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Heating and Controls

Low Carbon Oxford North

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Low Carbon Oxford North

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WELCOME TO OUR FIFTH HOUSEWARMING GUIDE

This is the fifth in the series of Housewarming guides created by Low Carbon Oxford North. The series focusses on each of the core retrofit areas that may be required to improve the fabric of our buildings - fundamental to cutting energy use and the associated carbon emissions. Stopping heat loss from our homes is also an essential step in moving away from fossil fuels and becoming heat pump ready, particularly for older homes. Our homes will become warmer, healthier, and more comfortable to live in too.

At the heart of all the guides is a focus on reducing gas and other fossil fuel use for heating and hot water as this is where the greatest long term carbon and financial savings can be made. Fossil fuel heating-coal, gas and oil-is responsible for 40% of UK household carbon emissions (The Fifth Carbon Budget, Committee on Climate Change, 2015).

This guide focusses on improving or replacing your heating system. It covers types of heating systems and how they can be best controlled to achieve maximum efficiency (low bills) and the desired level of comfort. We also discuss air source and ground source heat pumps and some of the implications to consider as you move away from fossil fuels. Energy-efficient design and insulation of a home go hand in hand with a well-designed and operated heating system.

A poorly designed and badly operated heating system in the most efficient home will cost more money than it should to run and will emit more carbon. It is also true that even the best heating system installed in a poorly insulated, draughty building will emit more carbon.

This guide focusses on improving or replacing your heating system

WHY DO WE HAVE HEATING?

A BRIEF HISTORY

It is sometimes said that fire was man's key step from animal to human. A fire provides many functions including light, warmth, cooking, safety and a focus for community. Open fires became commonplace in dwellings until closed stoves were developed in the coldest parts of Europe as these are more efficient and their heavy casings can keep a room warm overnight.

England's milder climate did not create the demand for such stoves, so a typical Victorian house had open fireplaces in many rooms. An open fire is not particularly comfortable in the coldest weather as the heat is radiant and therefore temporary and there is a cold draught of fresh air through the room to allow the chimney to 'draw'.

The development of central heating and the availability of cheap fuel changed all that. In 1970 only 30% of homes had central heating but this rose to 60% by the 1980s as North Sea gas was rolled out. Now we expect a house to have central heating.

It is only in the last 50 years that fossil fuelled heating has become a huge source of CO_{2e} emissions. When central heating was first installed it was generally to provide background heating to about 18°C whereas today there is an expectation that every room will be heated to 21°C or more which, when combined with poor insulation, is why carbon emissions from homes are now so high.

COMFORT

The Energy Saving Trust says that "The thermostat should be set to the lowest comfortable temperature, typically between 18°C and 21°C". However, the temperature at which we are comfortable depends on many factors including personal preference.

On a day which starts with a frosty morning, when humidity is very low, we will feel colder than on a drizzly day at the same temperature. If we sit in a draught, we will feel colder than in still air at the same temperature. Scientific research has shown that if our feet and face have more than 2°C difference in temperature we will feel uncomfortable.

How active we have been, when we last ate, what we are wearing, and our mood all make a difference to our level of comfort at different temperatures. This means how we heat our homes and how the system is set to operate is related to who is in the home and what they do. Despite this, a more energy-efficient home will always be more comfortable as well as having lower bills and lower emissions.

HEALTH

We could save a lot of energy by going back to the Victorian model of open fires or no heating at all. This is not sustainable especially for the very young, very old or those with certain health issues especially if they are not active. Cold itself can be unhealthy for these groups of people if experienced for long periods of time.

If a cold house is not well-ventilated then damp will begin to appear. When there is damp mould eventually starts to grow. As well as being a sign of poor conditions moulds release spores into the air and these can cause respiratory problems in some people and exacerbate existing problems such as asthma. The conundrum is that a well-ventilated home in winter may be a colder one.

Overheating a home can also cause health issues. It is rarely likely to be a direct cause of problems, but, if the house is too hot, the occupants need to drink more water. Once again, vulnerable groups are at most risk: the very young and very old are least able to know when they are getting dehydrated and are more susceptible to the infections that can result.

FINDING A BALANCE

We need to reduce our CO_{2e} emissions to prevent damaging climate change. We cannot revert to unheated homes with occasional open fires so we need to make our homes really efficient. Then we can have high levels of comfort without using much energy and, in turn, can switch to much more environmentally friendly technologies such as heat pumps with extremely low CO_{2e} emissions.

CO_{2e} - or Carbon Dioxide Equivalent

CO_{2e} is a standardised unit for measuring carbon footprints. It expresses all greenhouse gases in terms of the amount of CO_2 that would create the same amount of global warming. Other greenhouse gases include natural gas leaks from our pipework, and nitrogen oxide (NOx) emissions from the boiler flue.

HEAT PUMPS AND BOILERS

In this section we discuss common ways to create heat to distribute around the home. We have started with descriptions of heat pumps as these are the lowest carbon option available for the foreseeable future. We have included discussion of others for comparison and so that you can adjust these for maximum efficiency and lowest bills until you switch to a heat pump.

HEAT PUMPS

Heat pumps are a well-established technology in many parts of the world and have been widely used in North America, Sweden, Germany and Switzerland for home heating for many years.

There are three main types:

- Air source heat pumps (ASHP) which extract heat energy from the air around us. Ultimately this heat comes from the sun.
- Ground source heat pumps (GSHP) which extract energy from the ground beneath our feet. This is mainly from geothermal energy but is supplemented by the sun's heat which warms the top layer of soil in summer.
- Water source heat pumps which need a flow of water or a substantial lake as the heat store. Energy is usually from the sun heating the water in summer unless the water source is connected to warm spa water or wastewater.

All three work rather like an air conditioning unit, but in reverse. Whereas an air conditioning unit emits hot air outside as waste, a heat pump extracts heat energy from the air outside (even air we might regard as cold) to warm the home.

ASHP and GSHP differences are discussed in detail later, but they share some common characteristics which we cover below. Water source heat pumps are technically and legislatively too complex for the vast majority of homes and would need extremely specialist advice.

Most homeowners will need an outside heat pump box unit for a heat pump installation. This will connect to the existing central heating system and replace your gas (or other) boiler system. In homes where there is not significant insulation, larger radiators are very likely to be required. You can heat hot water using the same heat pump and will need a heat-pump suitable hot water tank inside the house. Sometimes it might make sense to have a small thermal buffer storage unit, but they are not normally required with modern heat pumps.

Temperature Management

The output temperature of a heat pump can be adjusted but the lower it is set the better as this improves the efficiency of the unit – and hence lowers your bills. Generally, it is advisable to have the output at 35C and certainly less than 40C. In contrast, a gas boiler heats water to a temperature of 70C. Because a heat pump for central heating produces water at a much lower temperature than a boiler, it means that radiators need to be much bigger to warm your home quickly to the temperature you are used to. (If you don't insulate your home you will need to replace your radiators, but if you do significantly insulate, the existing radiators will probably be OK). This also means heat pumps are ideally suited to feeding underfloor heating systems.

The temperature of the water that heat pumps produce and the way they operate tends to mean they will run for longer than a gas boiler to get your home to the same temperature (but they don't need to run 24/7!); they deliver the same total amount of heat but over a longer period. You will need to set the heating to come on maybe an hour or two earlier to have the house warm in the morning. Even though they run for longer, as heat pumps are so much more efficient than a gas boiler your bills should be smaller if the system is well designed, installed and properly set up. The 'feel' of the building will be slightly different: no radiator will be 'hot' to the touch though the rooms will still be at the right temperature.

If the heat pump feeds underfloor heating, then that part of the system needs to be controlled separately and tuned to match it properly: Underfloor heating has more 'thermal mass' so takes longer to warm up but also is slower to cool down so you will need to it to come on a few hours earlier, but it can go off earlier too. You can have a mix of radiators and underfloor heating with the right controls in place.

You will need a hot water tank for baths and showers. All this is discussed in greater detail in the later section below on getting the heat where it is needed.

Performance

Heat pumps produce more heat than the electricity used to run them; meaning that their efficiency is well over 100% which also means that they emit far less CO_{2e} than a gas boiler.

Two measures are used to express how well they perform:

- **Coefficient of Performance (CoP)**

  This is usually about 3 for ASHP and about 4 for a GSHP unit. This tells you how much heat you get out for each unit of electricity that goes in. So, a CoP of 3 means that every unit of electricity extracts three units of heat from the air around us. The number is measured under laboratory conditions to compare different heat pumps under identical conditions so doesn't take account of weather or how the pump is installed.

- **Seasonal Performance Factor (SPF)**

  This is calculated for the heat pump as installed in a particular home. This tells you how much heat you should get out for each unit of electricity that goes in over an average year for that particular installation. This is much more useful for comparing heat pumps for a particular home. This is the number you should look for from potential installers.

The SPF for an air source heat pump is likely to be around 2.5 to 3 and for a ground source around 3.5 to 4.5.

Seasonal Performance Factor (SPF)

We can use the SPF to calculate how carbon intensive a heat pump will be. With an SPF of 2.5, the heat output from a heat pump will be about 0.085 kg CO_2e/kWh. This calculation is the result of dividing the carbon intensity of electricity from the UK grid (0.212 kg CO_2e/kWh) by 2.5.

This compares to 0.204 kg CO_2e/kWh for a very efficient gas boiler, making about a 60% carbon saving. This will be nearly a 75% saving for a heat pump with an SPF of 4.

As the UK electricity generation mix continues to decarbonise the carbon intensity of the UK grid will fall still further until it is close to zero. For more information on UK grid emissions see Chapter 2 of Net Zero - Technical Report, Committee on Climate Change, 2019.

Maintenance

As for a bicycle, car or boiler, annual maintenance checks are important and may even include software updates or re-gassing to improve efficiency. As regulations change (or have changed) regarding greenhouse and ozone depleting gases so research has been undertaken on the gases within heat pumps. As a result, there will likely be small (~5%) efficiency improvements in future by replacing the gas within the heat pump. This is already possible for some commercial systems.

Electrical Connections/Distribution Board

One of the biggest potential changes required to fit a heat pump relates to its peak electrical power demand. As a rule of thumb, a heat pump with a rated output of no more than 15kW is the most likely size for a well-insulated 4-bedroom home. A unit of over 24kW will almost certainly need an upgrade to your electricity supply.

If there is any doubt, you should have your electrical system checked by an electrician experienced in connecting heat pumps.

As heat pumps are electrically powered there also needs to be sufficient capacity in the house electrical connection. Most homes in the UK are on single-phase connections with a maximum total draw of 100 Amps. This means that the maximum power the whole house can draw is 25kW. If you are cooking Sunday lunch in an electric oven and using an electric hob and someone is using an electric power shower this may already be near the limit.

There may not be remaining capacity for a heat pump and you may need an upgrade to your electricity supply. Some larger, more powerful heat pumps use a three-phase connection and most houses do not already have this and so will definitely need an upgrade. This is likely for a large, poorly insulated house.

This is a key reason for first making your home more energy efficiency - you will need a smaller, cheaper heat pump that needs less electricity to run and there will be no need for an upgrade to your electricity supply.

AIR SOURCE HEAT PUMPS

Air source heat pumps (ASHP) come in a range of sizes to suit everything from a small house to a large commercial building. The principle of operation is the same: outside air is blown through the heat exchanger and then a series of pumps, valves and fluid circuits within the unit extract the heat from the air and pass it to the central heating loop or a hot water tank.

Size

Household units are about the size of a refrigerator, around the size of an under-worktop fridge-freezer for a small, well-insulated house and a larger American style fridge-freezer for a large house. They are mounted outside, normally on the ground but occasionally on the side of the building.

Noise

The fan does make a sound when the device is running. Whether this sound is considered noisy depends on how loud it is compared to background levels in the area where it is to be installed. The manufacturer or installer should be able to tell you about this. A typical ASHP might produce noise at a level of 46 dBA when operating at full output.

This is about the same as a noisy fridge or a quiet office, not a problem during the day but at 5 a.m. on a summer morning might wake someone who has the bedroom window open. Many local authorities require sound output data for the ASHP as part of building regulations or planning permission you may need. Some units have a ‘night-time’ mode which automatically switches on between set times to make it very quiet.

Efficiency

Because air source heat pumps get their energy from the air, changes in that air affect their efficiency and effectiveness. Modern designs lose only some efficiency in winter as air temperature falls but with high humidity and low air temperature ice can occasionally form on the heat exchanger. This has to melt away before the heat pump can operate at full power. This means that a buffer tank may be necessary for some installations, to be the temporary heat source for 10 to 20 minutes while the heat pump is ‘defrosting’. This needs to be discussed with the installer and heat pump manufacturer. There will definitely be times when condensation forms so there must be a drain to dispose of condensate and water from melted ice.

Planning Considerations

From the 1st December 2011 the installation of an air source heat pump on domestic premises is considered to be permitted development as long as certain conditions are met. For example, an ASHP needs to be at least 1 metre away from your property boundary. Planning permission may be required for front of house sites in conservation areas or for listed homes.

For full details talk to your local planning department and look at:

https://www.planningportal.co.uk/permission/common-projects/heat-pumps/planning-permission-air-source-heat-pump

ASHPs are the lowest cost heat pumps and the easiest to install and are therefore becoming much more familiar in the UK. These are the type most likely to be installed in an urban area such as Oxford.

GROUND SOURCE HEAT PUMPS

Ground source heat pumps (GSHP) come in a range of sizes, generally slightly larger than air source heat pumps. They can typically suit a medium house to a large commercial building and are well suited to district heating (shared heating across a number of homes). The principle of operation is the same regardless of size: a fluid is pumped through a long series of pipes in contact with the ground, then through the heat exchanger and a series of pumps, valves and fluid circuits within the unit to extract the heat and pass it to the central heating circuit or hot water tank.

Example of a Panasonic air source heat pump.

There are three main types of buried pipe run:

- Long loops of pipes buried in the ground about a metre deep and spaced a metre apart. The length is in proportion to the total heat output required but will be at least 500 metres for a modest sized house and can be several kilometres long for a large property.
- ‘Slinkies’ which are partially coiled pipes also buried about 1 metre deep. These carry more design risk of not extracting the right amount of heat but are cheaper to install.
- Boreholes which are typically 50m to 100m deep depending on ground conditions. These are the most efficient, but also the highest cost. The cost may be reduced if several houses in the same location are having boreholes.

Ground loops and ‘slinkies’ require a large area of land clear of trees, buried services and rocks and most houses will not have this. For example, for just a 6kW heat pump (small, well-insulated house) you would need at least 170m² of clear land (nearly a whole tennis court). The pipes cannot be buried near trees as the roots will be damaged by the extraction of heat. A poorly designed system, trying to extract more heat than is available, carries the risk of ‘ground heave’ where the ground freezes in winter.

The heating capability of the ground varies with the type of soil and how wet it is. This must be taken into account by the specifier of the system or it may not work properly.

Size

As with air source heat pumps, household units are about the size of a fridge-freezer: around the size of an under-worktop unit for a small, well-insulated house and a bit bigger for a large house, especially if it includes an integrated buffer tank of around 100 litres.

GSHPs are mounted inside the house, normally in a plant room or utility room. Co-locating with a hot water tank makes the overall installation more compact.

Efficiency

Because ground source heat pumps get their energy from the ground, their efficiency and effectiveness does not vary through the year if the system is properly designed. Borehole systems are the most efficient as ground temperatures at 100m can reach 18°C in some parts of the UK and are at typically above 12°C all year unless there is significant ground water flow.

Because of the length of buried ground pipework or boreholes, GSHP are more costly than ASHP. Over a long period of time, depending on energy prices, they may have a better financial payback than ASHP due to their higher performance. If you have a very large garden or have the extra budget for a borehole and intend to stay in your house for a long time, then a GSHP may be appropriate.

Planning Considerations

The installation of a ground source heat pump on domestic premises is usually considered to be permitted development, not needing an application for planning permission. If you live in a listed building or a conservation area you should contact your council to check local requirements.

Ground source heat pumps make no more sound than a boiler. You are very unlikely to need planning permission for a GSHP as they are no more intrusive to any building than a boiler.

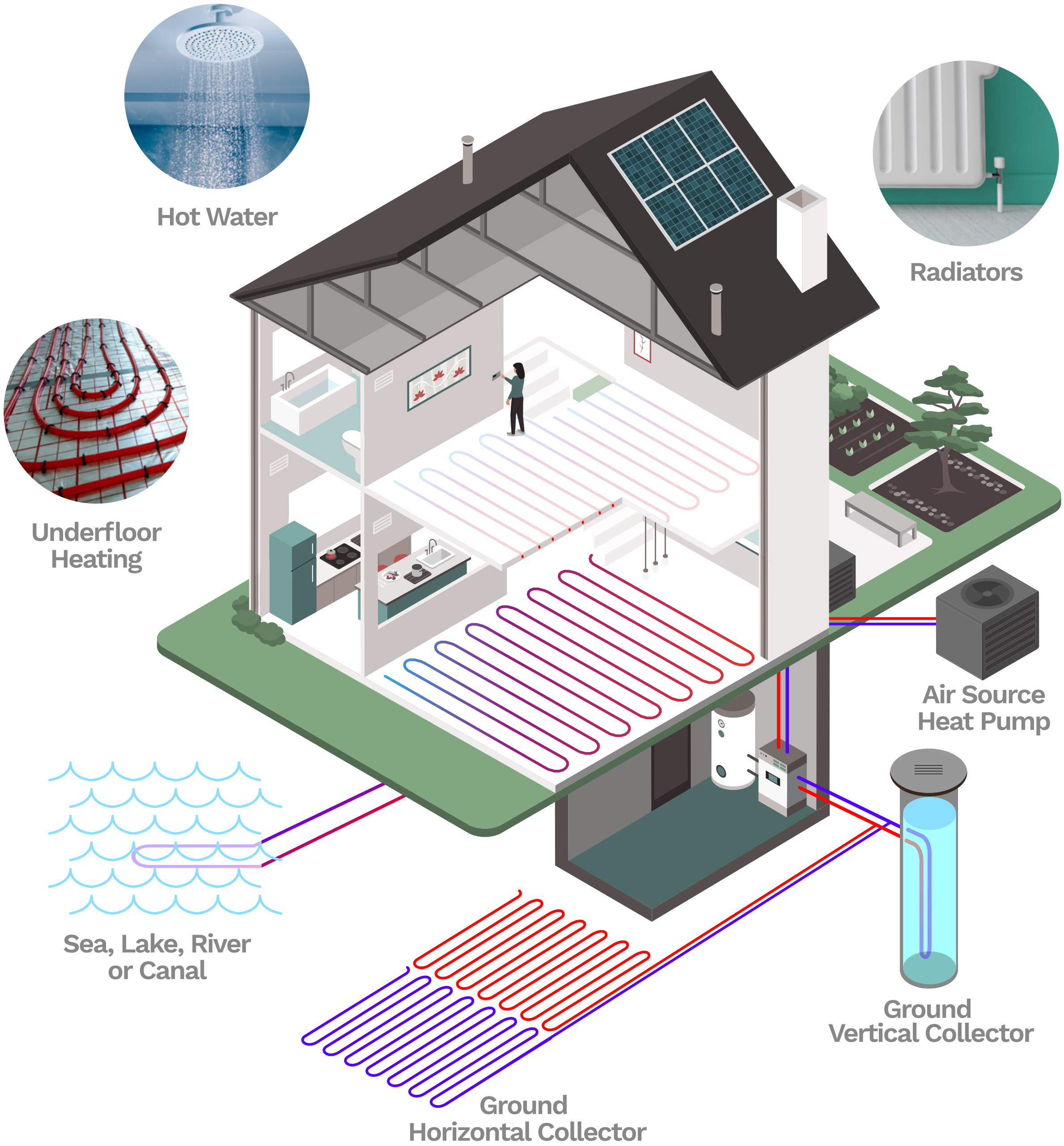
Community Schemes and District Heating

In some parts of the country district heating networks are being developed where a group of homes share a common heating source and system. These have historically been heated by gas, Combined Heat and Power (CHP) or by using heat produced from the combustion of municipal waste ('waste to energy') that is then piped to homes. Early examples of district heating networks using ground source heat pumps do exist and may well be developed as we decarbonise our communities.

A community-led approach is required to design and install a retrofitted district heating network. All homes would need to become energy efficient, and an organisation would need to be set up to manage the system. Where multiple houses are to be connected, the road in front of the properties to be heated would need to be dug up for the district heating network to be installed, connections to each house made and a central plant building constructed nearby.

Billing for heat would be by heat meters instead of gas or electricity meters.

DIFFERENT TYPES OF HEAT PUMP SYSTEMS



FOSSIL FUEL BOILERS: GAS, OIL AND LIQUIFIED PETROLEUM GAS (LPG)

From 2025 no new property will be allowed to have a gas boiler – but you could still use one that is already fitted in your home.

You may have read about hydrogen being a possible fuel of the future to replace or mix with natural gas for home heating. This is a very long way off and requires a government policy decision to declare in which regions this might happen and how companies will be supported to begin production of 'green' hydrogen. It is extremely unlikely to be a choice for individual homeowners, as it requires the entire gas piping network to be upgraded across an area, which would be wholly uneconomic, even if feasible, home by home.

The most common form of central heating in the UK is by gas boiler. An LPG boiler is almost identical to a mains gas unit, with small changes to burners and controls. An oil boiler is very similar, but the burners are substantially different. They all cost similar amounts, in the few thousands of pounds to install, with LPG and oil costing a little more (plus the cost of tanks). They all produce CO_2 in the flue gas which is largely why household CO_{2e} emissions are so high.

The boilers also burn a fossil fuel and they are all huge sources of CO_2. Boilers are also a source of nitrogen oxide (NOx) which can be a particular urban pollution problem and is associated with photochemical smogs and asthma. Modern boilers must meet limits on NOx production, but they still produce some.

What do we mean by boiler efficiency?

The efficiency of a boiler is a measure of how much energy in the gas is converted to heat we can use in the home. Some heat will always go out of the flue in hot gases, but modern boilers are very good at capturing as much of that heat as practicable.

Every boiler sold in the UK since 1999 has had an officially recorded efficiency. Modern boilers are tested in special facilities which simulate how they run in homes. The resulting test score is a very good indication of how efficient it will be in practice. The results are presented as a percentage and as a simplified A to G rating, where A is the best.

Generally, the newer your boiler the better it will be. There is hardly any room for development to make them any more efficient and so we need to replace them to reduce CO_{2e} emissions in the UK.

You can find the efficiency of your boiler in the documentation about it, on the manufacturer's website or in a national database:

https://www.ncm-pcdb.org.uk/sap/

This also includes efficiency information about a wide range of other devices.

If you have an old boiler which is not on the database or is Band F or G, then you should replace it as it will pay back quickly.

Modern boilers are ‘condensing’ which means they are most efficient by capturing heat from the flue gases by condensing the water vapour from them. This is why new boilers have a condensate drain which lets water out to the drain outside.

This should not be confused with ‘combi-boilers’. A combi-boiler produces hot water direct to your taps, bath or shower: there is *no hot water tank in the house*.

A ‘combi-boiler’ can also be ‘condensing’. Any type of gas boiler currently for sale must meet minimum efficiency standards and so will be condensing.

The consequence of this is that all boilers on sale achieve around 90% combustion efficiency, i.e. 90% of the energy in the fuel you buy is turned into heat. Boiler technology is at its limit and very little gain in efficiency is likely in future.

The boiler must be set up correctly to achieve this efficiency; incorrect settings will deliver much less, so adjusting the controls correctly can save you money. Consider zoning your home so that you are heating different areas when you are most likely to be using them too. We cover this in more detail in the Controls section later.

Every boiler has a maximum output or peak output rating. Domestic boilers are limited to 30kW (due to the gas supply capabilities), but many lower rated versions are available, e.g. 18kW, 24kW. To get maximum efficiency out of a boiler, it is best to match it to the heat load of the home. Thus, a small new house might have a 12kW boiler, whereas an older, larger house might need a 30kW boiler.

A combi-boiler produces hot water direct to your taps.

A combi-boiler will generally be rated at 24 to 30kW as the peak output is required for producing instant hot water for a shower, bath or kitchen tap – or all three at once. This can mean it is not as efficient for heating as a smaller boiler correctly matched to the property.

Most current gas boilers also have the ability to reduce their output automatically according to the heat demand, which makes them more efficient in mild weather. As a result, the design convention is to oversize the boiler. This means the maximum output of your boiler could be up to 25% higher than you need. So, the kW size of your boiler should not be used as the kW rating for a heat pump heating the same house.

A key feature to recognise in the context of getting heat pump ready, is that the water leaving a fossil fuel boiler is at around 70°C. This is important as it determines the size of radiators required to heat each room and the type of hot water tank you connect to them. Because the water is hot the radiators can be quite small to achieve the required heat output (although our radiators are often slightly oversized: see later section on radiators).

BIOMASS BOILERS AND STOVES

A domestic biomass boiler or stove burns a solid fuel derived from plant matter. The majority in the UK will burn logs or pellets. If the plant matter is sourced sustainably or it is a waste material (wood or straw) that would otherwise produce CO_2 then biomass fuel is a very low carbon way to heat your home. There are other environmental issues to consider such as land use, transport and the need to dispose of ash.

A biomass boiler will require a bunker of fuel which should be enough to last the whole of December and January. For a typical family home this will mean a volume of several m^3. This will end up being similar in size to a small shed by the time automatic fuel feed machinery, ventilation and access are included. For a house in a rural area which currently uses oil for heating, this may simply mean replacing the oil tank with a biomass store, though it will need to be right next to the boiler. Deliveries can be arranged in a similar way to oil, so this looks like a good alternative to oil when seeking a low-carbon solution.

In an urban area where the current heating is by mains gas, biomass is not likely to be a good solution. Finding space for the fuel store and allowing access to a truck bringing regular supplies of fuel may be tricky.
A modern biomass boiler will be required to meet air quality targets and will create little pollution if burning good quality fuel.

Like other boilers, the water leaving the boiler is at around 70°C.

Biomass boilers and stoves need more maintenance than gas and oil units. This is because of the type of fuel they burn. Firstly, ash needs to be disposed of and at appropriate intervals (see manufacturer's instructions) the combustion space needs to be thoroughly cleaned of ash. In addition, the flue can slowly clog with tar and soot – even with a modern device – and this can eventually cause problems and a risk of fire. This is especially a risk in an old chimney which has not been lined and where wood is often burnt in an older stove.

OPEN FIREPLACES AND STOVES

Open fireplaces are often used to create an atmosphere in a room. Unfortunately, they are probably the most inefficient way to heat a room, at best only 25% efficient. In addition, open fires also allow warm air to escape up the chimney even when the fire is not lit and create a cold draught across the room in doing so.

A wood-burning or pellet stove can be a useful way to add heat to a room in really cold weather or to make just one room cosy at the weekend when the first autumn frosts arrive. This is efficient because it avoids heating the whole house for just a few hours.

The fuels are the same as for biomass boilers, but the quantities are much smaller. Some pellet stoves are automatic, with an integrated hopper which can be loaded with a sack full of pellets to last several days.

The main benefit of a closed stove is that, when fitted properly, they are considerably more efficient than an open fireplace, typically reaching 75% efficiency compared to 25% or worse for an open fire. A closed stove also stops most warm air escaping up the chimney when it is not in use, and can be completely closed.

The amount of CO_2 emitted is strongly related to the fuel used. Locally sourced logs from woodland management, e.g. diseased and dead trees or branches, are a sustainable and low-carbon heating fuel. Using coal or smokeless fuel is extremely high CO_2 and should be avoided.

There has been concern raised about smoke and particulate emissions from wood stoves and open fires. They can produce PM 10 and PM 2.5 particulates which are damaging to health. Recent changes to legislation require wood to be of a certain quality which reduces these emissions. There is also a standard for lower emission stoves, 'Ecodesign'.

Defra has issued a guidance document:

https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1901291307_Ready_to_Burn_Web.pdf

You must not use a wood stove in a 'Smoke Control Area' within Oxford.

OTHERS: ELECTRIC, RADIANT AND HOT AIR

As the main reason for these guides is to reduce carbon and save energy (and money), we do not cover electric, radiant or hot air systems in much detail.

Direct electric heating, whether night storage heaters, oil-filled, fan, radiant or any new variant, simply use 1 unit of electricity to produce 1 unit of heat and emit about 0.21 kg CO_2 for 1 unit of heat – about the same as from a gas boiler. They will always be far worse than heat pumps which extract about two thirds of the heat they put into the house from the air or ground around us. At the moment ASHPs emit about 0.08 kg CO_{2e} and GSHPs about 0.05 kg CO_{2e} for 1 unit of heat and this will reduce as more renewables and nuclear provide our electricity.

Storage heaters are the least efficient and controllable as they leak heat when you do not want it and so use more electricity than required. They were popular in the past as they used cheap off-peak electricity and so made sense in some properties, especially if permanently occupied, such as sheltered flats.

Portable fan, oil-filled and radiant heaters can be beneficial if you want to heat just one room when the rest of the house is kept cold (for example if one person is working from home during the day). In a Passivhaus, they might be needed for a couple of weeks of very cold weather and so, on a life-cycle basis, are very low carbon compared to manufacturing and installing a whole heat pump based heating system.

Radiant electric heating may have a role in certain well-defined circumstances. For example, heating the congregation in a church for the period of the service is far more efficient, cheaper and lower carbon than trying to heat the whole building for just a few hours.

Very few hot-air heating systems are still in use in UK homes, though one or two can be found. They are very inefficient and are generally noisy and dusty.

INCIDENTAL AND SOLAR HEAT GAINS

All houses with active people inside derive some heating from so called incidental heat gains. In addition to warmth from people, these include, for example, the heat from the TV, your laptop and cooking. They are relatively small in most cases but do make a contribution. In a super-insulated Passivhaus they are the main source of heating – there is no need for a dedicated heating system.

If you have glazing on the southern side of the house, this will also contribute solar gain. In other words, when the sun is shining through the window at any time of year there will be some warmth coming in. This will be the least in the winter, but that is when it is most valuable.

In a very well-insulated house, incidental and solar gains become significant. This means that control of heating in individual rooms becomes much more important.

Almost all houses benefit from Solar Gain.

DEVICES TO GET THE HEAT WHERE IT'S NEEDED

It is important to match your heating system to the 'emitters' which deliver the heat to where you need it. If you don't, you could be cold in winter, the system will run inefficiently, or unreliably, or all three. There are many types which we discuss below, all of which can be used with any heating system if matched correctly.

Examples of fanned radiators:

Under kitchen unit, floor-level fanned radiator.

Ambir fan convector radiator.

RADIATORS AND FANNED RADIATORS

Radiators do not actually radiate much heat. They use the hot water passing through them to heat the air around them and then natural convection (the movement of hot and cold air within your home) moves the warmed air into the room.

A fanned radiator can be smaller as the fan can deliver heat more quickly than natural convection. The radiator size, whether it is double or single, and the fins determine its heat output, but the size of the radiator chosen for a particular room is also related to three other factors:

- The water temperature within it.
- The heat loss from the room in the coldest weather.
- The temperature target for the room.

The water temperature is important in matching the radiator to the heating system. Boilers produce water at about 70°C whereas a heat pump produces only about 35°C water and the lower this temperature the more efficient it will be. This means that, as a rule of thumb, radiators heated by heat pumps need to be about twice the size of those heated by a boiler.

The heat loss from the room in cold weather means that if you insulate your house and reduce your heat loss, you can use smaller radiators. This is one of the reasons why it makes sense to insulate and draught proof your home before replacing a gas boiler with a heat pump. If you can halve the heat loss, then you may be able to use the existing radiators.

The temperature target for the room means that where you accept a lower temperature, you can have a smaller radiator, for example in a utility room. It is normal practice for radiators to be slightly oversized when fitted. This avoids the risk of a room being cold for a range of reasons but overall will not affect the efficiency of the system as long as the correct controls are fitted and set properly.

All radiators have a ‘flow’ and ‘return’ pipe. At each end there is a valve; one end has a lockshield valve which should be adjusted once during commissioning to balance the system. This makes sure all rooms get a fair share of heat from the boiler. The other end is the control valve and this is where a Thermostatic Radiator Valve (TRV - see later) is generally fitted.

Aside from aesthetics and cost, there is only one other feature of a radiator you need to check. This is its heat output in kW at a stated water temperature and room temperature. These figures are given in manufacturers’ catalogues.

UNDERFLOOR HEATING

The simplest way to think of underfloor heating is as a radiator spread out over a large area. Underfloor heating is very well suited to heat pumps because of the large area for heat to be conveyed into a room. It also brings the advantage that generally underfloor heating makes us feel warmer so we are less likely to nudge the thermostat up! This in turn means the house and heating system are more efficient.

As with a radiator, underfloor heating needs to be matched to the room. Instead of the size and number of fins, it is the total length of pipe under the floor which determines how much heat can get out. This in turn means that for a large room with high heat loss many pipes of the right diameter need to be laid close together.

The type of floor and the floor covering are important to the correct operation of underfloor heating and the life of the floor.

- The floor must have good insulation below it or the system simply heats the ground (or room) underneath.
- Underfloor heating works best in a solid concrete or screeded floor. ‘Clip-in’ ceramic panels can be fitted between floor joists and under floorboards.
- Any floor finish must be specified to be suitable for underfloor heating or it can rapidly deteriorate. Ordinary floorboards may not be suitable as they can distort if they are heated from below. Check with the installer.
- The top covering of carpet or rug must be chosen with care or it will effectively insulate the underfloor heating from the room and prevent it functioning.

These are all issues that should be discussed with professionals before choosing an underfloor heating system and floor finishes.

PRODUCING HOT WATER

Heat pumps cannot produce instant hot water directly like a combi-boiler. This means if you have a heat pump fitted you will need a suitable means of storing or producing hot water.

From the Main Central Heating System

As with radiators, the design of a hot water tank needs to take account of the water temperature that is being used to heat it. Because the water temperature from a heat pump is lower than that from a gas boiler, a heat pump needs a specific heat pump appropriate tank because the internal heat exchanger design has to be different.

The tank should also be larger because the stored water temperature is lower and so more hot water has to be used for baths and showers. They are best located centrally so pipe lengths to taps are as short as possible. All pipes should always be insulated.

Electric Immersion Heater

An electric immersion heater in a hot water tank is an alternative or supplementary means of providing hot water. If running on economy 7 or from solar PV export it will be lower cost and low carbon.

This immersion tank can be the same size as for a gas boiler. You may even be able to keep the one you have already. The disadvantage is that the immersion heater could take up to an hour to re-heat the tank if everyone has had showers or baths.

Separate Dedicated System

There are a few dedicated hot water tanks with their own air source heat pump mounted on top. These provide hot water at very high efficiency because the heat pump is specifically sized to make just hot water, especially in summer when the air is warm. They are installed within the house but need ducts to bring in outside air and exhaust the cold waste air.

Some of these offer the ability to provide 'comfort cooling' in summer if the air ducting is installed in a particular way.

Examples include:

Earth Save Products Ecocent.

Ariston's Nuos.

Dimplex Edel.

Separate Point-of-Use Heaters

There are several novel point-of-use devices to provide hot water. For a kitchen sink or downstairs toilet where little water is used these are a good and low-carbon idea, particularly if they avoid a long pipe run from the hot water tank.

Research suggests that when we draw small amounts of hot water from a tank or combi-boiler about 60% of the heat is wasted in the pipes that bring it to the taps.

The first to market was probably the Quooker which can produce boiling water 'on-tap', though many similar devices exist. There are also many smaller units for hand basins including Redring's inline heaters and, of course, the many under-sink electric water heaters by Triton, Ariston and own-brand units from various plumbing supplies companies.

The most compact under-sink versions of these devices need about the same space as a breakfast cereal packet. A larger and more powerful unit might be twice or three times that. A small unit for one tap on a hand basin is about the size of a big mixer tap.

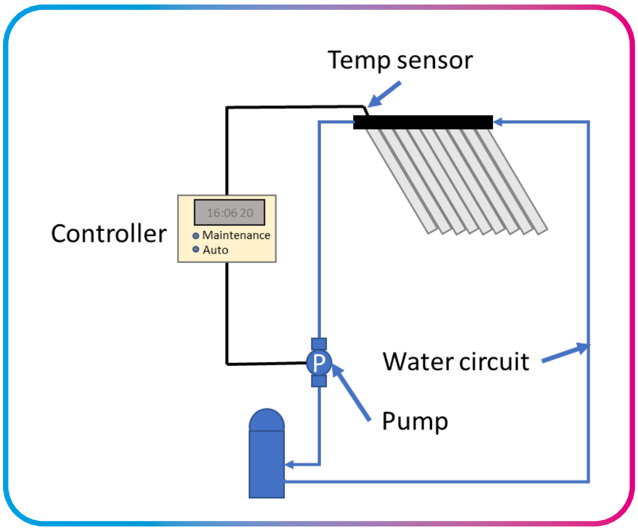
Triton's above sink inline hot water heater.

Below worktop unit from Ariston.

Solar Hot Water

Solar water heating was probably the first renewable technology to appear in large numbers in the UK in the 1980s and 1990s. The systems reached peak effectiveness around 20 years ago with evacuated tube collectors. About 20 of these are placed on a south-facing roof and the heat is transferred, through glycol (anti-freeze) to indirectly heat the hot water tank.

A well designed, installed and maintained system can produce 60% of annual hot water use in a typical home. They rely on frequent, daily hot water use to operate effectively. They need regular maintenance, certainly annually, and have shown signs of unreliable operation in hot summers when the house is left empty as the water can overheat.

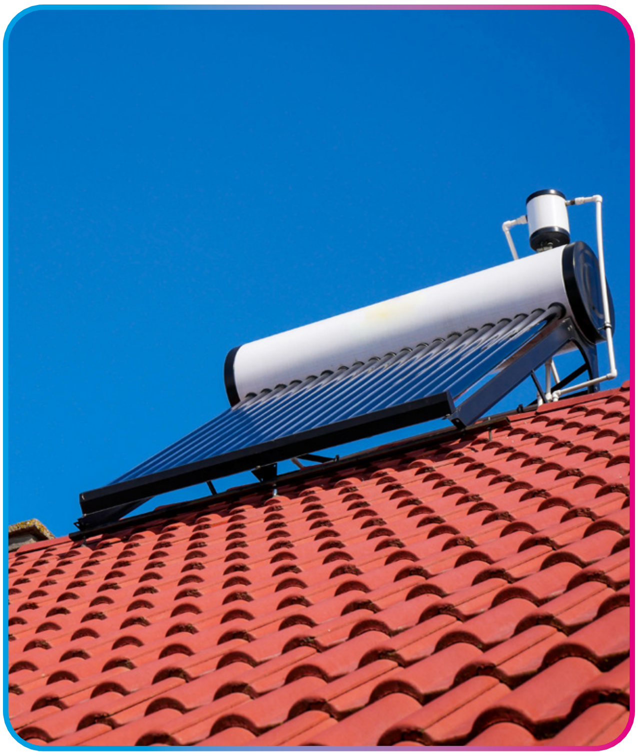


Example solar hot water set-up.

They can operate in parallel with any other heating system, subject to certain control interlocks.

However, if you have space on your roof for solar then solar PV is probably best. Any spare generation that you don't use that would otherwise be exported to the grid can be diverted into an immersion tank to heat water. You would use one of many solar diverters available on the market e.g. Marlec's iBoost, Earthwise Solic 200 or MyEnergi Eddi.

Housewarming Guide H7: Electricity, Appliances and Home Renewables explains solar hot water, solar PV and solar PV diverters in more detail.



Solar water heating was one of the first renewable technology to appear in the UK.

CONTROLS

Regardless of how efficient your heating system is on paper, if it is not well controlled it will cost more to run and produce more emissions than it should.

A good control system should respond to:

- When you need the heat.
- How the weather affects this.
- How warm a house, or room needs to be.
- And, operate in conjunction with the heat source to keep its efficiency high.

In a bigger house or home that can easily be split into rooms in use and those unoccupied for parts of the day or week, then splitting the heating system into zones (see later) and controlling them separately will also help reduce bills and carbon emissions.

There will be basic control settings on your boiler and these can have considerable impact on efficiency, especially if you have a modern condensing boiler.

If these settings are not optimised as per the manufacturer's manual, then the boiler may not operate efficiently and as much as 15% wastage can result – and your bill will be 15% higher.

There will be a similar set of controls on a heat pump and these too must be set correctly for maximum efficiency: read the manual.

TOP TIP: read the manuals for your boiler and heating controls and adjust everything for maximum efficiency. You might make an instant 15% saving!

Typical condensing boiler front panel

System water pressure needs to be right

Information panel

Boiler temp, when heating hot water (if fitted)

Boiler temp, when heating radiators; the lower the better

On/Off switch

Refer to boiler manual to set these correctly for maximum efficiency

TIME CONTROL

The most basic control of your heating system should be when it comes on. When central heating systems were first used for background heating in the UK this was all that was fitted. The system was not powerful enough to overheat the building and would run for only a few hours a day.

Modern time control systems can be set for many different time periods during the day and week. Weekday and weekend settings can be different and there can be many time bands during a day to reflect the use of the building. Most also have a setting for 'away on holiday' and a back-up 'frost' setting. Many also have a 'boost' setting to allow one hour more run time before going back to the standard, fixed timetable.

THERMOSTATS

Thermostats work by detecting the temperature where they are and sending an 'on' signal to the heating if it is colder than the chosen setting. As the temperature rises, so eventually it reaches the chosen temperature and then the thermostat sends an 'off' signal to the heating.

There should be at least one room thermostat in the house which controls the central heating. If you have zones you will need a room thermostat for each zone.

There are several schools of thought about where to put thermostats:

- In a hallway so the heating is triggered to come on when cold air enters after someone comes in through the front door and before it gets to the rest of the house.
- In the main living room where people spend most of their time.
- To be carried with you so it is in the room where you (or most people) are that day. This is the approach suggested by some cloud-based heating controls.

The answer will depend on your house, your lifestyle and the heating system: there is no simple answer.

A thermostat should never be placed near to a radiator or other source of heat, such as where the sun can shine on it, or it will badly reflect the need for heat. This may make the occupants of the house fiddle with it to feel comfortable and so the system may be left at too high a temperature, increasing the energy bill.

Thermostats should be set to the lowest comfortable chosen temperature and left alone for maximum efficiency. Frequently changing the temperature of a thermostat means the heating system is likely to be turning on and off more than it should which leads to inefficient operation. In addition, there is a risk the thermostat will be left at a higher setting than it needs to be for most of the time and this will also use more energy and result in a bigger bill The normal setting range is between 18°C and 21°C.

Older 'turn and click' type thermostat.

Modern digital multi-time and multi-day thermostat; also wireless.

Some modern digital designs can be set so there are different temperatures for different times of day and days or week. This is a good idea for an active, busy household. For example, the heating can be set to be on for a really cosy house as people get up in the morning, then adjusted down for the rest of the day if only one person is at home, coming back up in the evening.

It may be that a brief boost around lunchtime is also helpful for comfort if only one person is at home. The weekend settings can be completely different. This will help save costs.

The benefit of these thermostats is that background heating can be on for most of the day if only one room is occupied (working from home) and this saves considerable energy compared to the standard setting – and is far more comfortable than finding a freezing cold house each time you leave the work room.

WEATHER CORRECTION

Some heating systems can accept an outside temperature input which is fed to a ‘weather correction’ adjustment in the control system. The main correction this usually applies is to reduce the temperature of the water leaving the boiler or heat pump in mild weather. The benefit of this is to avoid heating a room too quickly and so potentially making it warmer than requested causing overheating which is wasteful. In a condensing boiler this also makes the boiler a bit more efficient.

ZONE CONTROLS

In a bigger house there are likely to be times of day or even days of the week when large parts are not in use. If the heating system is designed so it can be split to match this, then different parts can be heated accordingly. For example, if one person is at home working in a study off the kitchen after everyone else has gone to school or work, there is no point heating the whole house. If the kitchen and study can be ‘zoned’ so the pipework leading to them can be heated separately from the rest of the system, then just this part of the house can be heated.

This is most easily achieved during design and installation of a new system, but existing heating systems can often be split into zones. Each zone is created by separating the pipework that feeds the water to those radiators or underfloor heating. Each will need a separate thermostat and control valve all linked to the main controller. If the thermostat and timer for that zone requires heat, then only that part is heated.

The simplest zoning is often by floor: ground floor, first floor, loft conversion. In a building which has a very old part and a more recent extension zoning by age will help as the newer part will generally need much less heating than the old. Similarly, south-facing rooms will benefit from solar gain and could be separately zoned to account for this.

Thermostatic Radiator Valves (TRVs)

A TRV is like an automatic hand to turn the radiator off when the room is warm enough and on again if it gets too cold. You set the chosen temperature by turning the knob to a particular number on the TRV, then leave it to do the work. It is an important part of a good heating control system. When the room is cold, the valve opens and, if the heating is on, hot water flows through the radiator.

As the room warms up the valve turns the radiator off. You can now buy some types which you can control via smartphone or computer app (though most need regular battery replacements). This allows you to have different 'target' temperatures across different times of day and to turn the heating in that room on or off remotely if you change your plans. This will help save costs.

INTELLIGENT AND INTERNET BASED CONTROLS

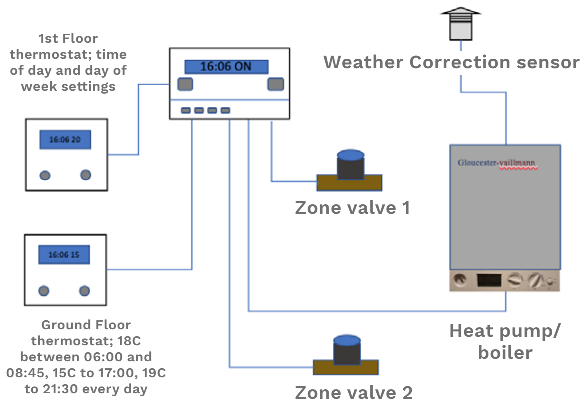
There has been a recent explosion of internet-based, smart phone controlled heating controllers. The biggest names are probably Hive, Nest and Netatmo but there are many others.

The main benefit of these is that they allow you to turn the heating off when you are out. Most systems claim to optimise the heating settings and make your heating more efficient, but it is too early to say if this is true and how much they save.

IDEALISED SCHEMATIC

The diagram shows how an idealised heating system would be controlled.

Idealised Example Heating Control Schematic



PLANNING FOR UPGRADING YOUR HEATING SYSTEM TO A HEAT PUMP

DO I NEED CONSENT?

For certain parts of an installation you need to employ professionals and they will issue certificates confirming that the system meets various legal requirements.

In a conservation area or with listed buildings you may need planning permission to install an air source heat pump as this will be visible outside the property. An air source heat pump can be concealed inside a specifically designed louvred screen so it cannot be seen. A properly designed screen will not reduce efficiency, but a bad one will.

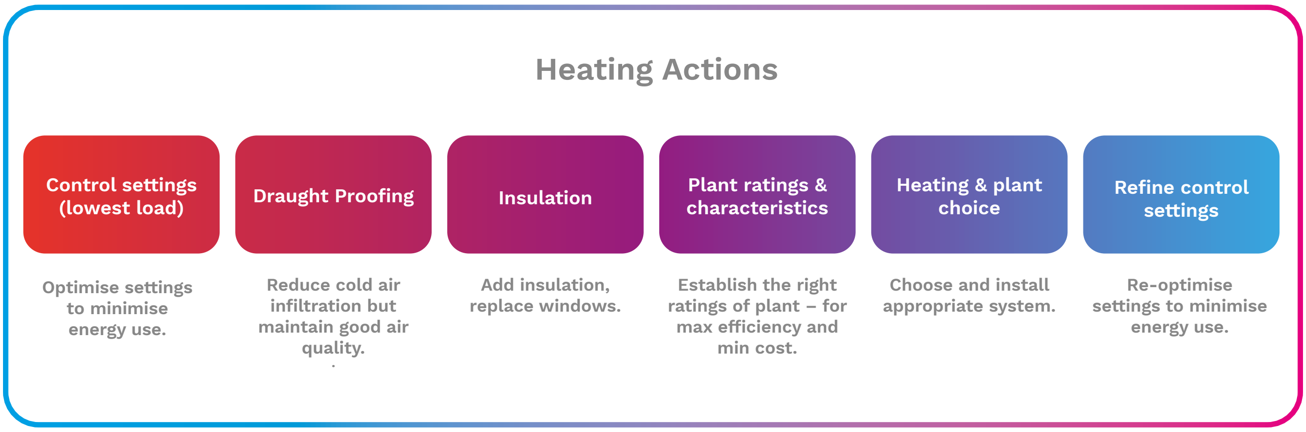
Some local planning authorities require a noise assessment to be carried out before an air source heat pump can be installed. They may require a specialist noise survey of your area to establish the background levels at all times of day and night. This is not because ASHPs are inherently noisy, but because this is a new noise, comparable to a tumble dryer or a boiler flue next door (neither of which requires a noise assessment). Talk to the planning department.

All heating systems will need to comply with Building Regulation Part L and other parts relating to fire safety, electrical connection, ventilation and so on.

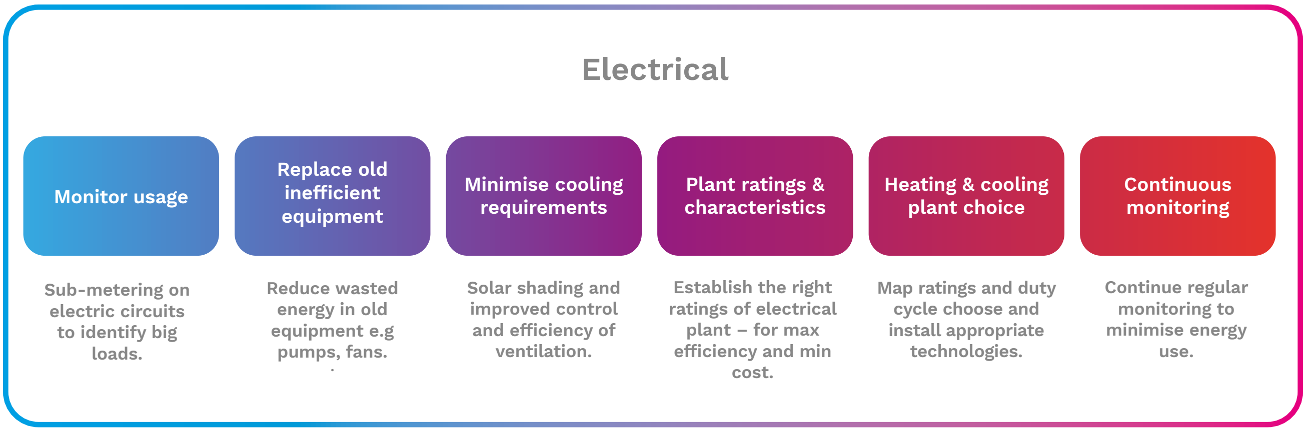
WHEN TO SWITCH

Our suggestion is to first improve the energy efficiency of your house, then select the right heat pump to match it.

The overall flow of decisions is illustrated below and overleaf:



Flow of decisions (heating).



Flow of decisions (electrical).

One benefit of this is that your energy use and carbon emissions will go down from the start. Another is that the size of the heat pump and radiators and the cost will also be lower.

The process is discussed in much more detail in our final guide, **H6: Preparing a Whole House Plan**.

ROLES OF THE PROFESSIONALS

Refer also to our first guide **H1: Taking Stock**, for more information on professionals who may help you.

Gas Safe Register

Any work on the gas supply, boiler, gas cookers and fires must be carried out by a Gas Safe registered and trained individual. This even applies to the removal of the boiler. A plumber will often be Gas Safe registered.

Plumbers

There is no particular requirement for training and registration of general plumbers, but a skilled and experienced plumber will be able to create a tidy and efficient installation. A skilled amateur can do a good job but may not have all the tools and experience necessary for the best installation.

Many plumbers will also be able to design your system, not necessarily creating full drawings, but sufficiently to give you an efficient and reliable system. This includes adding zones into an existing system.

Heat pump specific experience is essential for the installation and commissioning of a heat pump and system. These have very different requirements to gas boilers and general plumbing to make them work effectively and efficiently. Look for MCS accreditation.

Electricians

All but the smallest adjustments to the electrical system in your home must be carried out by a qualified and certified electrician.

Guidance can be found here:

https://www.electricalsafetyfirst.org.uk/find-an-electrician/

If you have made your home more energy efficient, you should be able to install a smaller heat pump and so you may not need to upgrade your electrical connection. An electrician with experience of heat pumps will be able to confirm this.

Once the installation of your heat pump has been completed you will need a Building Regulations Part P certificate for the electrical connection.

Mechanical and Electrical Services Consultants (M&E)

This group of professionals can calculate the most complex heating, ventilating and electrical needs for your home. If the work to insulate, draught proof and generally improve the heat loss of your home is done in stages before replacing your boiler with a heat pump, an M&E Consultant is probably not necessary. Most of the calculations can be carried out along the way by suppliers and installers. If you are planning a major one-off strip-out, remodelling and retrofit of your whole home then it is advisable to have someone on board who can advise on how best to incorporate all you need for the best end result. This may well be an M&E consultant.

INSTALLATION ISSUES

Location of Units

The location for a heat pump unit will generally become obvious once you start to talk to installers. Generally, they need to be fairly close to the house and any existing hot water tank and pipework, and away from bedroom windows so they don't cause disturbance early in the morning.

Heat pump manufacturers will specify various conditions in their technical literature including, for example, space behind the unit and a wall, clearance from vegetation, need for a water drain and maximum distance from the house or neighbours.

Hot Water Tank

Installing a hot water tank is usually necessary and sensible when installing a heat pump. Heating the tank either from a main heat pump which is sized for the central heating or from a dedicated heat pump unit will be efficient (see earlier section on Producing Hot Water).

The hot water tank should be sized a little larger than for a gas boiler because the stored water is at a lower temperature, so expect about 200 litres. The volume of the hot water tank is essentially determined by the number of people in the house and so the number of bedrooms.

Ensure you choose the right sized hot water tank.

The aim is to have enough hot water for a household to have baths and showers and do the washing up without running out. The Hot Water Association advises between 35 and 45 litres per person. This size is calculated in combination with the heating system power to ensure that the tank may be heated up again quickly. The installation will include a 'legionella cycle' of heating by the immersion heater once a fortnight.

This is to ensure any bacteria are killed that could cause problems. Expect very hot water every two weeks.

Most houses in the UK used to have an airing cupboard where you would usually find the hot water tank but, as the combi-boiler became popular with plumbers (much easier to fit than a ‘system’ boiler and hot water tank), owners of smaller homes had these tanks removed. This has the potential to be a real barrier to retrofitting heat pumps across the UK.

If you already have a hot water tank, then the simplest approach is to replace it with a heat pump appropriate one which has an internal heat exchanger designed specifically to be efficient when working off a heat pump. The tank will need a space, ideally centrally in the house but towards the bathroom and kitchen so the pipe lengths from the tank to those taps and shower are shortest. Installing in the loft might appear convenient but this will waste energy as the loft will normally be very cold in winter. Installing it in a utility room can make sense.

Pipe Lengths

All pipe lengths need to be kept as short, straight and well insulated as possible. Heat pump manufacturers specify a maximum length for some of the external pipes and this can be found in their technical literature. This means that locating the heat pump all the way down the garden is not going to be possible. You might be able to mount the unit on a single storey flat roof but take care as the sound would travel further and so be more likely to be a nuisance.

Internal pipe lengths can be run as per standard central heating plumbing. It is best to insulate them where they are under floors and especially if they run through the loft. This reduces losses and keeps the heat going to where you want it.

Zoning

Now is a good time to re-design the pipe layouts and add zones so you can control them separately. See the above section on zonal controls for more suggestions.

MAINTENANCE

Annual maintenance of a heat pump system is just as important as for any other system to ensure peak efficiency and comfort. Leaks, however small, should be fixed quickly or corrosion will occur inside the pipes and radiators.

This in turn reduces efficiency and may cause sludge to block some pipes and ultimately the boiler itself. It is worth having a whole system check every 7 years or so and especially a check of the corrosion inhibitor strength. It may be worth having the system fully flushed out and correctly refilled at this stage.

SUMMARY

CRITICAL QUESTIONS TO ASK

Can you make immediate savings in your energy bill by simply getting the settings of your heating system right? Read the manuals for the boiler and controls to see if you can adjust them better.

Have you got the full suite of controls required for the best control: time, temperature and weather correction? Could you have zone controls easily added? These will all be relevant for any type of heating system.

What is the actual peak heat load for your house now? Ask an energy surveyor to calculate this. This is a key part of reducing your energy consumption and is discussed more in our final guide, **Housewarming H6: Preparing a Whole House Plan.**

Knowing the peak heat load, how far away are you from being able to install a heat pump? What is the capability of your home's electrical connection and fuse board? Does this limit how big a heat pump might be, or could you have the electrics upgraded?

Can you use the above information to help set a target for how much you need to reduce the heat loss from your house?

Do the planners need a noise assessment or any other permissions?

IMPORTANT DECISIONS TO MAKE

Do you have a hot water tank and if not where would you put one when you convert to a heat pump?

Assuming you do not have a huge garden, where would you put an ASHP?

If you cannot add zones or underfloor heating to your house now, could you do so when you do other improvement work to reduce heat load?

DISCLAIMER

This guidance document is written with the intention of providing a better basis for home owners to decide how to reduce the energy consumption and carbon emissions of their homes.

We have not surveyed your home and so the suggestions and discussions in this document can only be a general guide and LCON and its consultants cannot be held responsible for or accept any liability for damage, failures or disputes which result from the use of this document.

We recommend that specific decisions are made only after a suitable survey by an appropriately qualified specialist.

We recommend gaining several quotes for work from a number of suppliers and suitably qualified and experienced companies with appropriate insurance.

It is essential to follow material manufacturer's instructions and specification sheets to avoid risks of damage to structure and property and to ensure the intended performance is achieved. We recommend the use of only those products with appropriate independent certification for the intended use e.g a BBA (British Board of Agreement) certificate.

We recommend appropriate contracts are used and signed by all parties before work is undertaken and suitable legal advice should be sought.

CREDITS

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