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HEAT PUMPS

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Contents

Section 1. Is this for me?

This guide is part of the E-Pack which is available to TECs members. We have made the guide available to everyone as it may also be of interest to others.

Heat pumps (**HPs**) like Photo Voltaic (**PV**) systems are all the rage when looking for ways to reduce our greenhouse gas (**GHG**) emissions. The government's GHG reduction plans assume that 600,000 heat pumps a year will be installed by 2028. At the same time a target of 300,000 new builds per year has been announced. This sets an expectation that at least 300,000 existing buildings per year will be fitted with heat pumps. At the time of writing roughly 2% of new builds are being fitted with heat pumps.

You will probably have considered replacing your heating system with a HP, but have heard some conflicting information about them. You may even have gone as far as getting a quote and held back because of that or the price quoted. This guide gives you the information you need to make a more informed decision.

The guide explains the important concepts around HPs, a quick answer to whether you should consider fitting a HP and how to go about it as well as a detailed explanation of the following:

- How heat pumps work;
- Terminology you are likely to encounter;
- Typical performance parameters; and
- The design of a system.

Section 2. What is a heat pump?

A heat pump is a device which extracts heat from a heat source and transfers it to a heating medium which is used to transfer heat to emitters within a building to heat your living space and provide hot water.

A key feature of heat pumps is that the total heat output is more than the electrical energy needed to drive the heat pump.

A heat pump operates in a similar way to a refrigerator, but in reverse.

2.1 Types of heat pump

Heat pumps are categorised by heat source and heating medium. The following types are common:

- Air Source Heat Pump (**ASHP**), these are the most widely marketed form.
- Ground Source Heat Pump (**GSHP**), these are usually the most efficient and can be:
- coils laid horizontally in trenches between 1 and 2 metres underground;
- pipes in boreholes up to 100m deep; or
- Shared ground loop (for multi-dwelling installations).
- Water Source Heat Pumps (**WSHP**), not common as they require a nearby body of water.
- Hybrid heat pumps which operate in conjunction with more traditional gas/oil systems.

The heat is delivered into the building through emitters. These can be in the form of 'wet systems' using a water mix through pipe/radiators (on walls or underfloor), this is the most common. The can also deliver the heat in the form of hot air into the living space, hot water cannot be heated by this option.

2.2 Why do we need heat pumps?

It is likely that it will not be possible to buy a new oil boiler after 2028 or a new gas boiler after 2033. Alternative heating technologies are likely to become the norm in 5-10 years. We need to make sure our homes and buildings are ready for these changes.

Increasingly, new build houses will be designed to be heated by a HP which would be a cost-effective (price and ghg emissions) alternative to a gas boiler, but this won't be enough. We need to consider which other buildings are suitable and how to make them suitable.

According to the energy saving trust heating accounted for 31% of household ghg emissions in 2017. This needs to be reduce by 95% if we are to have a chance of reaching net-zero carbon.

As we decarbonise, we need to provide heat from low-emission sources. That means either electricity from low-emission sources, or alternatives such as green hydrogen or burning biomass.

An essential assumption of this strategy is to generate plentiful low-emission energy that can be distributed to where/when it is required. Unfortunately, neither the policies nor the resources to upgrade the electricity/gas networks are in place to deliver this assumption in the time remaining before Carbon Budgets are exceeded.

Section 3. What determines the effectiveness of a HP?

Unlike any other heating system (e.g. coal, gas, direct electricity or biomass) HPs can have an efficiency of over 100%, possibly over 400%. So why doesn't everyone install them when other heating systems have an efficiency below 100%, some as low as 40%? Are HPs not automatically more effective?

The answer to this question depends on what the objective of replacing an existing heating system with a HP is. Typically, it is to reduce energy costs as well as reducing ghg emissions. Heating buildings, however, is primarily about comfort and health (of occupants and the building itself). So we need to compare:

- cost: initial capital; running costs; cost pay-back period
- ghg emissions: embodied emissions; emissions from operating fuels; carbon pay-back period
- comfort: ambient indoor temperature/humidity; availability of hot water; ease of managing/controlling/maintaining the system.

To ensure effectiveness, we need to compare all three objectives, either like-for-like, an improvement to the current heating system or to a known standard for effectiveness. Typically, minimum standards are set by building regulations (currently SAP), but higher standards such as EnerPHit or those the AECB have defined for retrofitting UK housing stock can also be set as an objective.

Once the objectives have been defined, it is possible to assess the necessary changes to the property and how the new heating system is specified/operated. This is done by assessing the intricate heat energy transfer of four key parameters:

- Input energy
- Heat loss/retention (for space and water)
- Times of operation (heating levels/duration)
- Temperatures (internal/external)

Strictly all of these (objectives and parameters) must be assessed (modelled) before determining whether a HP will achieve the required effectiveness for a specific building and its occupants. This is expressed in terms of a Seasonal Performance Factor (**SPF**) or Seasonal Coefficient of Performance (**SCOP**).

At current typical energy prices and Carbon Intensities (CI), a minimum SPF=3 is necessary to ensure operational cost parity for a unit price for electricity (tariff) of ~25p/kWh. While only an SPF of ~1.5 is needed for emissions parity at a Grid Intensity of 280g CO2e/kWh when compared to a mains gas boiler. This assumes a target average internal temp of ~19^{O}C. Also note that these are generalised indicators for the most common examples, costs and ghg emissions associated with making, installation and operation of a HP compared to existing heating systems can vary significantly and will change over time.

It is the interplay between these key parameters, each of which have several sub-parameters that need to be considered in the modelling of heat energy flows in a building. Modelling this can be complex, so most modelling tools will make assumptions or approximations. The worst thing is not to consider all four key parameter and clearly state the assumptions/approximations. Unfortunately, this is something that many practitioners tend to do, especially those promoting/opposing a generic solution or vested interest.

Luckily, there are some simple guidelines and rules-of-thumb that can help get an approximate answer to: how effective would a heat pump be for my building/use. This is the “simple model” available to TECs members using the E-Pack heat analysis.

Section 4. The Quick Answer to Why and How I Should Get a HP

When installed with suitably sized radiators or underfloor heating a heat pump can save you money on energy, but a poor installation can lead to increased costs. Not every building is suitable, so you have to make sure yours is before you decide to have a HP installed.

A HP is one of many measures you can undertake to reduce your GHG emissions, improve comfort and possibly even pay less for your heating. TECs would strongly recommend that you take a more wholistic approach rather than opting for a measure which you've heard about, it may not be right for your objectives or circumstances.

Here are some basic steps which you should undertake to help you make that more informed decision:

- Decide what your aims and priorities are.
- Measure what and where your emissions, energy use and costs are.
- Get a whole building assessment done with a list of priced options and their effectiveness.
- Do the quickest and most effective measure first.
- Check if this worked as you expected before moving on to other measures.

Much of this you can do yourself using the TECs E-Pack for heating. You will probably need help when it comes to doing detailed heat-loss analysis. This can be provided or signposted by TECs to its members.

Your approach should always be guided by the following Energy Hierarchy:

1. Reduce heat energy consumption by cutting out waste. This could be changing how/where you heat or simple measures to reduce heat loss with draught proofing or temporary insulation like curtains.
2. Reduce heat energy loss by improving the fabric of the building, i.e. insulation and uncontrolled ventilation. This is where you need to follow the steps above to make sure that any measures are effective, but also take account of minimum ventilation and condensation so as not to cause discomfort or damage the building fabric.
3. Only when you have managed to reduce your heat-energy consumption sufficiently, should you consider low-emission heating technologies such as HPs.

This makes sense because you'll get significant benefits from steps 1&2 regardless of whether you also do step 3.

As a minimum, you should do the 'simple' heat assessment available in the E-Pack. This will give a good indication of the likely effectiveness of a HP compared to your existing system. You can also pay for an independent assessment such as Energy Saving Devon or other commercial providers. Do this before engaging a HP installer so you can compare their heat assessment against an impartial one.

Section 5. Central heating system components

The most common central heating system consists of:

- A heat source (typically gas or oil boiler) which heats a heating medium – normally water.
- Pipework that allows the heating medium to flow to each room.
- Radiators in each room that deliver heat.

Such a system might also have:

- A timer and one or more room thermostats which determine when the boiler runs.
- Thermostats on radiators which control how much heat is delivered by the radiator.

5.1 Hot water

Central heating systems also deliver hot water, this may be at temperatures as high as 80C. For most usage, a water temperature at the tap of ~40C is sufficient.. To protect against legionella the temperature should be raised above 60C from time to time. In most systems the hot is heated to 60C by default to guard against legionella.

When a low temperature source, such as a heat pump is used then the temperature should be boosted to 60C periodically, this can be done by the heat pump or with a separate heating element in a hot water tank (e.g. an immersion element).

5.1.1 Legionella

Legionella bacteria can multiply in hot water systems, the conditions for this include:

- Water in some of the system being between 20 and 45C
- Organic material to feed the bacteria such a sludge which can come from the mains water supply
- Parts of the system that have stagnant water

To guard against legionella it is recommended that:

- Hot Water is heated to 60C
- When a tap is turned on water should reach 50C within 1 minute
- Cold water is distributed below 20C

For further details see here:

Residential landlords and non-domestic building managers are legally responsible for the health and safety of building users, and so should perform a risk assessment that includes legionella. For more information see this link and this.

5.2 Radiators

Traditional radiators are designed to deliver a specified amount of heat (in Watts or BTUs). The heat output is specified at a delta T (ΔT, difference between water temperature and room air temperature). ΔT is usually 50C,. This means that heating a room to 20C using a conventional system the boiler will supply water at 80C to the radiator and it will return at 60C giving an average of 70C.

A radiator sized to work with a ΔT of 15 (as is the case for a heat pump), rather than 50, needs to have nearly 5 times the rated output. This means that it needs to have a much larger surface area, which can make the radiators impractically large, one way round this is to size for a higher flow temperature, but a higher flow temperature may not be achievable or cause the heat pump to operate less efficiently. In practice, because most radiators are oversized, a heat pump could work reasonably well at a ΔT of around 30C. Provided sufficient heat can be delivered to achieve the desired room temperature under the coldest outside temperatures.

Many radiator sellers and traditional plumbers use calculators for radiator sizing that typically take as input:

- Room type
- Room dimensions
- Type of windows

This is simple, but doesn't take account of building construction, so is likely to be inaccurate. This may not matter as a safety margin is built into the calculation, but they will also assume a water temperature of about 70C.

Strictly, these calculations must also take account oft the heat source and room construction. It is therefore advisable to get the calculations done by a qualified heating engineer familiar with heat pumps.

A simple test you could apply if you have a conventional gas/oil boiler is to reduce the flow temperature to the lowest point that is comfortable during cold periods, if this is at or below about 55C you could probably fit a heat-pump without any alterations to your plumbing.

Not all gas/oil boilers display the flow temperature. You may be able to deduce these from the user manual for the different settings. Failing this, you can measure the outlet pipe as close to the boiler as possible using an infra-red or traditional thermometer designed for the range of temperatures 0-100C.

5.3 Flow Temperature and plumbing

As we have seen in the last section radiators are sized relative to the difference between room temperature and water, this is known as the flow temperature. If this difference is lower, then a larger volume of water will need to flow in order to transfer the same amount of heat from the radiator into the room. This means that heating pipes need to be large enough to deliver this.

Many houses have sufficient plumbing capacity (radiators and pipes) for conversion to a heat pump. In these cases, installation is relatively simple.

In other cases, it may be necessary to replace radiators or fit larger pipework, this is particularly the case for microbore plumbing which was popular in the 1970s.

5.4 Underfloor Heating

While direct electrical underfloor heating is sometimes deployed, this section covers water based underfloor heating systems.

Underfloor heating provides a means of increasing the area of the heating surface without losing any wall space. This should be the system of choice for a new build as it makes them future proof in terms of being heat pump ready. It can also improve the level of comfort for occupants as heat is rising close to them.

Installation in an existing building is extremely disruptive, as it requires the floor to be taken up and re laid. This should only be considered if doing a deep retrofit.

A typical underfloor heating installation consists of a circuit of pipe laid under the floor in a snake like fashion so that pipe is evenly spaced under the floor as shown in the photo above right (Oak house construction 10/4/2011)[1].

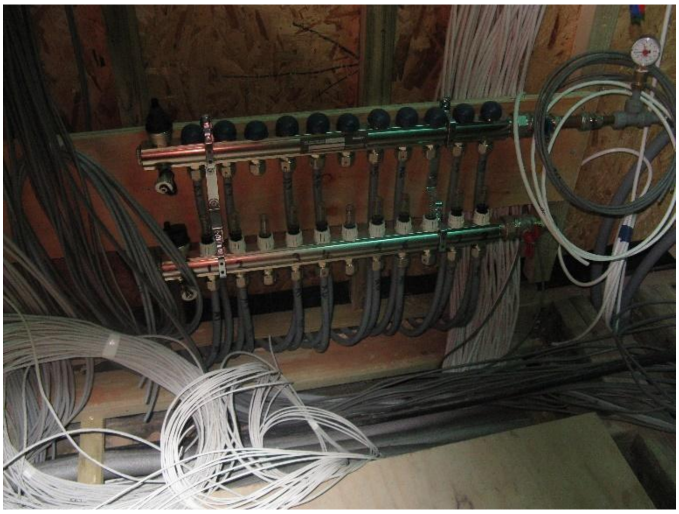
When installed at ground floor level pipes are typically laid over insulation and a vapour proof membrane. These are then clipped as shown in the photo above right. The pipes are then covered with a layer of screed about 75mm thick which provides thermal mass for limited heat storage capacity. The screed is then finished with a thermally massive material such as stone tiles. Note that it is not a good idea to finish the floor with carpet as this impedes the heat reaching the room.

For other floors pipes are laid on special panels (above left) over insulation between joists the pipes run in grooves routed into each panel. These are then covered with a layer of plywood and finally the floor finish.

Other options for floor constructions and finish (e.g. engineered wood) are also available.

5.5 Manifold (zone valves)

A water-based heating system needs a means of regulating the flow of water to a zone in the house or to each room, this is done with a manifold, which consists of a set of electrically operated valves that are opened by thermostats in each zone/room. The picture right shows a manifold during installation of an underfloor heating system in a new build.



5.6 Thermostats

Traditionally one thermostat is fitted for the whole house, and more recently thermostats per

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[1] Oak house construction 10/4/2011

radiator (TRV). With underfloor heating the equivalent of the radiator TRV is not user-settable as this is designed to regulate the flow temperature in the underfloor pipe.

With underfloor heating is installed the zone/room thermostat determine the amount of heat delivered. These measure the air temperature in the area/room and signal to a controller for whole house systems or individual valves that the heating should be adjusted in the area/room. This is achieved by actuating the associated manifold/zone valve.

Recently thermostats have become available that are Wifi enabled, these can be monitored using an App, which can also be used to control the heating.

5.7 Heating controller

All systems have a controller, which is responsible for:

- Switching the heat source on and off to a desired schedule
- Maintaining a target flow temperature in the heating system
- Diverting flow to the hot water system
- Controlling any pumps in the system
- Implement weather compensation if included

A controller will typically also have a number of modes of operation:

- Boost Heating (sets higher temperature for a short period)
- ECO Heating (usually weather compensation)
- Hot Water and associated Legionella cycles
- Frost Protection – maintains just enough flow temperature to prevent pipes freezing

The controller may also take inputs from a number of temperature sensors.

In some systems the controller will be built into a boiler, but in others it is separate.

Section 6. Using a heat pump

6.1 For Heating

There is a relationship between the efficiency of a heat-pump and the difference between ambient temperature and temperature to which water circulating in the system is heated (the flow temperature). To operate as efficiently as possible, the heat pump should supply a little heat for a long period of time. In practice this means that you should aim to keep the temperature constant and avoid letting the house get cold. This is done by having adequate insulation/ventilation, but also by not leaving doors and windows open especially when it is cold outside.

A weather compensation feature helps to automatically select the most efficient flow temperature.

Those who are used to a gas or oil boiler will be used to running the heating for a short period just before they need it. That isn't the most efficient way of running a heat pump. Your installer should set your system to operate at its highest efficiency, please refer to section 3 for an overview of this.

6.2 To heat hot water

When a heat pump also supplies hot water, it normally heats a water cylinder, when it isn't supplying space heating. Heating a cylinder is normally turned off when a thermostat in the cylinder reaches a target temperature typically 55C.

There is typically a 5-minute delay between heating starting and the temperature at the hot water thermostat starting to rise. This means that small temperature rises that occur over a short period of time are very inefficient.

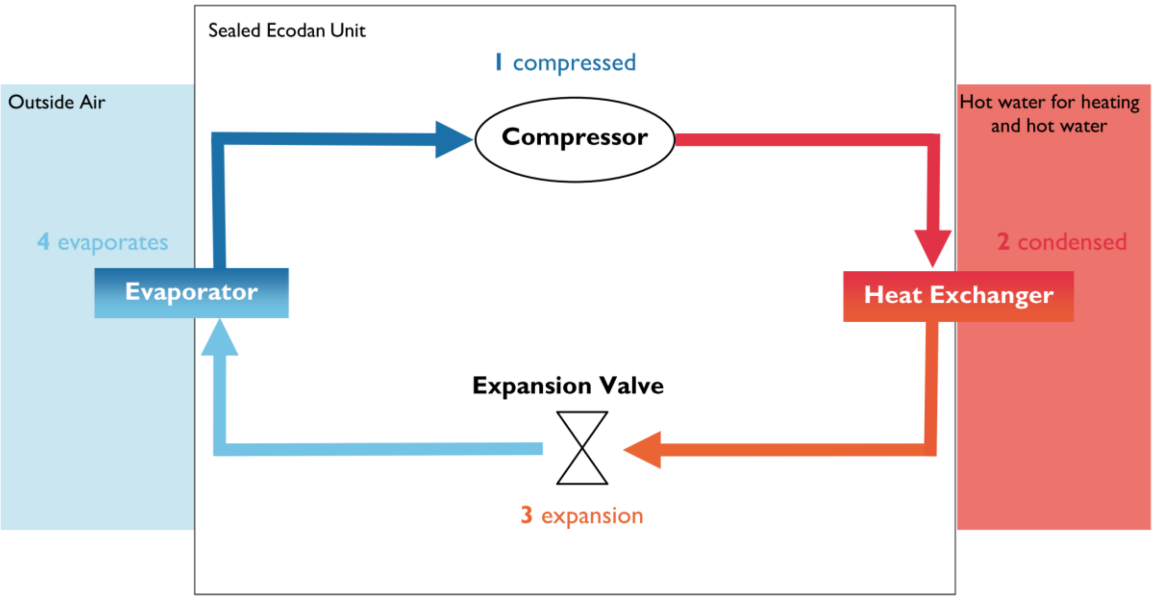
As the water temperature reaches the limit of the heat-pump it is probably more efficient to use an immersion heater to heat water, particularly if this is connected to a PV divert device. Similarly, it may be more efficient not to use the heat pump in the summer months when no space heating is required. You'll need to discuss your requirements and circumstances with the installer to ensure the best setup.

Section 7. Heat Pump specific components and types

The heat source in a heat pump based system will differ from other heating systems. It will have a pump, compressor and a heat exchange part which can be from air, ground or water.

The heat pump works by passing refrigerant though the heat source to extract heat which cools the heat source The refrigerant is then compressed to heat it up. The compressed refrigerant is passed through a heat exchanger to pass heat to the heating medium, then the refrigerant passes through an expansion valve which cools it again.

This cycle is shown in the diagram below[2].



(From Mitsubishi FTC2 Installation manual)

The same principle applies to air, ground and water source heat pumps.

7.1 Air Source Heat Pumps (ASHP)

An air source heat pump uses a fan to pass outside air over the evaporator, this slightly reduces the temperature of outside air surrounding the heat pump.

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[2] Mitsubishi FTC2 Installation manual

7.2 Ground Source Heat Pumps (GSHP)

A ground source heat pump passes a mixture of water and antifreeze through an array of pipes or a borehole in the ground. Heat is extracted from the water/antifreeze mix at the evaporator. This is the most common indirect closed loop system.

Other GSHP types include

- Direct – where the refrigerant is passed through the pipe array.
- Open loop where an existing water source is used.

As the ground temperature is more stable and higher in winter than air temperature, ground and water source heat pumps are more efficient, but can be more difficult to install. See here.

7.3 Water Source Heat Pumps

Water source heat pumps work in a similar way to ground source heat pumps, except that pipe array is placed in a water source, such as a lake or river.

7.4 High temperature heat pumps

High temperature heat pumps are designed to operate at higher flow temperatures.

Characteristics of this class of heat pump include:

- Capable of operating at flow temperatures 65°C and above.
- between 2.1 and 3.0.
- Cost 20 – 30% more than a standard heat pump.

For more details see here:

These can be used to avoid upgrading radiator/pipes.

Whilst a high temperature heat pump can operate at a higher flow temperature, it is less efficient than a lower temperature heat pump, so more electrical energy will be required to generate heat.

As with any heat pump the output characteristics need to match those required by design calculations. More so in this case as the reduction in running costs and ghg emissions is likely to be marginal.

See also here.

7.5 Hybrid Heat Pumps

Hybrid systems use a conventional gas or oil boiler in conjunction with a heat pump and a suitable controller. This can be used in a number of ways:

- It can provide flexibility in when to use either system.
- The backup boiler provides heat when the heat pump does not have the capacity to produce sufficient heat efficiently.

BEIS produced a report on hybrid heat pumps in 2017[3]

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[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700572/Hybrid_heat_pumps_Final_report-.pdf

This report includes the results of various studies that show a wide range (30% to 96%) of heat coming from the heat pump. Different heating schedules account for some of this variability, as heat pumps are more suited to maintaining a constant temperature.

As these systems are used in poorly insulated/ventilated homes, at best they may reduce running costs and ghg emissions by only a small amount. We therefore don't think these are a good option, except in exceptional cases. There are likely to be several alternative heating system options in most cases where such systems are suggested by installers.

Section 8. Technical terms for HPs

When investigating heat pumps, you will undoubtedly encounter several terms all of which have a bearing on performance. Figures quoted by heat pump manufacturers relate to precise definitions that do not necessarily reflect in-use conditions.

Most of the following terms will apply to all types of heating systems, but some are specific to HPs or have a specific meaning in such heating systems.

8.1 Emitter

An emitter is a surface which transfers heat from water heated by the heat source, and the air in a room. Typically, this is a conventional radiator or underfloor heating.

8.2 Flow/return Temperature

Flow temperature is the temperature of water flowing in the central heating system as it leaves the heat source. Return temperature is the circulating water as it returns to the heat source.

Typical values range from 30C to 75C. Temperatures above 60C are common with gas and oil boilers, but heat pumps work more efficiently if the difference between the source temperature and flow temperature is as small as possible. A flow temperature of 55C is generally regarded as an upper limit for heat pumps.

8.3 ΔT (delta T)

Delta T or Δt refers to the difference in temperature between the water circulating throughout your central heating system and the room temperature. When replacing any radiators in your home it's important that you use the correct Delta T. This is because the same radiators can have different outputs at different water temperatures due to the heat source you are using. (See https://www.stelrad.com/news-events/blog/the-importance-of-delta-t-in-calculating-heating-output/)

Typically heat output of a radiator is quoted at ΔT=50, based on a European standard.

This means that to heat a room to 20C, the average flow temperature of water is 70C. Typically this means that the flow temperature is 80C and the return temperature is 60C.

8.4 ΔT correction factor

As heat pumps work better at lower flow temperatures, the temperature difference between room and radiator will be different from the quoted ΔT for the radiators used, so when calculating the heat output of radiators a correction factor needs to be applied.

Correction factors are given in the following table[4]:

ΔT	Correction Factor
5	0.050
10	0.123
15	0.209
20	0.304
25	0.406
30	0.515
35	0.629
40	0.748
45	0.872
50	1.00

If the flow temperature is 55C rather than 70C, then to get an output of 100W you would need a radiator rated at 100 X 1.0 / 0.629 = 159W

If the flow temperature were instead to be 35C, then the radiator would need to be rated at 100 X 1.0/0.209 = 478W

See here.

8.5 Thermal Mass in buildings

In the context of a heating system in a building, thermal mass can be used to store heat. In an underfloor heating system, a screed is sometimes used as thermal mass. Thermal mass determines how fast the system responds to heat applied. A system with high thermal mass will require more heat input to reach its target temperature, but will also lose temperature more slowly.

Depending on the heat loss characteristics of a building, if the building has high thermal mass, it is more efficient to try to maintain a constant temperature. Whereas if a system has low thermal mass, it is more efficient to heat only when heat is needed.

8.6 Weather Compensation

A heat pump works most efficiently at lower flow temperatures. Weather compensation sets the flow temperature at an appropriate level to just meet heating demand given the current weather conditions. You'll need to refer to your system manual or installer to see if this function needs to be

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[4] https://www.buildingservicesindex.co.uk/entry/136540/AEL-Heating-Solutions-Ltd/How-to-calculate-the-delta-T-for-a-radiator/

adjusted after the HP has been turned off/low for some period, e.g. returning from holiday or end of the summer period..

8.7 Coefficient of Performance (COP)

COP is the ratio of heat output to electrical energy input under standard test conditions. A COP value of 4 means that you get 4kWh of heat out for 1kWh of electrical energy in.

For air to water pumps COP is typically quoted in terms of the air temperature (A) and flow temperature (W), this is codified as follows.

Aaa/Www

aa represents the air temperature

ww represents the water temperature

Example: A2W35 means air 2C, water 35C

Typical values are:

Air temperature	Water Temperatures	Mirai COP	Ecodan COP[5]
7	35	4.51	4.26
7	45	3.64	
7	55	3.02	
2	35	3.83	3.11
2	45	3.05	
2	55	2.5	

It must be emphasised that these values are under test conditions, they do not represent real world conditions. It can however be seen that the performance of any air source heat pump deteriorates as the temperature difference increases.

Similarly ground and water-based HP manufacturers will quote a COP. Here the ground/water temperatures will have a more limited range.

8.8 Seasonal Coefficient of Performance (SCOP)

In order to estimate annual performance, the European Union's Ecodesign regulations utilise a test and calculation standard (EN14825:2016) at a wide range of temperature conditions. These are used to calculate a Seasonal Coefficient of Performance (SCOP) for a heat pump, which is used to derive an energy label class (A++ to G) for comparison purposes.[6]

See BRE definition.

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[5] ECODAN PUHZ-HW140V/YHA2(BS) http://www.mitsubishitech.co.uk/Data/Ecodan/Air/Monoblock/Outdoor/PUHZ-W/2015/PUHZ-(H)W-VHA2(YHA2)_Databook.pdf

[6] https://tools.bregroup.com/heatpumpefficiency/background

Unfortunately, the SCOP estimation of performance misses a number of important aspects that may affect the performance of a heat pump when installed in homes. These include:

- Heat loss of the actual dwelling in which the heat pump is installed is ignored
- It uses average European climate data
- Hot water heating operation is ignored, including its impact on space heating operation
- Heating hours
- For inverter (modulating) heat pumps, the minimum heat output is not defined, meaning some heat pumps may cycle on/off more than others at identical temperature conditions
- Weather compensation is always assumed to be present

Tables of SCOP values for specific heat pumps are available from the MCS certified product directory[7], if you know the manufacturer or better product number for a heat pump you can look up its details, including SCOP values.

Here are SCOP values for Mitsubishi Ecodan PUHZ-HW140VHA2-BS

Flow Temperature	35	36	37	38	39	40	41	42	43	44
SCOP	3.87	3.83	3.79	3.75	3.71	3.68	3.64	3.6	3.56	3.52
Flow Temperature	45	46	47	48	49	50	51	52	53	54
SCOP	3.48	3.44	3.41	3.37	3.34	3.3	3.26	3.23	3.16	3.12

For this heat pump values above 55C are not given. This ASHP was certified in 2009, we should hope that more recent designs have better performance.

Again, you can see that SCOP deteriorates with flow temperature.

8.9 Seasonal Performance Factor (SPF)

This standard was devised by BRE to get around the shortcomings of SCOP[vii].

SPF estimates heat pump annual efficiency, an annual combined space and hot water heating duty cycle is used, which incorporates hourly space and hot water heat load and temperature assumptions, using average UK weather data (taken as City of Leeds). Heat pump test data satisfying Ecodesign regulation requirements (EN14825:2016) (SCOP) is used as an input to the calculation.

This provides a more likely and useful estimate of UK domestic heat pump performance.

BRE publish a tool called Domestic Annual Heat Pump System Efficiency (DAHPSE) which allows you to compare the UK performance of heat pumps in their database. It plots a graph of annual efficiency by design heat loss.

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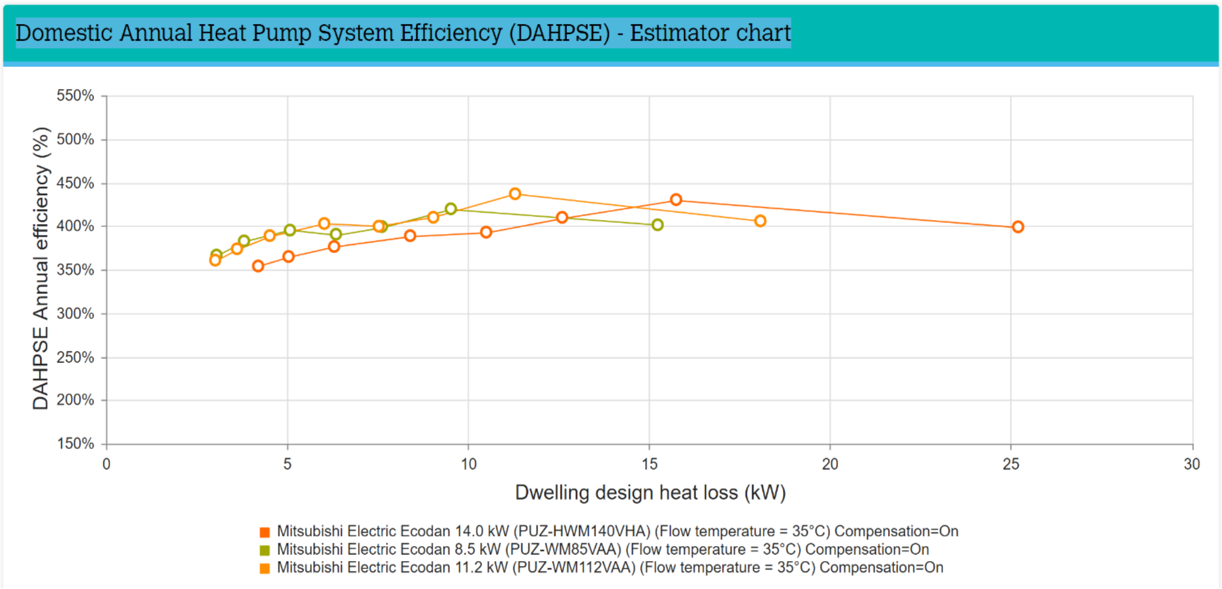
[7] https://mcscertified.com/product-directory/



Section 9. System Design Process

This section outlines the process used to size a heat pump.

- For each room calculate:
  - heat loss at design interior and exterior temperatures
  - calculate flow temperature based on current radiators/emitters
  - if flow temperature is too high either:
    - Reduce heat loss
    - Change radiator to increase heat output
    - Repeat calculation until flow temperature is suitable for a heat pump
- Work out required flow temperature for building as is
- Reduce heat loss or increase emitter size until flow temperature is acceptable
- Find a suitable heat pump

9.1 Microgeneration Certification Scheme (MCS) Heat pump Calculator

MCS provides a heat pump calculator[8] (macro enabled spreadsheet) which is commonly used to produce illustrations of system performance. The inputs to the calculator are:

- Design temperatures
- Assumed U Values for each element type and floor (ground, mid, upper) – a U Value calculator is included in the tool.
- Details of each room:
  - Heat loss

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[8] https://mcscertified.com/wp-content/uploads/2021/04/MCS-Heat-Pump-Calculator-Version-1.10-locked.xlsm

    - Energy usage
    - Design Temperature
    - Does the room have an Open Flue?
    - Air Changes per hour
    - Floor Area
    - Volume
    - W/m^2
- Details for each room are input on a separate sheet which includes all dimensions.

Outputs include:

- Sound output from the heat pump
- Ground loop sizing (for GSHP only)
- Radiator sizing
- Underfloor heating sizing
- Fuel price comparison, Annual running costs, CO_2 Emissions
- Compliance Certificate

Section 10. Requirements for installation

10.1 Insulation and ventilation

Emitters need to warm the air in each room. As emitter temperatures are lower with a heat pump installation, this takes longer than with a conventional radiator with a 50°C temperature difference. If the room is draughty or poorly insulated, then the air that has just been warmed will escape and its embodied heat will be lost.

10.2 Space considerations

Depending on the type of heat pump installed you need to have space for it both inside and outside.

10.2.1 Air Source Heat Pump Outside Space

The heat pump should be installed on a concrete base outside the building as close as possible to the interior parts of the system.

- There should be sufficient ambient air circulating around the heat pump.
- The heat pump should be positioned so that it is easy to get at for maintenance.
- Avoid positioning it under a bedroom window or near neighbours as it will make some noise.
- This heat difference article gives further information.

10.2.2 Inside space for plant (plant room / large cupboard)

Inside the house you will need a large cupboard or plant room which might contain:

- Hot Water cylinder
- Expansion tanks
- Pumps, valves and other plumbing
- Controller
- Underfloor heating manifold if required

10.2.3 Ground Source Heat Pump Outside Space

As mentioned earlier there are 2 types of installation:

- Horizontal coils buried in trenches about 1 to 2 metres deep and a metre wide. This type of installation needs a sizeable lawn or field.
- Boreholes require less space. A house that requires 10kW of heating capacity will probably need 3 boreholes 80 to 110m deep. These should be 5 - 6m apart and 6m from any building. There needs to be sufficient access for a drilling rig. See the Green Match article for further information.

A GSHP will also need space in the plant room

This article gives an idea of the space requirements for a GSHP.

10.2.4 Solar Thermal

In some cases a heat pump is installed in combination with solar thermal system. This heats the bottom part of the hot water cylinder which pre-heats water to about 30°C so the heat pump only has to raise its temperature to about 50°C when the heat pump heats the top part of the tank.

It is difficult to justify the additional cost as solar thermal systems do not provide much heat energy during the heating season.

10.3 Comparison with conventional alternatives

We need to consider carbon emissions and running cost both now and in the future. The following table shows emissions for a typical heat load and latest available typical real-world data, please adjust as appropriate for your installation):

Heating technology (energy source)	Provisional energy carbon intensity in 2023 (g CO_2e/kWh)	Average efficiency of measured systems installed in 2022 (%)	Estimated emissions for an annual heat load of 10,000 kWh (kg CO_2e/year)
Condensing gas boiler (mains gas)	208	90	2,311.11
Condensing gas boiler (LPG)	208	90	2,311.11
Oil fired boiler (heating oil)	306	85	3,600.00
ASHP average 2022 (electricity)	288	274	1,051.09
GSHP average 2022 (electricity)	288	334	862.28

Electricity carbon intensity is expected to reduce, by how much and when is a challenging question as it depends on many competing factors.

Similarly running cost comparison clearly depends on the relative prices of the different energy sources. The following table compares the cost of running an ASHP using average data, please adjust as appropriate for your installation:

Heating technology (energy source)	Ofgem/market energy energy unit price in 2024/5 (p/kWh)	Average efficiency of measured systems installaed in 2022 (%)	Estimated annual costs for heat load of 10,000 kWh (£/year)
Condensing gas boiler (mains gas)	6.89	90	765.56
Condensing gas boiler (LPG)	9	90	1,000.00
Oil fired boiler (heating oil)	8	85	941.18
ASHP average 2022 (electricity)	27.35	274	998.18
GSHP average 2022 (electricity)	27.39	334	820.06

The break-even electricity rate (unit price, £/kWh) for comparison with your current fuel source is given by:

- $R_{breakeven}$ = Break even rate for electricity
- $E_{current}$ = Efficiency of existing heat source (as a %)
- $R_{current}$ = Current rate you pay for fuel
- $E_{heatpump}$ = Efficiency of heat pump = SPF as a %
- Then
- $R_{breakeven} = (R_{current} / E_{current}) X E_{heatpump}$

If the rate you expect to pay for electricity is less than $R_{breakeven}$, then a heat pump should cost less to run. If you multiply this by the amount of annual units (kWh) you need to heat your space and water, you can work out your annual electricity cost for the electricity used by the heat pump.

Several electricity suppliers offer multiple rate tariffs. If your heat demand is low, so that room temperatures do not drop significantly during the day it can be cost effective to boost the heating a bit when electricity is cheap in order to ensure it isn't used when it is expensive.

According to homebuilding.co.uk an installed ASHP system costs between 11K and 20K, whereas a Combi-boiler costs between 2K and 4K installed.

Section 11. Subsidies

Heat Pumps could qualify for a number of subsidy schemes.

11.1 Boiler Upgrade Scheme

Through the Boiler Upgrade Scheme, you could get a grant to cover part of the cost of replacing fossil fuel heating systems with a heat pump or biomass boiler.

An overview of the BUS is available here.

A summary of the main eligibility requirements is:

- You own the property you are applying for.
- You are replacing fossil fuel heating systems - such as oil, gas, electric or LPG (liquefied petroleum gas) with qualifying low carbon heating at the property:
  - Air Source Heat Pump (ASHP) air to water only.
  - Ground Source Heat Pump (GSHP)
  - Biomass Boiler (in rural areas not connected to the gas grid only)
- The property has a current Energy Performance Certificate (EPC) (within the last 10 years). There is no longer any requirement to have any outstanding recommendation for wall or loft insulation on the EPC carried out.
- New build and social homes are not eligible, though self-build homes are

For qualifying heat pumps the grant is £7,500, and for qualifying Biomass boilers the grant is £5,000. The scheme is administered by Ofgem.

A more detailed description of the BUS is given in Ofgem Boiler Upgrade Scheme Guidance (last revised May 2024).

The scheme is now funded until 2028

The property owner contacts an MCS installer to complete an application under the scheme and obtain a voucher. The installer instals the system and gets payment from Ofgem, (any balance is paid by the owner to the installer).

Other references:

This MCS article describes the changes made to the BUS in May 2024

11.2 Local Authority Delivery Scheme

The full title of this is the Green Homes Grant Local Authority Delivery Scheme

It evolved out of the part of the Green Homes Grant (GHG), local authority part. There have been several versions of this scheme:

- LAD1 - the original scheme allocated £200m which local authorities had to bid for, this scheme ran from August 2020 to March 2022.
- LAD2 - allocated £300m to 5 Net Zero Hubs in different regions in April 2022 to work with local authorities.
- LAD3 - was a further competition for low income low energy performance (E,F,G) homes with gas heating, combined with Home Upgrade Grant (HUG1) for those off the gas grid. Projects had to be completed by August 2023. Devon County Council was a successful consortium bidder.

- HUG2 - is currently running for low income (less than 36k per year), low energy efficiency (EPC D,E,F,G) homes off the gas grid.

The LAD scheme aims to raise the energy efficiency of low income and low energy performance homes with a focus on energy performance certificate (EPC ratings of E, F or G).

LAD3 and HUG1 statistics

Effectively only HUG2 remain, although some providers may still be delivering legacy grants.

11.3 Energy Company Obligation (ECO4)

In its latest guise ECO4.

Medium and larger energy suppliers are obligated to fund energy efficiency measures. Those eligible include:

- Core group customers of the Warm Homes Discount scheme (fuel-poor pensioners)
- Those in receipt of certain benefits

The scheme is administered by local organisations such as TDC or ECOE.

For more information see this Ofgem link.