

This guide focuses on heat pump systems providing heat. However, one of the main benefits of ground- and water-source heat pumps (compared with air-source heat pumps) is that they can also provide low-cost cooling in comparison with some heat pump classes. This can avoid the need for separate chillers and increase the SPF of the heat pump in heating mode.

On a refurbishment or new build project, the avoided capital expenditure on chillers and the increased SPF of the heat pump system in providing cooling can significantly improve the financial viability of a heat pump system, even before other benefits are taken into account.

Where cooling is to be provided by the heat pump system, the cooling load must be determined. The cooling load[4] must be accurately determined, so that the system is sized correctly. This is outside the scope of this guide.

[4] EN ISO 11855-2: 2015

A heat pump that provides both heating and cooling will, by design, provide some heat that has been rejected in cooling mode and some naturally occurring heat. A heat pump system that provides heating and cooling is likely to offer considerable energy efficiency benefits over a separate boiler system that provides heating and air-conditioning, or chillers providing cooling.

4.5. Heat emitter system

The temperature to which a heat pump has to heat water is a key factor in determining its SPF. Therefore, one of the main considerations in determining if a heat pump is feasible, is the flow and return temperatures of heat emitters. Reducing the flow and return temperature of the heat emitter will improve the heat pump's SPF, often very significantly. For example, for a typical heat pump system, it is estimated that a 1 °C reduction in flow temperature will result in a 3% increase in efficiency.[5]

At the feasibility stage, this means:

- Identifying the heating systems to which the heat pump would provide heat,
- Determining the flow and return temperatures of the existing system(s) (if there is one), and
- Establishing ways to reduce the operating temperatures to a level suitable for heat pump use.

4.5.1. Temperatures required

As discussed above, the first thing you should consider is the flow and return temperatures that the heat emitter system requires from the heat pump. These will depend on:

- The SPF necessary to meet the project targets
- The type of heat pumps
- The source temperature

For space heating, the heat distribution system consists of the heat emitters (e.g. radiators) and the connecting pipework. For hot water, it is the hot water storage tank. For process heating, it is the equipment that the heat pump provides heat to.

A heat emitter system designed for use with a traditional boiler is typically based on standard flow and return temperatures of 82 °C and 71 °C respectively. Therefore, the radiator system is the same regardless of the boiler type (or combined heat and power system).

This is not true of most heat pump systems. Typical temperatures (for an acceptable SPF) are 45 °C flow and 40 °C return. As discussed above, the lower the flow temperature that can be used, the higher the SPF of the heat pump system. The ultimate owner/operator of the system should be informed that the radiator temperatures will be lower.

Therefore, one of the first steps in determining if a heat pump system is technologically viable is to confirm that a heat emitter system, suitable for the lower flow and return temperatures in heat pump systems, can be installed and will deliver enough heat.

[5] CP2 Surface water source heat pumps: Code of Practice

In very general terms, for a packaged heat pump, a flow temperature of approximately 50 °C and return of 45 °C means that a heat pump can deliver heat and reach the minimum SPF required to be considered renewable. Higher SPFs (and therefore, lower temperatures) are likely to be required for renewable heat support schemes, as discussed in Section 1.1. There are circumstances in which it is possible to have higher flow and return temperatures (e.g. very large heat pumps, those specifically designed to work at high temperatures, or those using a higher temperature source).

In a building or system with several different loads, there may be some heat loads that are suitable for a heat pump and others that are not. Two separate heat pump systems can achieve a higher SPF and be more cost-effective where there are very different requirements, such as one heat pump system providing very low temperatures for a space heating system and a separate system providing high temperatures for hot water. This means that the space heating system can be designed to operate at as low a temperature as possible, while the heat pump(s) providing hot water can be designed to operate at higher temperatures.

4.5.2. Choosing a heat emitter system

In highly insulated and air tight buildings, there are usually several options for distributing heat effectively and at low temperatures. Even buildings that cannot be insulated to modern standards (e.g. historic buildings) can still have a low temperature heat distribution system installed, although choice is likely to be limited and the cost and level of disruption may be very significant. A building built or refurbished with minimal fabric insulation may require too much heat input for a heat pump to be feasible.

Heat emitters for use in heat pump systems include:

- Standard radiators, oversized to allow for lower mean temperatures (i.e. larger than those used with a boiler system)
- Low temperature radiators
- Underfloor heating
- Fan coil units
- Ceiling cassettes

Figure 8 shows when different heat sources for space heating can be used, how the heating load affects the choice of heat emitter, and the impact of flow temperature on SPF. Heat emitters are briefly described below. A more detailed description can be found in the Technology Guide.

Figure 8: Likely heat emitter options for 45 °C and 40 °C flow

45°C flow (based on MCS[6] heat emitter guide)[7]

Heat emitter type / Building heating requirement (W/m2)	Fan-assisted radiator (appropriately sized)	Standard radiator (appropriately oversized	Underfloor – screed and tile	Underfloor – screed with carpet	Underfloor – aluminium plates with carpet
Up to 30	Green	Green	Green	Green	Green
30 to 50	Green	Green	Green	Green	Green
50 to 80	Green	Yellow	Green	Green	Red
80 to 100	Green	Yellow	Green	Red	Red
100 to 120	Green	Yellow	Red	Red	Red
120 to 150	Yellow	Yellow	Red	Red	Red

40°C flow (based on MCS heat emitter guide)

Heat emitter type / Building heating requirement (W/m2)	Fan-assisted radiator (appropriately sized)	Standard radiator (appropriately oversized	Underfloor – screed and tile	Underfloor – screed with carpet	Underfloor – aluminium plates with carpet
	Green	Green	Green	Green	Green
Up to 30	Green	Yellow	Green	Green	Red
30 to 50	Green	Yellow	Green	Red	Red
50 to 80	Yellow	Yellow	Green	Red	Red
80 to 100	Yellow	Orange	Red	Red	Red
100 to 120	Orange	Orange	Red	Red	Red
120 to 150	Orange	Orange	Red	Red	Red

Key

Likely to be feasible	Green
Caution required when designing the heat emitter system	Yellow
Possible, but heat emitters are likely to be excessively large	Orange
Not likely to be possible without fabric and ventilation heat loss	Red

[6] Microgeneration Certification Scheme
[7] https://www.microgenerationcertification.org/images/MIS_3005_Supplementary_Information_2_-_Heat_Emitter_Guide_v2.0_Print_Version.pdf

Steel radiators

If standard steel convector radiators are used, then the lower flow temperature (compared to the flow temperature from boilers) means they must be oversized compared to those in a heating system with a boiler. Radiators must have at least three times the volume of the oil or gas boiler equivalent. Buildings with high heating requirements (even after insulation measures have been introduced) may not be able to accommodate sufficiently sized radiators. This a practical limitation on the use of standard steel radiators.

Figure 9: Example of a standard oversized radiator

Figure 10: Low-temperature radiator

Low-temperature radiators

Specially designed low-temperature radiators allow higher heat output for a given size. These radiators are passive aluminium radiators, or active radiators, which use a fan to blow heat through a radiator with aluminium fins. Low-temperature radiators tend to be more expensive than standard steel radiators. Low-temperature radiators are used for entire systems. Alternatively, fan-assisted, low-temperature radiators are used only in specific rooms with very high heat loads or space constraints, and oversized standard radiators are used elsewhere.

Underfloor heating

Underfloor heating is very well suited for use with a heat pump. Underfloor heating operates at low water temperatures, has a high thermal mass and can run at a low temperature difference. However, underfloor heating can only be installed as part of a new build project or major refurbishment.

Figure 11: Cutaway of an underfloor heating system

There are various types of underfloor heating.[8] The amount of heat delivered and the temperatures required to operate the systems depend on the construction of the floor and the floor coverings. Solid floors with stone or tiles produce the most heat. Floor coverings that are highly insulating (for example underlay and a thick carpet) limit the heat transfer through the floor into a heated space and are therefore often not suitable for use alongside an underfloor heating system.

Fan coil units

A fan coil unit is a simple device consisting of a heating and/or cooling heat exchanger or 'coil' and fan. It is part of the heating, ventilation and air conditioning system often found in residential, commercial and industrial buildings. A fan coil unit is used to control the temperature in a single space, or serve several spaces using ductwork to direct warm or cold air to where it is needed.

Ceiling cassettes

Ceiling cassettes are compact and lightweight. Typically, they are inserted into the false ceilings of offices, shops and restaurants. As they are placed in false ceilings, this leaves the maximum amount of floor and wall area available (compared to radiator systems). Air is discharged from the units in many directions, by altering the angle of the flaps of the units, or closing some flaps completely (if the unit is located in a corner). Ceiling cassettes are typically used in rooms with ceiling heights up to 3.5 m. Some units can be extremely quiet, but the issue of noise from the units due to air flow should be considered prior to installation.

4.5.3. Can the heat emitter system be improved?

Once an initial design has been considered for the heat emitter system, you should check if the flow and return temperatures can be reduced, to further improve the efficiency of the system. The key to this, is to understand the specific constraints on lower flow and return temperatures. The limiting element can often be a single room (or a small number of rooms) in a large building. Typically, this is a corner room with a large area of glazing, or a small room with a high ventilation rate (such as a WC).

In these instances, there may be a solution (specific to those areas) that enables a lower flow temperature across the whole system. For example, in a care home where oversized standard radiators are being considered, using low-temperature fan-assisted radiators in rooms with a higher heat demand (such as the living room) could allow the flow temperature to be reduced in the entire building.

4.5.4. Hydraulic system design

Most heat pumps work better with a smaller difference between the flow and return distribution temperatures in the system (typically 5 °C to 10 °C). The temperature difference for boiler systems is typically 10 °C to 20 °C. This means that the flow rate of water through a system heated by a heat pump is higher, and larger pipework and higher capacity pumps are necessary (compared with boiler-based systems). For this reason, when existing systems are being upgraded, it is necessary to do a full survey of the heating system, including pipework and pumps, and allow for any upgrades in the final design.

Transcritical heat pumps operate at much wider temperature differences. They can supply heat at a higher temperature and often require a very low return temperature (below 30 °C). For this reason, they are most often used to provide hot water. If a transcritical heat pump is being considered, it must be discussed with a supplier to determine how it will influence the system design.

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[8] CIBSE - HVUH/16 Underfloor Heating Design & Installation Guide

4.6. Other practical considerations

4.6.1. Electricity supply

The electrical connection required for a heat pump depends on the size and type of heat pump to be used. The maximum size for a heat pump on a single-phase supply depends on the specific electricity connection agreed and is likely to be approximately 15 kWth to 20 kWth. Heat pumps above this capacity are likely to require a three-phase supply.

The electricity connection requirements are determined by the approximate capacity of the heat pump and operating temperatures for the specific heat loads. The electricity supplier sets the price of a suitable connection. For more information, please see the accompanying Technology Guide.

4.6.2. Suitable location for plant

There must be a location suitable for installing the heat pump, buffer tanks and associated plant. Air-source heat pumps are located outside in good airflow. Location should also be considered with regard to the impact of noise pollution on neighbouring premises. For ground- and water-source heat pumps, the space required for a heat pump, pipework, circulating pumps and heat exchangers is slightly more than for a fossil fuel boiler. Some systems require a lot more space, for example, for water treatment systems or for a large number of packaged heat pumps.

The compressors in heat pumps often produce low frequency noise, which can penetrate building structures. They also produce higher frequency noise that is more easily attenuated. This should be taken into consideration when locating a heat pump.

Buffer tanks and thermal stores take up a lot of space (usually this is not needed for fossil fuel boilers). The buffer capacity depends on the system and consists of a single tank or of multiple tanks connected together. Where plant room ceilings are high enough, taller buffer vessels can be used, making the footprint smaller. This helps to maximise the space available for access and for other plant items.

In systems planned for existing sites, there is often a practical limit on the size of buffer vessels in order to fit the plant into existing spaces. In new build systems, or those using prefabricated plant rooms, the limit is more likely set by what can be delivered by lorry. Up to around 100 m^3 tanks can be delivered as a single pre-fabricated tank. For larger systems of several MW in capacity, buffer tanks are delivered in sections and assembled on site.

Prefabricated plant rooms provide a location for a plant to be installed. They minimise installation time on site.

4.6.3. Hydraulic separation

Hydraulic separation between a heat pump and the heat emitter system may be necessary. This is important for a new system interfaced with existing pipework or items of the plant that require a lower pressure. Plate heat exchangers provide hydraulic separation between the systems, but mean a slight reduction of the seasonal performance factor, due to the temperature difference across the heat exchanger.

4.7. Decide on need for backup

On some sites, it is possible to install a heat pump, but not one that meets all of the demand (e.g. a limit on the available electricity supply). Other sites (such as hospitals) require a high degree of resilience in heat supply. In these instances, an additional heat source may be required. A heat pump system that uses another heat source as well is called a bivalent system. This is discussed in more detail in Section 5.5.1.

At the feasibility stage, you should determine if an additional heat source is required, and if so, what type of heat source is suitable. It could be an existing boiler that can be retained, or a new system.

4.8. Possible heat sources

Once it has been established that the heat load can be supplied from a heat pump and that a suitable electricity connection can be installed (a lengthy process if upgrading to the grid is necessary) the next step is investigating heat source options for a heat pump.

4.8.1. Air

Air-source heat pumps are the most straightforward heat pump technology, however, the SPF is usually lower than for other types of heat pump. Provided the conditions described so far in this section can be met, air-source heat pumps are suitable for most sites.

Figure 12: Air-source heat pump

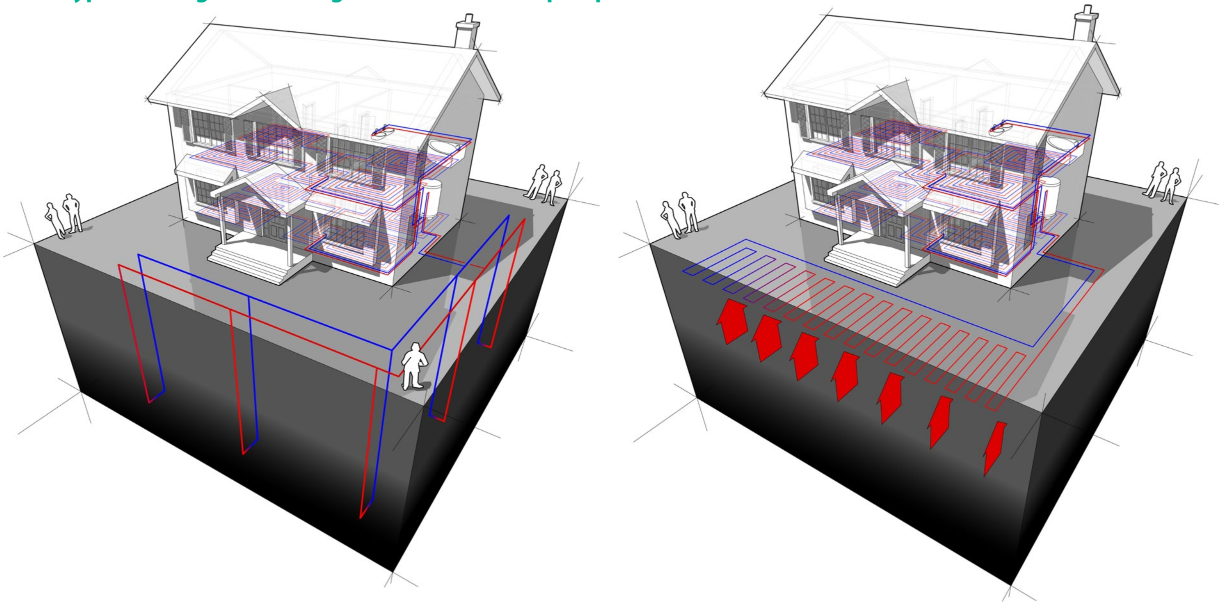
Each air-source heat pump has its own performance envelope defining the temperature supplied to the heating system at different outside temperatures. The lowest air temperature that air-source heat pumps can use as a heat source is usually around -20 °C. However, low outside air temperatures have an effect on the SPF. The fan and air movement make noise, but this is managed on most sites by careful choice of plant location and installing abatement measures such as fencing. Sites close to the sea may need coatings on the evaporator to prevent corrosion.

Air-source heat pumps (together with ground-source heat pumps) have the advantage that the operating hours can be increased without changes to the system. There is more information available in Section 3.1. of the Technology Guide.

4.8.2. Ground

Ground-source heat pumps extract heat from the ground through a series of loops of plastic pipework, usually high-density polyethylene (HDPE) of 25 mm to 40 mm. These loops are usually installed vertically in boreholes or piles, or horizontally in trenches 1–2 m deep. For new buildings, it may be possible to use other types of ground collectors, such as thermal piles.

Figure 13: Typical configurations of ground-source heat pumps



Horizontal trenches require a lot of space. For example, when supplying space heating, trenches are likely to cover an area several times the total floor area of the space being heated. For this reason, many commercial ground-source heat pumps use vertical boreholes. These are usually between 100 m and 200 m deep, and multiple boreholes are often required to meet a given load. The boreholes are usually 6 m apart from one another, this distance is a rule of thumb, and when a specific design is being developed a suitably qualified person should calculate the distances between boreholes based on factors such as the nature of the heat load and the thermal properties of the ground. The cost of drilling boreholes can be significant, which means that the capital costs of ground-source heat pumps are higher than for air-source heat pumps. However, ground-source heat pumps can also provide cooling at high efficiencies. For buildings with heating and cooling loads, ground-source heat pumps can often represent a particularly good option.

The total size of the collector array depends on the peak heating requirement, the total heat extracted and the ground conditions. Dry sand/gravel has extremely poor thermal properties and necessitates large heat collectors. In contrast, certain soil and rock types have good thermal properties and smaller ground collectors can be used. The designer of a heat pump system determines the size and layout of the ground array. The diameter of pipework and length of each loop is selected as part of the design process to avoid laminar flow in the collector pipework and minimise the energy required for pumping.

For any ground-source heat pump system, there is a finite amount of heat that can be extracted during each heating season without freezing the ground around the pipes and causing operating problems. If the array is insufficiently sized for the amount of heat being extracted, then the temperature of the ground gradually decreases year on year, resulting in a lower SPF and, ultimately, system failure.

For this reason, a ground-source system must be carefully monitored to make sure that it continues to meet the requirements of the heat pump, and the heat load of the building or process. This is described further in the accompanying Operation & Maintenance Guide. The Geothermal Association of Ireland provides further guidance.

It is important to test the ground conditions before finalising the design. On some sites, ground conditions are tested for other reasons (e.g. building foundations), yielding good information at the feasibility stage. On other sites, it is better to conduct a desk-based assessment of ground conditions before spending money on testing ground conditions.

To determine the ground conditions a test borehole is drilled. This must be to at least the depth planned for the final design. Some design work is necessary to make sure that the test borehole is representative. In many systems, the test borehole forms part of the final collector array. A thermal response test may be performed on site in order to measure ground thermal properties, which may aid in system design and sizing.

More information can be found in Section 3.2. of the Technology Guide.

4.8.3. Water

Water-source heat pumps extract heat from surface water or groundwater. They are very efficient in heating mode and, unlike air-source heat pumps, also provide cooling at high efficiencies.

The operating hours of water-source heat pumps that use water from highly productive aquifers, large rivers, lakes or the sea, are not usually limited by the risk of depleting the resource. You should organise a step drawdown test to determine the capacity of the aquifer.

For heat pumps that use groundwater, two wells are usually drilled. One is used to extract the water and supply it to the heat pump and the other to return the water to the ground. This means that the site must be above an aquifer large enough for water to be extracted at the required flow rate.

Surface water is extracted and returned in the same way, or a closed loop system is used, much like a ground-source system. This involves sinking either a loop of plastic pipework, or a series of metal plates, into the water to extract heat.

Figure 14: Water well being drilled

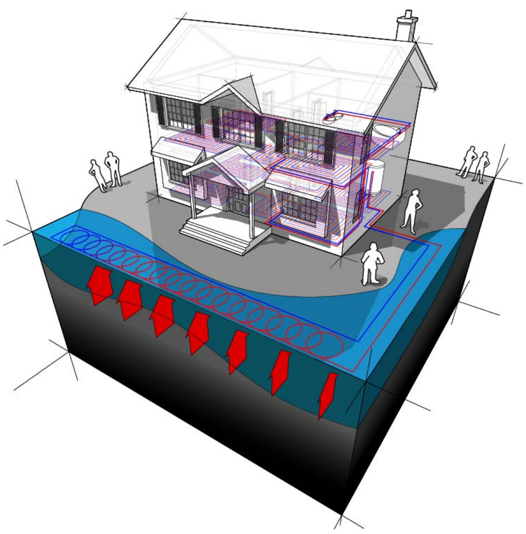


Figure 15: Closed loop surface water-source system

Both systems require an accessible body of water within a reasonable distance from the heat demand. You should assess the volume of the source, and whether it can provide sufficient heat over a year.

The quality of the water is also an important factor, and this must be checked. Water filtration or treatment may be necessary, and the quality of the water can affect the choice of materials.

Such systems could have environmental constraints, such as limits on the extent to which a body of water can be heated or cooled without causing damage to wildlife.

Extracting heat from very shallow water can cause problems associated with freezing, especially in winter. For more information, please see Section 3.2. of the accompanying Technology Guide.

4.9. Recovery of waste heat

In general, a heat pump has a higher SPF when the temperature of the source is as close as possible to the temperature supplied to the heating system. The closer these temperatures, the less energy the heat pump uses to upgrade the heat and therefore the higher the SPF. Section 4.5 of this document discusses strategies for reducing the distribution flow and return temperatures necessary for heating mode. There are often practical limits to how low this temperature can be.

The other way of reducing the temperature gap between the source and the heating system (and therefore improving SPF) is to increase the temperature of the source. Good design of the ground- or water-source systems ensures that heat extracted for the heat pump is as high as possible.
If waste heat is available, you should consider whether it can be used in the system. This has three main benefits:

- If the temperature of the recovered heat is higher than the temperature of naturally occurring heat, it improves the SPF of the heat pump system.
- It can help replenish source temperatures, either by reducing the size of the heat source system, remedying problems with an undersized heat source system, or extending operation of an existing system.
- The potential for improving the overall energy efficiency of the site (such as by providing cooling from the ground loops instead of an electric chiller).

Section 3. of the accompany Technology Guide discusses in more detail the information required when considering if a heat source is suitable for use with a heat pump.

4.9.1. Is recovering the heat permitted?

The Renewable Energy Directive (under revision at time of writing this guide) defines what heat is counted as renewable. For heat pumps, this is any heat stored in ambient air, under the ground or in surface water. Other heat sources (e.g. waste heat) may be technically feasible and there may be a good reason for using them, but the current definition should be checked in order to ensure that it qualifies as renewable heat.

Some funding schemes stipulate that only energy efficiency measures are eligible for funding (such as a heat pump using waste heat) and others are specific to renewable heat measures (such as a ground-source heat pump providing heating). It is important to understand the conditions of each support scheme.

4.10. Initial financial assessment

The initial financial assessment should include a comparison of heat pump systems with other potentially suitable technologies. The objective is to establish whether there is a commercial case for a heat pump system. The financial assessment covers the whole lifetime of the heat pump system (i.e. over a 10- to 5-year period). Standard techniques, such as calculating the internal rate of return of the investment in the heat pump system, the simple payback period, or the net present value, help to assess viability. These results are then compared with the targets set for the system.

A site is likely to have a large number of possible permutations of heat sources, heat pumps and heat emitter temperatures. This is particularly true at an early stage of the feasibility process. Since so many factors depend upon the flow and return temperatures, it often makes sense to consider more than one option for these temperatures. A system with a lower flow temperature will often have higher capital costs (e.g. heat emitter or process equipment upgrades and increased size of heat source), but lower running costs and reduced carbon dioxide emissions.

For this reason, an iterative feasibility/design approach is useful to narrow down the options and identify the best solution. It may be worth considering doing an initial financial assessment of a number of options (taking account of known constraints at an early stage) to establish which ones are viable. The financial assessment can then be refined for more promising options, in order to find the best solution. This approach is useful when there are many possible options.

Factors that need to be considered when conducting a financial feasibility calculation include:

- **Capital costs**

These are discussed further in Section 4.10.1.

- **Maintenance costs**

Including regular servicing (allowing for breakdowns and spare parts) and the cost of labour for day-to-day tasks carried out by on-site staff (e.g. investigating any control alarms, changing settings and carrying out other weekly or monthly tasks such as monitoring the system and taking meter readings). More detail can be found in the accompanying Operations & Maintenance Guide.

- **Electricity costs**

These may be established through discussion with electricity suppliers or based on current prices for electricity. Electricity consumption is estimated from the annual heat load to be supplied and the SPF of the heat pump.

- **Savings and income streams**

Including:

- Savings in the purchase of fuel for the current/alternate system supplying heat to the buildings/facility. This is usually established from fuel invoices for existing systems, and may be estimated in the case of alternate systems;
- Avoided costs of standard boiler replacement (if applicable); and
- Government support (e.g. grants or cost support) – the scheme criteria should be carefully checked, and the phasing of payments taken into account.

4.10.1. Capital costs

When conducting a financial assessment, it is important to include the costs for all of the works required to form a complete and working system, not just the heat pump itself. These costs include the heat source system, heat distribution system, system upgrades, electrical connections, control systems (both for the heat pump and any building energy management system), and any enabling works, such as concrete bases for mounting plant or installing an electricity sub-distribution board.

The SPF and reliability of a heat pump system depends on the heat source system and heat distribution system. If all parts of the system are not designed to work together, then it is highly likely that the heat pump system will not achieve the desired SPF or be reliable. If parts of a system are to be retained, such as pipework to different areas of a building, it is important to consider a contingency budget. It cannot be assumed that any component that is part of an existing boiler system is going to be suitable for use with a heat pump, unless it has been specifically checked.

At the feasibility stage, a supplier gives an indication of costs. You should get a more detailed quote (for use in a more detailed financial assessment) once the system design has been finalised. Costs are also sometimes established from other similar installations, or benchmark figures for some system elements such as pipework.

However, some costs, such the cost of the ground-source pipework network and its installation varies significantly from site to site, and therefore care should be taken when costs are being estimated in this manner.

The cost of some specialised services, such as drilling boreholes, can be very significant. The cost depends on the number and size of the boreholes, which in turn depends on factors such as the capacity of the heat pump system, total heat delivered by the system per year, the SPF and the ground conditions. At the feasibility stage, not all of these factors may be known, but an indication of costs is still useful to decide if further investigation is warranted.

You should make note of any assumptions on derived costs. As more information becomes available, you should ensure that the estimated costs are revisited and refined.

4.10.2. Sensitivity analysis

A number of variables affect the final design and cost of any heat pump system. It is not possible to determine all of these factors accurately at the feasibility stage. Therefore, it is useful to do some sensitivity analysis around key variables to make sure that the financial assessment is robust. Factors that are useful to vary include the capital costs, SPF, proportion of heat delivered, the cost of backup fuels and displaced fuels.

5. Design

Key messages

- **A detailed and accurate assessment of the building's heating requirements must be undertaken. An air tightness test informs this calculation. A robust design relies on an accurate calculation of the heat load.**
- **It is important to be able to fairly compare potential suppliers. This requires the tender specification to be drafted so that different systems can achieve the same levels of performance, and that the assumptions used in the tender responses are noted and understood.**
- **The heat emitter system should be designed for the lowest feasible flow and return temperatures, in order to maximise the seasonal performance factor.**
- **The controls, pipework and pumps in the heating system are assessed as to whether or not they need to be upgraded.**
- **For a ground-source heat pump, the design of the source system depends on both the peak heat load and the total amount of heat delivered. A heat meter should be included so that the heat delivered can be compared to the design load.**
- **For ground-source systems, accurately determining ground conditions is essential. A test borehole is usually required for borehole systems. Specialist software modelling is necessary.**
- **For water-source heat pumps, the water quality must be checked to ensure that the materials used are suitable.**
- **For air-source heat pumps, the heat output depends on the air temperature entering the heat pump. The heat pump must be sized at the output for the same outdoor air temperature assumed when calculating the building's heating requirement.**
- **The option of a buffer tank should be considered. For sizing, you should adhere to the manufacturer's guidance.**
- **A heat pump can operate alongside another heat source, where necessary. This has implications for the pipework layout and control systems design which must be considered.**
- **The financial assessment includes different types of heat pump and the enabling works. An initial high-level assessment helps to select options worthy of a more detailed feasibility study.**

5.1. Designing for safety and environmental impact

5.1.1. Health and safety

It is important that the heat pump system is installed, commissioned and operated safely. This is addressed during design, and implemented during installation (along with safety measures for the installation itself), and managed on an ongoing basis. This is discussed in the accompanying Operation & Maintenance Guide. It is essential to comply with health and safety legislation and follow best practice.

5.1.1.1 Risks

Design risks include:

- Electrical safety
- Leak of refrigerant gas, particularly in situations with:
    - Enclosed spaces
    - Explosive gases
    - High pressure systems
    - Rapid expansion (risk of freezing)
- Legionella growth
- Fire risks
- Water-source systems (suction risks)

The outline process for management of risks is to:

- Identify risks
- Develop a health and safety plan
- Take mitigating action
- Keep records

This process is continually updated during the design, installation, and operation of the heat pump system.

For more detail, see the accompanying Operation & Maintenance Guide.

5.1.1.2 Legionella

Legionella is a naturally occurring bacteria, present in rivers, lakes and reservoirs. It can cause Legionellosis, which can take two forms: Pontiac fever, a mild influenza-like illness; and Legionnaires' disease, a more serious (and potentially fatal) illness.

Legionella grows in water of between 20 °C and 45 °C. Designers of hot and cold water systems must follow design guidance and include methods for preventing Legionella growth. The bacteria cannot survive above 60 °C and is dormant below 20 °C.

For this reason, hot water should be stored at 60 °C. Some heat pumps cannot heat water to 60 °C. In these instances, it is necessary to use an additional heat source, such as an immersion heater, to heat the hot water cylinder to 60 °C.

The control system must automatically control the additional heat source, so that the heat pump heats the cylinder as much as possible before the control system triggers the second heat source. When a lot of hot water is required, a high temperature heat pump may be installed to heat the cylinder to 60 °C (without a second heat source).

A full assessment of the hot and cold water distribution system identifies risks in cold water storage tanks, uninsulated cold water supply pipework, dead-legs and hot water storage tanks.

Detailed guidance documents relating to Legionella include:

- National Guidelines for the Control of Legionellosis in Ireland 2009;
- Legionnaires' disease. The control of legionella bacteria in water systems Approved Code of Practice and guidance; and
- HSG274 Part 2 Overview: Legionella bacteria in hot and cold water systems.

5.1.1.3 During construction

The Health and Safety Authority (HSA) sets out the requirements for health and safety during construction in Safety, Health and Welfare at Work (Construction) Regulations 2013 (S.I. No. 291 of 2013).

The regulations set out the main requirements for the protection of the safety, health and welfare of people working on construction sites. The regulations apply to all construction sites, including places where heat pump systems are being installed.

The regulations clarify the responsibilities of all parties (clients, project supervisors, designers, contractors and employees) in relation to occupational safety, health and welfare in construction work. Full details can be found on the HSA website.

Responsibilities

- **Client**
  - Employ competent third parties and appoint them in writing before work starts
  - Supply necessary information
  - Keep and make available the safety file for the completed structure
  - Provide a copy of the health and safety plan to every person tendering for the project

- **Project supervisor (design process)**
  - Identify hazards arising from the design and eliminate or reduce them
  - Communicate necessary control measures
  - Prepare a written health and safety plan
  - Prepare a safety file for the completed structure and give it to the client

- **Designers**
  - Identify design hazards and eliminate or mitigate them
  - Communicate the control measures and remaining risks to the project supervisor
  - Take account of any existing health and safety plan
  - Comply with the project supervisor's instructions

- **Project supervisor (construction stage)**
  - Manage and coordinate health and safety matters throughout the construction stage

The project supervisor is appointed before the construction work begins and remains in that position until all construction work on the project is completed.

- **Contractors**
  - Cooperate and comply with the project supervisor
  - Provide the information required for the safety file
  - Report accidents
  - Comply with site rules
  - Identify hazards and reduce or eliminate them
  - Facilitate the appointment of a site safety representative
  - Provide workers with a site-specific induction and safety pass card
  - Monitor compliance and take corrective action if required

This is the most up-to-date legislation at the time of writing. You should check the HSA website for updates.

5.1.2. Environmental risk

There are a number of environmental risks to be managed over the lifetime of a heat pump system. Some of these risks are at installation and commissioning, and others during the operation phase. For each heat pump system and site, risk factors and legal obligations should be assessed. You should consider particularly ISO14001 and the F-gas Regulation in relation to environmental safety.

Important measures include:

- Incorporating your heat pump into your company or organisation's ISO 14001 system;
- Considering the effect of the heat pump operation on the temperature of water courses;
- Complying with F-gas regulations;
- Mitigating the risk of thermal transfer fluid leakage;
- Avoiding the disruption of silt in water courses (this causes de-oxygenation); and
- Avoiding or mitigating the risks posed by contaminated land (when excavating or drilling).

5.2. Apply for permits

Building control and environmental permits are required for heat pump system installation. These are identified at the feasibility stage. You must be granted a permit before installing the heat pump system.

It is important to submit the correct information for each permit. If applications are rejected, this delays the project. You should be careful to schedule permits correctly in the project plan.

Some permits impose conditions that affect the design of the system. This means that permission should be applied for before finalising the design. If a specific permission greatly affects the overall viability of the project (e.g. a licence to disrupt a protected species on site), then apply for that first, before incurring further costs.

Government support schemes usually require the correct permissions to be in place or to be applied for as a condition of funding. You should check with the specific grant scheme to clarify.

5.3. Detailed calculation of heat load

5.3.1. Peak loads

To correctly specify the heat pump system, a detailed calculation of the space heating, hot water and process heating requirement is necessary.

Space heating

For space heating, a room-by-room heat-loss calculation is required. Through site inspection or from scale plans, determine the floor area of each room, the size of each building element (e.g. windows, doors) and the thermal properties of each. You should establish the design conditions for inside and outside temperatures.

The **inside temperature design** is matched to the current use, and anticipated future use, of the space.
The **outside temperature design** is site-specific and depends on the location and elevation of the site.

Hot water

You should understand the peak water rate use and produce a usage profile. A combination of calculation, monitoring and metered data (e.g. half-hourly gas meter readings) helps to establish this.

Process heat

For process heating, the heat load depends on the type of process and the equipment used. It may be necessary to assess the heat load and the temperatures used in existing equipment. If the heat load is not already metered, install a temporary heat meter. For new equipment, the manufacturer or installer can provide a specification detailing the flow and return temperatures required.

Combined peak load

The system designer uses the various peak loads to size the plant. If several heat loads require heat at the same time, then the heat pump system must be designed to meet this demand. However, many systems are used for different purposes at different times, for example providing space heating during the day and heating hot water storage overnight.

Usually, real buildings do not perform exactly as simulated. This can be because there are differences in the construction of the building compared to the initial design and the way the building is used, or incorrect assumptions that were made in the calculation.

If the building uses more heat than planned for, this affects the heat pump system performance. Therefore, it is important to verify the building's energy performance and heat loss through methods such as air-tightness testing.

It is also important to allow sufficient margin in calculations. This makes for a robust system that can accommodate reasonable variations in the building's performance.

5.3.2. Total annual heat usage and load profile

The design of ground- and water-source heat pump systems depends on the total amount of heat the system will have to provide. Therefore, it is necessary to estimate how much heat will be required by the various loads.

The usual approach is to calculate the total amount of heat required and validate the calculation with fuel or meter records. Allowances should be made for future uses, such as enlarging a process or extending the building being heated.

There are different calculation methodologies available. The system designer must choose the most appropriate methodology for the project. It may be necessary to use software to conduct a simulation, particularly for more sophisticated systems.

The system designer must carry out a number of additional calculations or simulations using different assumptions. This helps to make sure that all elements of the system are robust (e.g. continue to supply heat in a winter with sustained low temperatures). A more robust system design is usually more expensive. Make sure that you clearly understand the implications of design decisions through thorough discussions with the system designer.

5.4. Designing heat distribution system(s)

5.4.1. Space heating

Once the heating requirements are calculated, the heat distribution system is designed. Heat pump performance is better when a heat distribution system uses a relatively low water temperature to meet the heat demand. This is typically done by oversizing radiators, using special low-temperature radiators or increasing the capacity of planned underfloor heating systems.

The feasibility stage usually includes an initial assessment of the space heating requirements. However, as the heating requirement for each room is more accurate at the design stage, it is only at this point that the size and type of heat emitters is finalised.

The system performance is limited by the worst performing room. If an entire building has been designed to run the heat pump system at 45 °C, except for one room which requires a flow temperature of 50 °C, the whole system will have to run at 50°C. It is useful to discuss with the system designers which rooms most affect system performance, and how this can be addressed (for example, using a local heat source in the room).

5.4.2. Hot water storage

By this stage, the amount of hot water to be provided and the profile for its use should have been determined.

Where a heat pump is meeting a load with varying temperatures, for example the temperature required to heat a hot water cylinder during peak times, hot water demands can affect the system's operation and efficiency. Taking this into consideration, you should agree on how best to operate the system. For example, if the hot water storage tank is going to be heated throughout the night when there is no space heating demand, the capacity of the hot water storage tank must be sufficient to allow for 24 hours of use under most circumstances.

In cases where the hot water will be provided by instantaneously heating cold water (by passing heat from a thermal store through a heat exchanger), the thermal stores will be larger than hot water storage tanks.

The time taken to recharge a hot water storage tank is an important factor in many commercial buildings, and one solution is to use dedicated heat pump(s) for hot water provision. This means the heat pump is specified for a higher temperature than that for space or process heating, and it can conduct a Legionella cycle without additional heat input.

Any hot water system should have a method of preventing Legionella growth, and this is discussed further in Section 5.1.1.2.

5.5. Determining the capacity required

5.5.1. Monovalent or bivalent operation

In many situations, a heat pump system is designed to meet 100% of the heat load. This is referred to as monovalent operation. In such cases, the heat pump is sized to meet the peak heat load (with an allowance for warming up the system).

There are some situations where it is not possible to install a heat pump large enough to meet the peak load. In this case, a boiler (or other type of heat generator) is used alongside the heat pump. This is a bivalent system. The way in which these two heat sources are controlled determines how much of the heat is provided by the heat pump system.

A bivalent system operates in two main ways:

- **Bivalent parallel**

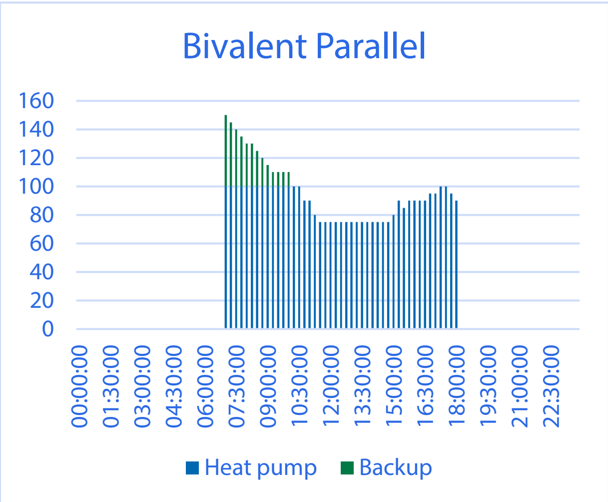
The heat pump and the second heat generator operate at the same time. This maximises the use of heat pump, but can pose challenges in practice.

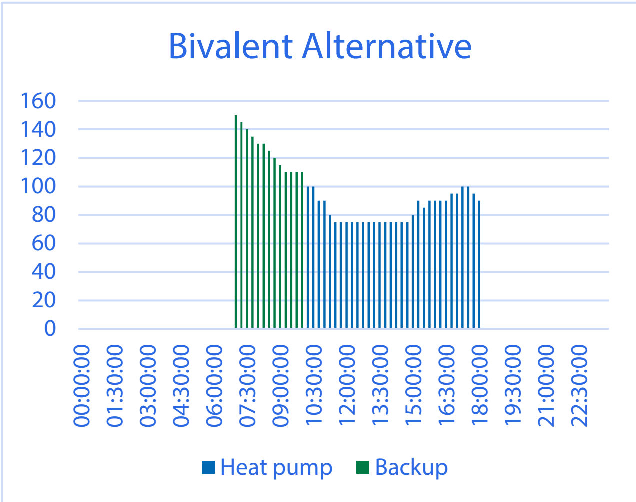
- **Bivalent alternative**

The second heat source takes over entirely for a period of time.

Usually, the back-up heat source operates at a higher temperature than the heat pump. In bivalent parallel mode, the design must include a method of controlling the flow and return temperatures from the backup heat generator, so that they are the same as the heat pump. This ensures that the two systems can operate together.

Figure 16: Example heat load profiles – bivalent parallel and bivalent alternative





Bivalent parallel operating mode should result in the heat pump providing a greater proportion of the overall demand (see Figure 16). However, parallel operation is not always possible.

One example of where a bivalent system might be appropriate is a building with a high heating load. In abnormally cold weather, the heat emitter system may not be able to meet the heat demand supply with the flow temperature that the heat pump can supply. The heat emitter system needs a higher flow temperature, and this can only be supplied by a back-up system. In this instance, the system might be designed to operate in **bivalent alternative mode**.

5.5.2. Determine optimal solution

Often, the heat pump system capacity is designed to meet the peak load. Alternatively, the heat pump system capacity is limited by the largest heat pump that it is technically feasible to install.

For more complex systems (with multiple heat loads, or multiple heat sources), the overall heat use profile is determined by the profile of the various loads, using software at hourly or half-hourly intervals.This helps the system designer to pick the best combination of heat pump and buffer tank (or thermal store).

The size of the source system (e.g. ground loops and water-source) depends on the size of the heat pump and the total amount of heat delivered. For example, a smaller heat pump may not result in very little change to the size of a ground array, if the heat pump heat load is stable throughout the heating season is still able to provide most of the total annual heat load.

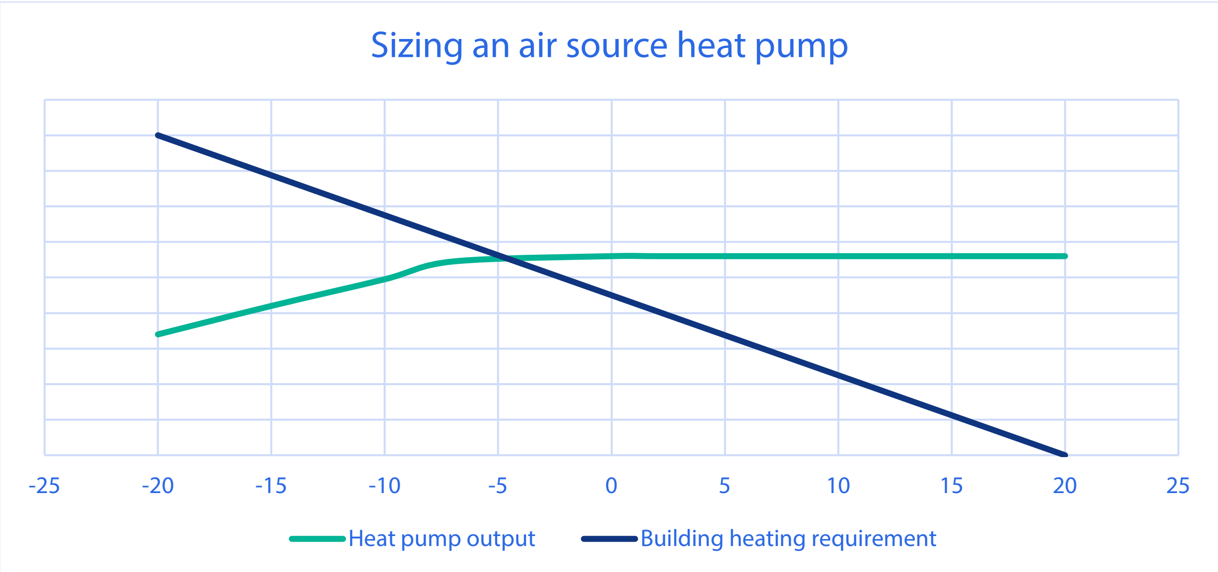
5.6. Heat pump model

Once you have ascertained the heat pump capacity, the system designer will select the heat pump model. This can be a single heat pump, or several smaller units. Using a number of packaged heat pumps together increases system capacity, but a single, large heat pump might have a better SPF or supply a higher temperature. Conversely, using multiple smaller heat pumps means the system heat output can be varied more.

Some heat pumps can reduce output to meet demand, for example by using an inverter-controlled compressor to control the heat pump. Many heat pumps only run at full capacity and do not modulate (or turn off). These heat pumps are used in conjunction with a buffer tank or thermal store. Manufacturers state the minimum buffer capacity for them to operate. More buffer capacity may be required for optimal design of a specific system.

Another consideration is that the output of a heat pump (in kWth) will often be less when the source temperature is lower. For air-source heat pumps, this greatly affects the design of a system, because the air-source heat pump output reduces as the outside air temperature drops and the building's heat load increases. Therefore, the outside temperature used to select a heat pump must be the same as the outside temperature used to size the heating system. In practice, this means that for any given system, the rated capacity of a suitable air-source heat pump is likely to be slightly higher (more kW) than that of a ground-source heat pump. Figure 17 shows a typical software simulation for sizing an air-source heat pump.

Figure 17: Sizing an air-source heat pump



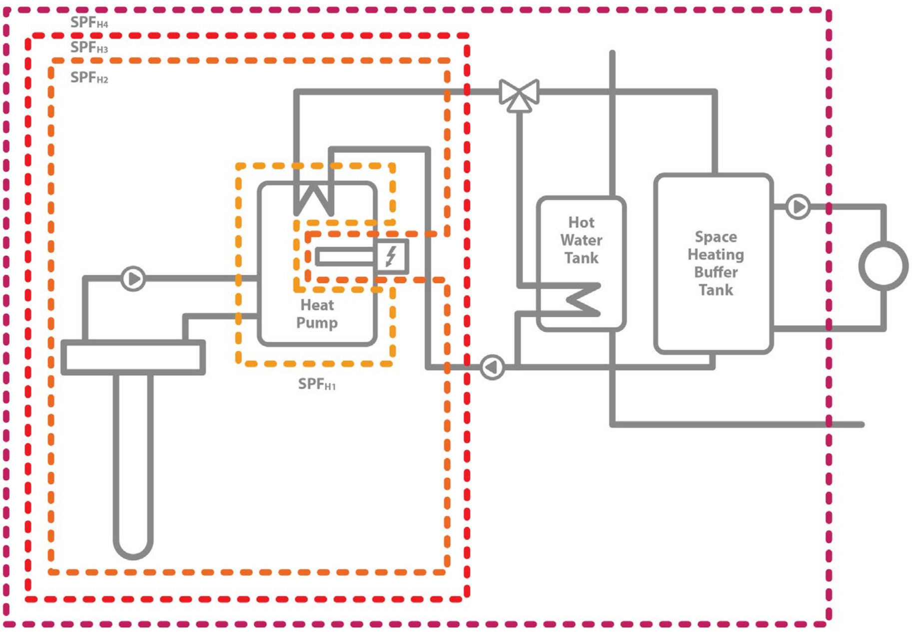
5.7. Determine likely operating efficiency

Once the heat pump model is selected, the system efficiency can be more accurately estimated than at the feasibility stage. The SPF should take account of any electricity-consuming devices required to make the heat pump run, such as a ground loop pump. There are a number of options for measuring SCOP or SPF. The simplest option is to record only the efficiency of the heat pump compressor (boundary H1 in Figure 18). However, in reality, the heat pump relies on circulation pumps and other electrical items to operate. This affects the combined efficiency (boundary H2 in Figure 18).

It is also possible to calculate a SCOP or SPF that includes elements of the heating system (e.g. in Figure 18 heat exchangers are included in boundary H3 and storage and buffer tanks in boundary H4). Therefore, when stating the SCOP or SPF for a system, it is important to also state what boundary has been used, particularly when comparing different options.

Once the heat pump model is identified, and its SCOP determined, the financial assessment carried out at the feasibility stage is updated. This is a more accurate assessment of financial viability. Any assessment of carbon savings should also be updated.

Figure 18: Examples of possible system boundaries for the calculation of SPF/SCOP



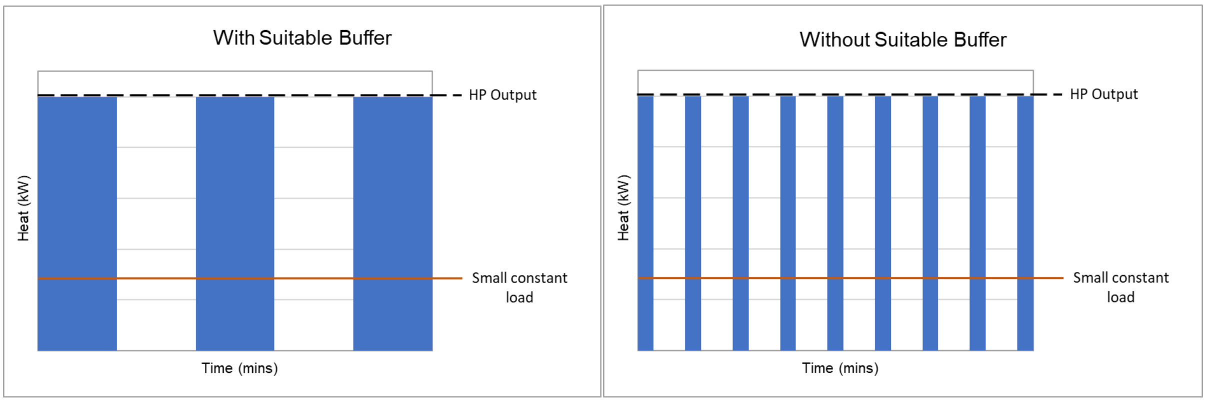
5.8. Designing the hydraulic interface with heating/cooling systems

5.8.1. Determining thermal storage requirements

Once you know the load and have selected the heat pump, it is time to size the buffer capacity or thermal store. Buffer tanks and thermal stores are integral to most heat pump systems, particularly in part-load situations. Some heat pumps cannot modulate output (and therefore operate only either fully switched on or fully switched off). In this situation, a buffer tank or thermal store is used to reduce the number of heat pump start/stop cycles. A lot of the wear and tear on a heat pump is due to starting and stopping. A system with fewer starts lasts longer.

Figure 19 shows how a buffer tank can reduce the number of times a heat pump cycles, comparing the performance with and without a buffer vessel.

Figure 19: A buffer tank reduces the number of times a heat pump starts



Using a thermal store also gives more control over heat pump operation. Heat is stored for later use. This means that system costs are lower, because the heat pump can operate during periods of cheaper 'off-peak' electricity.

The size of a thermal store in a heat pump system is often much larger than in an equivalent boiler-only system. This is because many heat pump systems need to operate at small temperature differences between flow and return (perhaps only 5 °C to 10 °C) to ensure optimal operation and SPF.

In contrast, the temperature difference over which a boiler system operates may be up to 20 °C. As the water in the thermal store is only heated up by 5 °C to 10 °C (rather than 20 °C), the heat stored is only a quarter to a half of that in an equivalent boiler-based system. To store the same amount of heat, the store has to be two to four times larger.

The size of buffer tanks and thermal stores may be limited by cost and space constraints, but it is important to understand and adhere to the heat pump manufacturer's requirements for the volume of buffer tanks. There are situations where it is necessary or beneficial to include a larger volume of buffer/thermal storage. See Section 5.8.2. for more information.

For air-source heat pumps, using a buffer tank to defrost the evaporator lowers electricity consumption. The accompanying Technology Guide contains more information on buffer tanks and thermal stores.

5.8.2. Managing flows and temperatures for effective operation

For effective operation and optimal SPF, the temperatures and flow rate to the heat pump must stay within the pump's designed operating window. The hydraulic design of the system must ensure that the minimum flow to the heat pump is maintained.

There are several proven design solutions that make sure that the system continues to meet heat demand, while keeping the heat pump within its operating window. It is important to include an appropriate solution at the design stage. The Chartered Institute of Building Engineers (CIBSE) documents TM51: Ground Source Heat Pumps and CP2: Surface Water Source Heat Pumps: CoP for the UK provide guidance on the hydraulic integration of heat pumps into heating systems. More information is also given in the accompanying Technology Guide.

5.9. Designing a heat source system

The feasibility study, and the subsequent financial and environmental assessments inform the choice of heat source system type. Information on the design of ground-source and water-source systems is provided in this section.

Packaged air-source heat pumps include the fans required to blow air across the evaporator and so no additional design work is required on the source system.

5.9.1. Ground-source system

The design of a ground-source system is a specialised and often complex process. Issues include:

- Building heating, cooling and domestic hot water loads
- Heat pump COP and estimated SPF
- Average ground and air temperatures
- Assessment or measurement of ground thermal conductivity
- Ground loop and header-pipe configuration and hydraulic implications, including ground loop pump sizing
- Pipe material selection, dimensions and layout
- Thermal transfer fluid characteristics and temperature constraints
- Trench, borehole, thermal pile or excavation design
- Trench or borehole spacing and backfill
- Manifold chambers or manifolds

For simply designed, small scale systems, an accredited installer associated with a heat pump manufacturer is usually able to implement the design.

However, a larger, more complex systems require the services of an experienced engineer or a chartered and appropriately trained geologist. According to the UK Ground Source Heat Pump Association, all bivalent systems, and all monovalent systems with a peak load of over 45 kW, or an annual heat load of more than 45,000 kWh, are considered complex systems.

Heat load to be met

The first step in designing the ground-source system is to determine the nature of the heat load to be met. This is discussed in Section 4.4. and 5.3.

The amount of heat that can be provided by a ground-source system defines its use. Allowing a margin when calculating the peak load and total annual heat load is beneficial for the long-term operation of the system. Similarly, a heat pump system that operates at a high SPF extracts more heat from the ground than a system operating at a lower SPF. This means that the ground-source system will need to be larger.

Consider the example of a care home, with a heat pump providing space heating only. Initially, radiators are sized to run at 50 °C flow and 45 °C return, and with a design SPF of 3. Sometime after the heat pump system is installed, the building undergoes an internal refurbishment. At this time, lower temperature radiators are installed that can operate at 40 °C flow and 35 °C return. The client anticipates that an improvement in SPF from 3 to 4 may be achievable if a new heat pump model is purchased. However, this new higher-SPF heat pump necessitates an increase in the total amount of heat extracted from the ground each year in the region of 13%. This increase may be within the capabilities of the ground-source system which was originally installed, but this cannot be assumed.

The cost of installing additional capacity in a ground-source system is often very significant and a calculation of value for money when compared to other options will need to be completed. Compromise is often necessary and it is important that the client is included in decisions when weighing up the costs and capabilities of the ground-source system.

Ground conditions

The next step is to understand the thermal properties of the ground. There are big differences in the heat output from different types of ground (e.g. a source system installed in a soil that retains moisture tends have a greater heat output than one installed in dry, well-draining soil). For rock, the type of rock makes a significant difference as does whether there is groundwater, and whether it is consolidated or fractured. For vertical boreholes, it is highly likely that there will be several different types of material (soil and rock types) that each borehole will pass through. It is important that the design includes the types (and properties) of soil and rock.

Online maps from the Geological Survey Ireland provide a first indication of the ground conditions. A geologist's report will detail the anticipated type and properties of the ground. For larger systems, drilling a trial borehole yields accurate information. A thermal response test can then be performed in order to confirm the properties of the ground formation into which the closed loop is installed.

In any system, after excavation or drilling has started, it is important to confirm that the conditions are as anticipated. If not, adjust the design of the system to suit the actual conditions.

There are a number of different types of ground collectors, and more information on these is given in the accompanying Technology Guide.

Heat injection into the ground

Some heat pump systems inject heat into the ground (e.g. if they are used to provide cooling during the summer months, or if the system is also using heat from solar thermal systems or from waste heat). In this case, the replenishment of heat in the ground (over and above what will occur naturally) needs to be taken into account in the final design.

In cases where a system is designed to operate with the aid of heat injection, it is important to understand whether the heat pump can operate in the absence of heat injection, for cases where it may become unavailable. This is particularly true when waste heat is provided by a third party, with higher risk of disruption or curtailment of the supply.

Software modelling

There is often more than one design possible for the ground array. To help select the best design, a ground loop system designer carries out a software simulation. The layout of the site is also an important design factor

Whichever type of heat collector is used (i.e. horizontal trenches or boreholes), the ground loop system consists of a number of loops of pipe connected to a single system. The number of loops and the diameter of the pipes is set by the system designer during the design process. This is a balance between ensuring that there is sufficient flow through each loop, and minimising the amount of energy used by pumps.

There are several ways to connect the loops. Usually, the connection is a manifold or number of manifolds, from which the loops radiate out, or the pipes tee into one another in a reverse return system. One factor to consider at this design stage is ease of ongoing maintenance. For example, if a single loop or borehole becomes blocked by circulating debris and must be flushed out, it must be possible to isolate each borehole. Identifying where access will be required, and incorporating it into the design, is essential to the effective and efficient operation of a system throughout its lifespan.

It is usually more cost-effective to have fewer, deeper boreholes than many, shallower boreholes. In practice, other factors may prevent this approach. For example, there may be access restrictions to the site, which preclude the use of a drill rig large enough to drill deeper boreholes. There are usually several iterations before the design of the ground array is finalised.

5.9.2. Open water source

River

Where water is being abstracted from a river, detailed information is usually required on the temperature, depth and the rate of water flow at different times of year. The EPA provides some information from existing monitoring stations. Additional monitoring at the proposed site may also be necessary. Water quality sampling is required (unless carried out at the feasibility stage) to determine what materials can be used in the system and to inform the design of any filtration or water treatment systems.

It is important to ensure that enough water can be extracted to enable the heat pump to operate year-round. When the river temperature is low, a higher flow rate may be needed so that the return temperature is above freezing.

It may be necessary to conduct an environmental survey to establish a baseline of the condition of the ecosystem and to determine if an environmental impact assessment is required. For advice and more information contact the EPA.

Lakes

The calculations performed at the feasibility stage to check that the lake is big enough to be a viable heat source should be repeated, using the updated heat demand estimate. This is particularly important if there is little or no flow through the lake.

Water quality sampling is required (if it has not been carried out at the feasibility stage) to determine what materials can be used in the system and to inform the design of any filtration or water treatment system.

Groundwater

Groundwater systems rely on a productive aquifer, and this should have been determined at the feasibility stage. A hydrologist’s report confirms that the aquifer is capable of supporting the flow rate required by the heat pump system. After drilling the water wells, the flow rate should be tested. Water sampling is necessary to confirm the quality of the water and inform the design of any filtration or water treatment system.

5.10. Hydraulic design of source pipework system

The source system design must ensure that there is sufficient length of heat collector pipework to meet the heat pump’s requirements, and that the size and configuration of the pipework is such that the flow is fast enough (i.e. above laminar flow), minimising the energy consumed by the pump.

There are usually several possible configurations of the pipework system within the space available. Software simulations can help to identify the optimal solution. For larger and more sophisticated heating and cooling systems, appropriate software must be used to simulate the solution.

5.11. Data collection and monitoring system

It is important to include a method of monitoring the source system, to check that it continues to operate as designed. For larger and more complex systems, an appropriate monitoring system records parameters such as the water temperatures and flow rates, with an alarm to alert the user if there is a problem. For example, if the temperatures drop too low, creating risk of freezing.

In simpler systems, it may not be possible to install an automated monitoring system, but it is still important to be able to confirm that the source system is operating as designed. Most heat pumps have some in-built monitoring and a simple system of logging temperatures can be enough. Essentially, there must be a system for signalling that remedial work is required, or that a backup heat source is needed.

6. Construction and installation

Key messages

- **Environmental risks and health and safety risks should be identified and mitigated.**
- **Water-source systems carry particular risks, necessitating permits and ongoing monitoring.**
- **Installation should be managed to ensure that the system constructed meets the design and any changes required on site are accounted for in a re-appraisal of the design.**
- **Flushing and correct pressure testing of pipework is essential to ensure that both the heat source system and the heat emitter system allow the heat pump to achieve the seasonal performance factor outlined in the design.**

6.1. Health and safety, and environmental issues during construction

A heat pump system incorporates refrigeration, electricity, plumbing and significant quantities of potentially toxic chemicals (such as antifreeze). All the associated risks must be identified and plans put in place to manage risk during the construction, installation and operation stages.

The Construction Regulations 2013 prescribe the main requirements for the safety, health and welfare of persons working on construction sites.

6.2. How to ensure installation meets design requirements

6.2.1. Appointing contractors

Heat pump systems contain a number of sub-systems, each of which may be installed by separate contractors. For example, it might be that the plumbing contractor installs the heat distribution system and the hot water system, and a heat pump specialist installs the heat pump equipment.

Since the optimal heat pump operation depends on the other elements of the system, it is essential that the contractual arrangements set out clear lines of responsibility and interface specifications.

6.2.2. Managing the installation

A heat pump system should be able to achieve an acceptable SPF and operate reliably with relatively little maintenance. As discussed in Section 5., for this to happen the detailed design of the system must be correct.

However, it is just as important to install the system as designed. Small deviations (albeit well-intentioned ones or those necessitated by changing site conditions) must be flagged and checked with the system designer.

The installation of a heat pump often requires different professionals, such as plumbers, pipe fitters, electricians, refrigeration engineers, groundwork specialists and borehole drillers, to work together. Usually, a small system is installed by a small team. Larger systems often require more (and different) contractors. Contractors must be managed in such a way that the combined result of their individual work is a fully functioning system. It is important to clearly set out how this will be achieved, such as through weekly site meetings with the system designer, the contractors and the project manager (as appropriate) all present.

Sometimes, site conditions necessitate a change in the system. Often, these problems are resolved on site by the installers. However, system designers must be notified of, and agree with, any changes to ensure that system performance will not be adversely affected. For example, if the rock type found when drilling boreholes is different from that anticipated, then more (or fewer boreholes) may be required. If a pipework route has to be significantly longer (or shorter) than designed (to avoid an unexpected obstacle, for example) then the diameter of the pipework or the size of the circulation pump may have to be changed so that the system operates as designed.

6.2.3. Flush and pressure testing of pipework

In ground-source heat pumps, the source system pipework should operate reliably and with minimum maintenance. For reliable operation, the pipework must be correctly installed, flushed and pressure tested. These tests are vitally important, but time-consuming for installers.

Furthermore, flushing the long pipe circuits of large pipework requires specialist pumping equipment (for a flow rate high enough to remove debris). The tests generally take place at the end of the groundwork, when contractors are often under pressure to meet installation deadlines. However, it is important to make sure these tests are carried out correctly and thoroughly.

6.2.4. Mixing thermal transfer fluid

The thermal transfer fluid used in the heat source pipework is often a mixture of water and a glycol-based additive at concentrations of between 25 % and 40 %. The transfer fluid must to be mixed before being put into the system. In large systems, this is a challenge (thousands of litres may be involved).

Therefore, mixing must be planned so that the right equipment is on site. Incorrect concentrations of glycol can cause the heat pump to freeze, resulting in system failure. Incorrectly mixed glycol concentrate can also cause operating problems.

7. Commissioning

Key messages

- **Commissioning should include the set up and testing of the heat pump and all of the associated plant items and control systems.**
- **Commissioning should be documented by recording the actions taken and all settings. Copies of these documents should be kept in a complete operation and maintenance manual that is left on site.**
- **Conditions for commencement of warranties should be understood and a clear date of handover agreed.**

Commissioning involves testing the equipment to confirm it is operational, and meets its design specifications, relevant technical standards, and all conditions of warranty.

Heat pump installations consist of a number of sub-systems (the source system, the heat pump itself and the heat distribution system). These sub-systems must all be commissioned. Therefore, commissioning may refer to the whole installation or one of these sub-systems. It is important to check the scope of commissioning required by an incentive scheme before submitting a commissioning date as the payment of a grant may be dependent on achieving this commissioning date.

Prior to commissioning, a plan should be drawn up by the lead commissioning engineer/technician responsible for a part or all parts of the system. The plan should set out the order in which systems should be commissioned and detail who will witness the commissioning. This is likely to include:

- **The source system**

A final flush and pressure test of a closed loop system should be witnessed by a representative of the client. The flow rates should be checked through each loop to ensure they are correct and sufficient to avoid laminar flow before they are fused together.

- **The heat pump and associated equipment**

This includes the electrical system, controls and refrigeration system set-up.

- **The heat distribution system**

This includes recommissioning the existing system, if this has been retained. A final flush and pressure testing should be carried out and witnessed by a representative of the client. Filtration and de-aeration systems should be confirmed to be present, suitable and functioning correctly.

- **The monitoring system**

- **Testing of the whole system under the range of normal operating conditions**

- **Extended plant performance and reliability tests**

Commissioning completion should be marked by a commissioning certificate being issued. This shows the scope of the commissioning and the date. It should be signed by a person qualified to carry out the commissioning, and witnessed by a representative of the client and/or of the system operators.

Evidence of commissioning may be required by building control or insurers. The commissioning date is important. It is important to understand when warranties start from, whether this is the date of commissioning, and to be aware of allowances for snagging periods. Evidence of commissioning is usually required by an incentive scheme. The level of support may be directly linked to the commissioning date.

Commissioning certificates should be kept on site as part of the installation records. Completion of the commissioning usually marks the handover of the system from the contractors to the operators. The operators should receive an operating, maintenance and safety manual; and should have received training in operation and basic maintenance. Systems should have a regular servicing regime in place based on the manufacturer's guidelines.

7.1. Warranty

Even with well-planned and executed installation and commissioning, faults may still occur. An initial snagging period, during which the system is modified for optimum performance, should be expected. As such, it is important to be familiar with the warranties on all equipment, the overall system and workmanship.

Any moving parts, such as motorised valves or electric motors, are the most likely to fail. The length of warranty is a good indicator of the manufacturer's confidence in their products. Most quality heat pumps have a minimum 2-year warranty, while some will have a 5-year warranty. Extended warranties are sometimes available. The cost benefit of an extended warranty should be assessed.

To make sure the warranty is comprehensive and fully used:

- Ensure it covers the whole system, all the components within it and the workmanship, and if several installers were involved, ensure there are no gaps between the coverage of the warranties;
- Check for terms and conditions, especially any that may void it, such as operating a ground-source system without sufficient antifreeze and not maintaining the system as per the manufacturers' specifications;
- To ensure the company providing the warranty is reasonably likely to stay in business for the duration of the warranty, check the company history and financial performance;
- Check if the warranty is for parts, labour, or both;
- Keep copies, and create a schedule of the warranties, with expiration dates;
- Schedule a service before the end of the warranty so that repairs and replacements can be identified and rectified under the warranty; and
- Keep a record of warranties for replaced parts, in case the part requires a second replacement within that warranty period.

Note: Some warranties are based on what occurs between a set time period or a number of operating hours. The expected time taken to reach the operating hours should be verified and monitored if it is likely to be less than the warranty time period, so that it is clear when the warranty expires.

References and other sources of information

- Ground Source Heat Pumps Association
  - Ground Source Heating & Cooling Guide
  - Shallow Ground Loop Standard
  - Thermal Pipe Standard
  - Vertical Borehole Standard

- Chartered Institution of Building Services Engineers
  - Open loop groundwater heat pumps: Code of Practice for the UK (Draft)
  - CP2: Surface Water Source Heat Pumps: CoP for the UK
  - HVDH Domestic Heating Design

- Microgeneration Certification Scheme
  - Heat Pump Guidance
  - Requirements for MCS Contractors Undertaking the Supply, Design, Installation, Set to Work, Commissioning and Handover of Microgeneration Heat Pump Systems – MIS 3005

- Health Protection Surveillance Centre
  - National Guidelines for the Control of Legionellosis in Ireland, 2009

- Health and Safety Executive (UK)
  - Legionnaires' disease. The control of legionella bacteria in water systems

- Geological Survey Ireland

- Department of Housing, Planning and Local Government
  - Planning Regulations
  - Planning Amendment

- Environmental Protection Agency
  - Fluorinated Greenhouse Gases

- HM Government
  - The Building Regulations 2010 – Sanitation, hot water safety and water efficiency -

- British Standard
  - BS EN 12831:2003 – Heating system in buildings. Method for calculation of the design heat load
  - BS 8558:2015 Guide to design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages. Complementary guidance to BS EN 806
  - BS EN 14511-4:2013 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling. Operating requirements, marking and instructions
  - BS EN 12309-1:2014 Gas-fired sorption appliances for heating and/or cooling with a net heat input not exceeding 70 kW. Terms and definitions
  - BS EN 16147: 2017 Heat pumps with electrically driven compressors. Testing, performance rating and requirements for marking of domestic hot water units

    - BS EN 14825:2016 Air conditioners, liquid chilling packages and heat pumps, with electrically driver compressors, for space heating and cooling. Testing and rating at part load conditions and calculation of seasonal performance
    - BS EN 12102:2013 Air conditioners, liquid chilling packages, heat pumps and dehumidifiers with electrically driven compressors for space heating and cooling. Measurement of airborne noise. Determination of the sound power level
    - BS EN 14825:2016 Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling. Testing and rating at part load conditions and calculation of seasonal performance
    - BS EN 15879-1:2011 Testing and rating of direct exchange ground coupled heat pumps with electrically driven compressors for space heating and/or cooling. Direct exchange-to-water heat pumps
    - BS EN 15316-1:2017 Energy performance of buildings. Method for calculation of system energy requirements and system efficiencies. General and Energy performance expression, Module M3-1, M3-4, M3-9, M8-1, M8-4

- International Organization for Standardization
    - ISO 52016-1:2017 Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads – Part 1: Calculation procedures

- Official Journal of the European Union
    - Commission Regulation (EU) Ecodesign requirements for space heaters and combination heaters

Glossary

Antifreeze	An additive that lowers the freezing point.
Aquifer	A stratum or layer of soil or rock from which water can be abstracted in usable quantities.
Aquifer (heat) re-injection	The disposal of warmer/colder water from open water-source GSHP systems by re-injection back into an aquifer.
Borehole	A hole drilled into the ground and suitably constructed (with permanent liners, etc.) to allow it to either be used for abstraction, re-injection or monitoring purposes or the insertion of heat exchanger pipes for a closed loop system.
Glycol	For ground-source heat pumps (used prominently in pipework) this is a generic term for a heat transfer fluid that has a freezing point lower than water.
Closed loop	A heat collection system whereby a pipe-work system is placed within the ground (or lake, river or sea) and a water/glycol mix is circulated through it. A heat pump extracts heat from the circulating fluid and the heat is replenished by the source (ground, lake, river or sea). The fluid is always contained within the system and does not come into direct contact with the source.
Commissioning	Progressing an installation, from the installation of all plant and pipework, setting up the working conditions, the regulation of the system, and the fine-tuning of static completion, to full working order in accordance with specified requirements. Commissioning includes recording all relevant measurements, flow rates and/or test results, and the preparation and submission of a commissioning report or certificate (as required by the relevant technology standard) that confirms the system can deliver the performance quoted to the customer.
Contract	An undertaking for the design, supply, installation, set to work, commissioning and handover of system covered by the relevant technology standard. All contracts must be compliant with MCS requirements.
Coefficient of performance (COP)	An expression of the output of a machine in heating mode as a proportion of input power (compressor and fans): the rated capacity divided by the rated power input. In practice this is expressed as a single figure or sometimes as a percentage.
Drawdown	In subsurface hydrogeology, drawdown is the change in hydraulic head observed at a well in an aquifer, typically due to pumping a well as part of an aquifer test or well test.

Ground-source heat pump	A ground-source heat pump is a heat pump that is thermally connected to the ground and extracts heat from it. This is usually used to heat radiators or underfloor heating systems and hot water, but can also deliver cooling.
Handover	The point in a contract where commissioning and certification of the system have been satisfactorily completed to the contract specification, enabling the installation to be formally explained and handed over to the client (along with all the relevant documentation required by the relevant technology standard).
Heat exchanger	A heat exchanger transfers heat energy from one medium to another. It can take a variety of different forms; the most common example is a central heating radiator. Here, hot water is circulated through pipes or plates and transfers heat to the surrounding air. A device used to allow heat to be transferred from one liquid to another without allowing the liquids to mix.
Heat pump	A device that takes heat energy from a low-temperature source and upgrades it to a higher temperature, at which it is used for heating and/or hot water. Heat pumps use different heat sources: ground-source, where heat energy is extracted from the ground (e.g. from boreholes, horizontal trenches or aquifers); water-source, in which heat energy is extracted from water (e.g. lakes, ponds or rivers); and air-source, where heat energy is directly extracted from ambient air. This includes solar-assisted heat pumps. A heat pump is a device for transferring energy in the form of useful heat from one place to another. It cannot store, make or destroy heat energy – it simply moves it. There are a number of techniques that exploit heat transfer; the commonest in use is the refrigeration cycle. A heat pump is capable of transforming a large quantity of low-grade, low-temperature heat.
Heat pump unit	A heat pump unit is a factory-assembled unit containing the complete refrigeration system.
Heat transfer medium	Fluid that is used to transfer thermal energy between components in a system.
Heating capacity	Rate of heat transfer to the indoor hot water or air, expressed in W or kW.
Hydraulic	Use of water or another liquid heat transfer medium such as glycol as the heat-transfer medium in heating and cooling systems. Also referred to as 'hydronic'.
Installation	The activities associated with the placement and fixing of a heat pump system.

Legionella	Legionella is a naturally occurring bacteria, present in rivers, lakes and reservoirs. It can cause Legionellosis, which can take two forms: Pontiac fever, a mild influenza-like illness, and Legionnaires' disease, a more serious (and potentially fatal) illness.
Load	Heating/cooling demand of a building or process.
Open loop	A heat collection system whereby water is extracted from either the ground or an open water source (lake, river or sea) and is passed directly through a water-source heat pump. This water may be re-injected back into the source or discharged. The latter may incur wastewater charges.
Power input	Electrical power input, of the compressor and ground circulating pump, expressed in W or kW.
Seasonal coefficient of performance	An efficiency metric of heat pumps that describes performance of the unit over a typical season where the source temperature varies. Frequently used with heat pumps where the source temperature changes considerably over the year (and hence the efficiency also changes).
Seasonal performance factor (SPF)	Similar to the seasonal coefficient of performance, the seasonal performance factor is a ratio expressing the efficiency of a heat pump by describing heat output to total energy input and taking into account variations in performance over the heating season. Under BS EN 1536, input energy includes auxiliary energy which may be all (or part) of pump/fan power. Attention must be given to whether this is intended to include heat from other sources (e.g. electric immersion heater), and to the full pump/fan power needed to overcome all resistances of circuits (i.e. not just the heat exchangers of the heat pump).
Thermal response test	A special test carried out on a closed loop borehole whereby the borehole is heated or cooled in a controlled way to determine the thermal properties of the borehole and of the surrounding ground.
Water well	A water well is an excavation or structure created in the ground by digging, driving, boring, or drilling to access groundwater in underground aquifers.

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