Low carbon equipment and building regulations – A guide to safe and sustainable construction

Ground Source Heat Pumps and Water Source Heat Pumps

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This guidance document is intended to be read in conjunction with the general introduction to low carbon equipment.

The Scottish Government

Low carbon equipment and building regulations: A guide to safe and sustainable installation

This chapter is one of a series that provides a basic introduction to different low carbon technologies and describes their relationship to the building regulations in Scotland. It should be read alongside the general introduction to this guide.

Ground source heat pumps and Water source heat pumps

1 Introduction to ground source and water source heat pumps

Heat pumps work like refrigerators in reverse. They can take heat from an outdoor source and put into a building. Ground source and water source heat pumps (GSHP and WSHP) upgrade low temperature heat from the ground or from a body of water to a higher temperature that can be used for space or water heating, using electricity to power the process. Pumping heat uses less electrical energy than other types of heating appliances which convert electrical energy to heat.

In a well designed and installed system, up to four units of heat can be produced for every unit of electricity used to drive the heat pump. Changes in ambient temperature do not alter the performance of GSHP and WSHP systems as they can do with air source heat pumps (ASHP).

Ground and water source heat pumps exploit stored solar energy to limit the demand for electricity and tend to be more energy efficient than air source heat pumps. However they are not suitable for all sites, due to the groundworks required.

Ground and water source heat pumps are used for space heating, domestic hot water or space cooling, and are suitable for new build or existing buildings.

A typical ground or water source heat pump system works as follows:

- the heat pump unit pumps heat transfer fluid (typically a mixture of water and antifreeze and often referred to as 'brine') around a heat collector loop which absorbs heat from the ground or water source;
- the transfer fluid delivers the heat to the evaporator which contains refrigerant gas at a very low temperature;
- the refrigerant gas absorbs heat from the ground or water source;
- the compressor compresses the refrigerant gas, which raises its temperature further;
- the condenser causes the refrigerant gas to condense to its liquid form, transferring the heat through a coil to the heating system;
- the expansion valve lowers the refrigerant pressure and the refrigerant liquid returns to the evaporator, where it becomes a gas again.

The heat produced by the heat pump is transferred to the heating system via a coil, either within the hot water storage cylinder or buffer tank.

This is an indirect system, in which heat transfer fluid in a collector loop conveys low grade heat to the heat pump. There are also direct systems, in which the refrigerant circulates through both the collector loop and the heat pump. However, there are concerns regarding leakage of refrigerant into the ground with a direct system and the choice of refrigerant should be carefully considered. The indirect system is the more common of the two and is covered in more detail in this document.

All ground source systems and most water source systems use a closed collector loop, but some water source systems use an open collector loop which transfers water to the heat pump and then discharges it. Permission to use an open collector loop must be obtained from the Scottish Environmental Protection Agency (SEPA).

As well as being used to provide heating in a building, the technology can be reversed to cool buildings. Heat pumps can be optimised for either heating or cooling depending on the application. A heat pump may not therefore be as efficient in cooling mode. In commercial applications, heat pumps can offer both heating and cooling with equal efficiency.

Figure 1 illustrates the principle of operation of an indirect ground source or water heat pump.

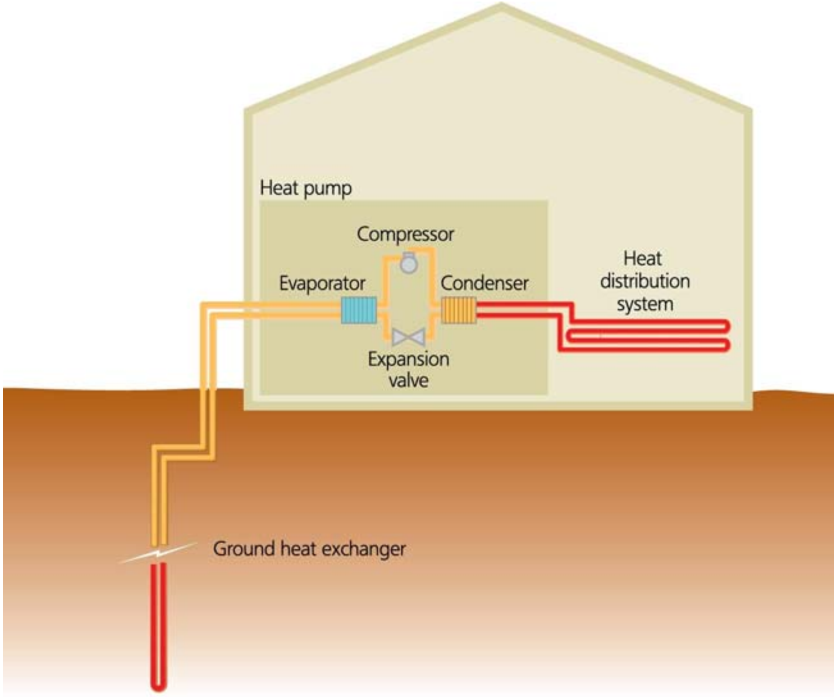

Figure 1: Schematic of an indirect ground source heat pump system
Source: Energy Saving Trust

2 Components and types of GSHP and WSHP systems

A ground source or water source heat pump system typically comprises the following components:

- heat collector loop – a continuous polyethylene pipe, containing heat transfer fluid (typically a mixture of water and antifreeze);
- heat pump unit – contains an evaporator, compressor, condenser, expansion valve, controls and circulating pump (the pump may be external to the unit);
- programmer;
- electricity supply to run the compressor and the circulation pumps; some also incorporate power management controls;
- low pressure hot water distribution system (underfloor heating and / or low temperature radiators with heat distribution manifold, and / or hot water distribution to taps).

plus:

- hot water storage vessel (if the system is also being used for heating domestic hot water);
- buffer tank (optional);
- supplementary heating (optional, essential for still water sources that freeze);

Some systems are integrated with a mechanical ventilation system with heat recovery.

2.1 Heat collector loop

There are six types of heat collector loops:

Ground loops:

- horizontal, laid out in a shallow trench and backfilled;
- Slinky®, another form of horizontal loop, laid out in a shallow trench and backfilled;
- vertical loops lowered into deep boreholes and grouted in place;
- compact collectors, laid horizontally or vertically in trenches and backfilled;

Water loops:

- closed loop collector placed in a body of water such as a lake;
- open loop collector placed in a body of water, such as a spring or ground water.

A combination of loops can be used for a heat pump system.

Horizontal closed collector loops

A horizontal closed loop system (see Figure 2) is popular for projects where land availability allows for trenching. It may not be possible to install a loop if bedrock is within 1.5 m of the surface, or there are large boulders.

The loop is placed at the bottom of a shallow trench (typically 1-2m deep, to get well below the ground's frost line).

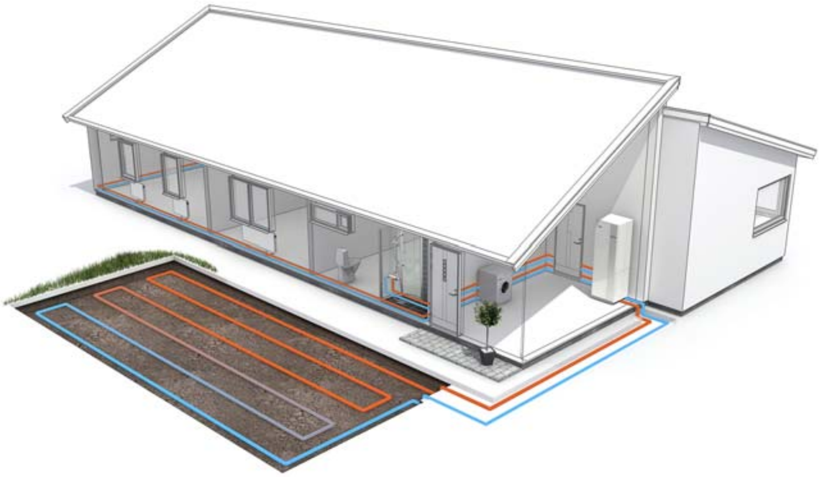

Figure 2: A horizontal ground loop
Source: Ecoliving

2.1.1 Slinky® collector loops

Slinkies® are a variation of horizontal collector loops. They are flattened coils of piping (see Figure 3) which are spread out and laid either horizontally in a wide trench or vertically in a narrow trench, then backfilled.

The relatively large area of heat transfer provided by the coil, compared with a standard horizontal loop, reduces the length of trench required. However the performance will be inferior to that of a non-coiled system with the same length of pipe, because the overlapping pipework draws heat from a smaller ground area.

a)  b) 

Figure 3: Slinky® loops installed a) vertically, b) horizontally
Sources: Geothermique, John Cantor Heat Pumps

2.1.2 Vertical bore hole collector loops

In vertical systems, U-shaped collector pipes are installed in vertical bore holes.

Vertical bore hole collector loops are typically used for housing where available land is limited, or for an existing building where the occupants do not want extensive disturbance of their grounds. For non-domestic buildings with a relatively heavy heating load, multiple boreholes can cover a considerable area, but for new buildings collectors can be integrated within piled foundations.

The depth of bore hole varies greatly but is typically between 50 and 100 m. The minimum distance between each borehole also varies, from 5 to 10m.

The number of boreholes required depends on the heat pump, the heating/cooling load profile of the building, the hydraulic design of borehole arrays and local geological conditions. It is important that each borehole is of the same depth with the same quantity of pipe.

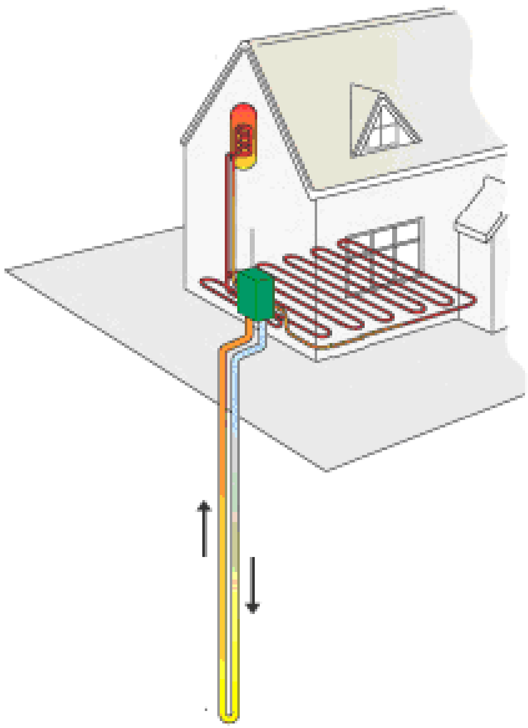

Figure 4: A vertical bore hole system
Source: Heat Pump Association

2.1.3 Compact collectors

Compact collectors require less ground area than a horizontal collector. The collectors are typically 2m tall and can be installed either horizontally in a shallow sloping trench, to reduce the depth of earthworks required, or vertically in a narrow trench (see Figure 5), to reduce the area of ground required. The thermal properties of the ground are particularly important with a compact collector. As with all types of ground loop, moist packed soil is the most efficient in transferring heat.

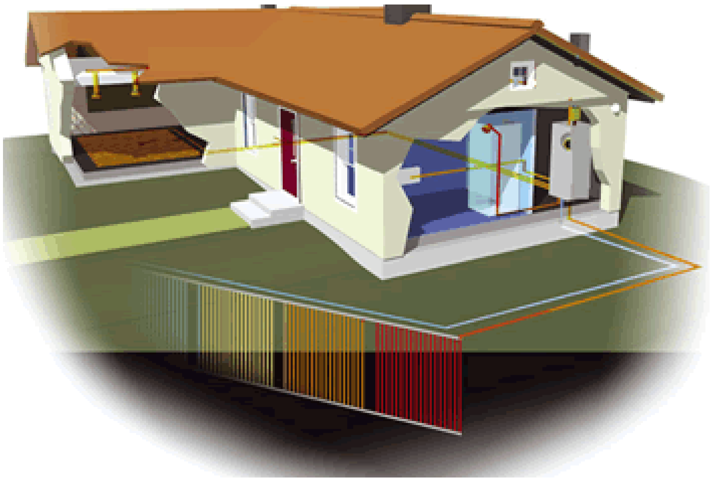

Figure 5: A compact collector system
Source: Ice Energy

2.1.4 Closed loop water source

A closed loop water source system can be an economic alternative to a ground source system when there is a source of water near the property as it eliminates excavation costs. The heat collector pipe is installed at the bottom of a large pond or lake (see Figure 6).

With a fixed body of water, such as a pond, special care should be taken when sizing the collector loop. If the collector is constantly taking too much heat out of the water it may significantly reduce the overall temperature of the water. This could disturb the natural habitat the water provides for pond life and reduce the heat available for abstraction.

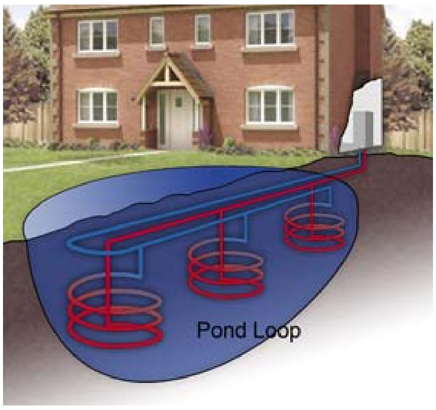

Figure 6: A closed loop water source system
Source: Rayotec

2.1.5 Open loop water source

Open loop systems pump water from a nearby source, extract the heat and then discharge the cooled water into another body of water or well.

Using well water as the heat source is often the most efficient as the well water remains at a relatively stable temperature all year round, whereas surface water may be considerably cooler in the winter. This means that a heat pump using well water does not have to use as much energy to increase the temperature of the incoming water to the required temperature for heating/hot water as one that uses surface water source, such as a river.

Whilst river water can also deliver very high-efficiencies for much of the time, this system may fail to operate adequately should there be insufficient flow or the water temperature drops (for instance below 5°C for some models). Therefore a back-up heat source may be needed. At low temperatures there is also an increased risk of freezing the heat exchanger and protection measures may be required to protect the heat exchanger in open loop systems.

2.2 Heat pump, programmer

Heat pumps for domestic ground source and water source systems are self-contained, usually with a footprint of about 600 x 600 mm. In systems for large buildings, the units are much bigger and require a plant room. Heat pump units containing a compressor are quite heavy and are not suitable for wall mounting.

The programmer may be incorporated in the unit, or there may be a separate programmer.

Figure 7: Example of ground source heat pump for internal installation
Source: NIBE

2.3 Electricity supply and power management

Electricity is required to run the heat pump and circulation pumps. The efficiency of the heat pump unit and the distribution system will limit demand for delivered energy and emissions of carbon dioxide (CO_2), but further savings can be achieved by combining the system with other low carbon technologies that generate electricity, such as solar photovoltaic panels or wind turbines. The amount they contribute will vary with size, with site conditions, with the seasons, and with the weather. It could be possible to have an autonomous system if there was space for sufficient on-site battery storage, but grid connection is more usual in the UK.

Some heat pump units incorporate an inverter which saves energy by reducing the number of times the heat pump will stop and start. When there is a demand for heating, the inverter-controlled compressor allows the heating capacity to be modulated, allowing the inverter to gradually increase its capacity, so that the desired temperature can be reached quickly. This reduces the start up time of the heat pump, using less power and making the heat pump system more energy efficient.

Inverter-controlled compressors start unloaded and do not require a high starting current. In this case the start current is always less than the running current. Compressors without an inverter may have a high starting load and it is advisable to seek permission from the electricity supplier before connecting to the supply.

2.4 Hot water storage vessel

A hot water storage vessel is required when the heat pump is used with a wet heating system and is used to supply domestic hot water. A cylinder is not required if the heat pump is only providing heating. It is important that the hot water storage vessel is sized correctly for the maximum heating capacity of the heat pump. Some companies offer matched systems, supplying the heat pump, vessel and controls from one source.

When used for heating domestic hot water, heat pumps usually heat the water to bring the temperature up to that needed at the taps. Sometimes they rely on another source of energy, such as a solar collector or an electric immersion element to boost temperatures. The energy efficiency of a heat pump reduces with higher supply temperatures but since the heat pump is still more efficient than an electric immersion heater, it is sensible to set the heat pump to produce the highest temperature it can reach.

2.5 Distribution system

Ground and water source systems can be used to supply domestic hot water as well as space heating, but only space heating is covered here.

Ground and water source heat pumps are most commonly used with a low pressure hot water distribution system for space heating. The lower the required output temperature from a heat pump, the greater the system efficiency.

Traditional radiator systems are usually designed for high distribution temperatures, typically 60-80°C. But with heat pumps designed for a maximum operating temperatures of 45-55°C, either underfloor heating systems are often used as they only require temperatures of 30°-45°C, or systems designed to operate with lower surface temperature radiators of 45-55°C.

If existing radiators have been oversized at installation, they may be large enough for the lower flow temperatures from a heat pump to maintain room temperatures. It is advisable to check if existing radiators are suitable before looking to change them when fitting a heat pump in place of an existing boiler. At the same time as changing to a heat pump system, it may be worthwhile considering some simple improvements to the building fabric, such as improving loft insulation, that will reduce heat loss and increase the potential for the existing radiators to be retained.

Traditional radiator systems require high distribution temperatures, typically 60-90°C, so underfloor heating systems are often used with heat pumps as they only require temperatures of 30°-45°C. Low temperature radiators are also often used, which are designed for a maximum operating temperature of 45-55°C.

Radiator and underfloor systems can be combined if an additional mixing valve is provided to adjust the supply temperature for the underfloor circuit.

Typically, the controller in the heat pump unit would be linked to a programmer-timer, to at least one room thermostat, and to thermostats on the hot water cylinder and buffer tank. Ground and water source heat pump systems may achieve greatest efficiency when run continually, but thermostatic radiator valves in each room can be used to limit unnecessary demand for heat.

With an underfloor or zoned heating system, space is required for a manifold with stopcocks for each distribution loop.

2.6 Buffer tank

Some ground or water source heating systems use a buffer tank to provide the system with a buffer or thermal store that absorbs excess heat provided by the heat pump. Buffer tanks can serve a similar function to an inverter, reducing the likelihood of the heat pump switching on and off unnecessarily and wasting energy, and a buffer tank may not be necessary where the heat pump is fitted with an inverter.

As well as acting as a thermal store for space heating, a buffer tank may be used to supply hot water to the cylinder. Some systems incorporate a 'tank in tank' which combines the buffer tank and cylinder. This uses the outer jacket as a buffer tank and provides hot water for heating and hot water. The requirement for the buffer tank is dictated by the volume of the heating distribution circuit, as the output of an air heat pump can change as the outdoor temperature increases.

A buffer tank would generally be required in buildings with several heating zones, but is often also used in housing to regulate the heating efficiently. However, a buffer tank may not be needed in well-insulated homes that are built with high levels of thermal mass, as the thermal mass of the building may act in effect as its own buffer, moderating fluctuations in temperature.

2.7 Supplementary heating

An integral electric heater, sometimes termed a 'boost,' 'back-up,' or 'emergency' heater, may be provided to supply backup heating if prolonged periods of low external temperatures are anticipated. Some heat pump units can be linked to an existing electric, gas, or oil boiler, with special controls to allow switching between the heat pump and boiler.

Whilst back-up heating may be provided by an electric immersion heater at any time, demand for electricity could be reduced by a solar thermal system that can supply the system with hot water for much of the year. The heat pump should be set to operate if the solar cannot provide adequate water heating.

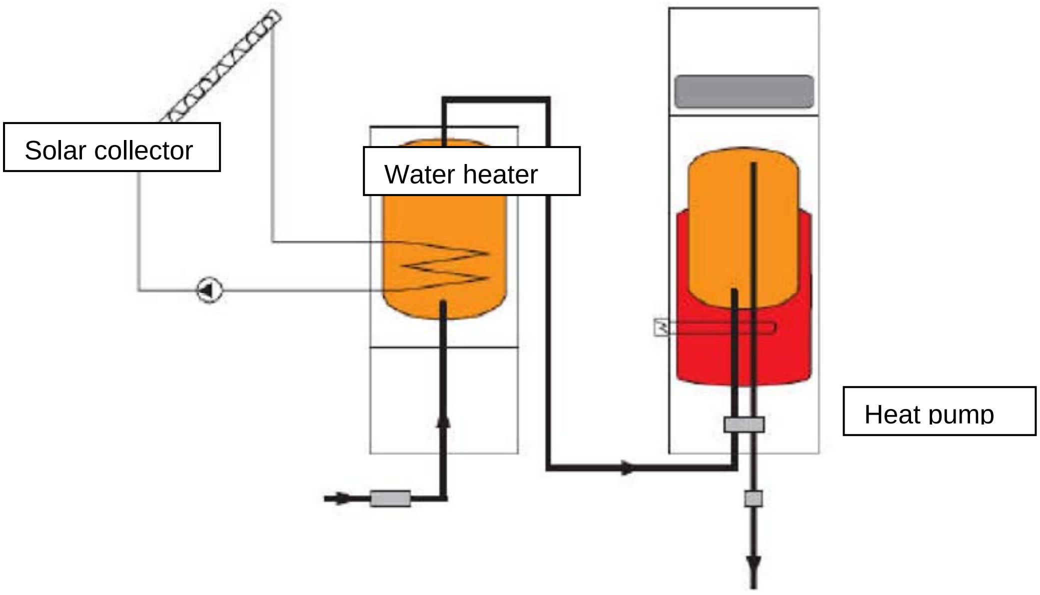

Figure 8: Solar water heating system supplementing heating by the heat pump, plus integral electric element to provide back up heating
Source: based on diagram by NIBE (provided by Ecoliving)

3 Building regulations: GSHP and WSHP systems

3.1 Building regulations and building warrants

All ground source or water source heat pump installations serving a building must comply with the requirements of the Building (Scotland) Regulations 2004, as amended, including the functional standards listed in Regulation 9, Schedule 5. However, it is not always necessary to apply for a building warrant to install a ground or water source heat pump:

- for a new building, the heat pump system should be covered by the building warrant.
- a building warrant is always required when a heat pump system is installed in or on an existing flat or a building containing flats, or for freestanding installations around flats.
- for existing houses, installations onto or within a building must comply with the building regulations. But some installations of ground or water source heat pump systems may not require a building warrant (see Regulation 5, Schedule 3). You should contact your local authority building standards office to check whether or not you need to apply for a building warrant, prior to works commencing on site.

Planning permission

Certain installations will need planning permission. Guidance is available in Planning Advice Note 45 Annex: Planning for Micro-renewables. However 'permitted development rights' have been extended to existing domestic buildings in specified circumstances thus removing the need to apply for planning permission. These rights cover solar PV, solar thermal, ground and water source heat pumps and flues for biomass and combined heat and power systems. Guidance is contained in Circular 2/2009.

Detailed consideration of planning requirements for non-domestic microgeneration equipment will follow. An Order for microgeneration in non-domestic buildings is required by section 71 of the Climate Change (Scotland) Act 2009.

SEPA

Permission is required from the Scottish Environment Protection Agency (SEPA) for abstracting and discharging water to and from a surface or groundwater source. Further information of abstraction permissions and contact information can be found at www.sepa.org.uk.

Permission may also be required for use of water from disused mine workings, from the Coal Authority.

3.2 Technical Handbooks

Guidance on complying with the building regulations is given in the Domestic and Non-domestic Technical Handbooks 2009.

This chapter highlights the issues in each section that should be considered when installing a ground or water source heat pump system, but you should check the Technical Handbooks for any other building standards and guidance that are relevant to the individual installation.

For any further advice on specific projects please contact your local authority's Building Standards office. Find them in your phone directory, the local authority website, or from the website of the Scottish Association of Building Standards Managers.

3.2.1 Section 0 General

Section 0 gives an explanation of Regulations 1 to 17. It includes guidance on appropriate standards of durability, workmanship and fitness of materials.

A particular consideration for a heat pump system is that sufficient space should be left around the components to enable access for maintenance or repair work (see Regulation 8).

If a heat pump system is used for cooling and has a total effective output of 12kW or more, it must be inspected at regular intervals and appropriate advice given to building users on reducing its energy consumption (see Regulation 17).

3.2.2 Section 1 Structure

Section 1 aims to ensure that the structure of a building does not pose a threat to the safety of people in or around buildings.

For ground source heat pump systems, particular consideration should be given to avoid damage to the structure, including the foundations of the building, particularly from the effects of frost heave.

- external pipework should be insulated when within 1.5m of any wall, structure or service, and at any point where it passes under paving, to avoid frost heave in the event of the pipework freezing the soil;
- the collector loop should not be laid under or near the foundations to avoid the risk of frost heave disturbing the foundations in the event of the pipework freezing the soil;
- a correctly designed ground collector loop should be of sufficient size to prevent long term continuous ground freezing thus limiting the risk of frost heave;
- where excavations have encroached on the area of ground affected by loads from the foundations, consideration should be given to a concrete backfill.

For any heat pump system, including associated water storage tanks, the following issues should be considered, to avoid damage to the structure of the building:

- the heat pump and associated hot water storage vessels are likely to change the loads imposed on the structure of the building and therefore, except for installations outside the building or on concrete ground floors, changes in loading should be assessed by a chartered engineer or other appropriately qualified person;
  - o the supporting structure needs to be strong enough, or made strong enough, to resist the loads imposed by the heat pump, including the weight of water when the system is operating, and any vibrations generated;
  - o for timber floor structures, loads should normally be shared across at least two joists and it may sometimes be necessary to add members to provide sufficient support;

- the installation of pipework and ductwork should not detrimentally weaken the structure of timber roofs, floors, or walls:
  - notches and holes should not be cut in rafters, roof ties, collars or hangers;
  - lightweight trussed rafters should not be cut, trimmed, notched or drilled;
  - notches should not be cut in wall studs, cripple studs or lintels unless a full structural appraisal has been carried out by a chartered engineer or other appropriately qualified person;
  - Figure 9 shows the safe locations and sizes for notches and holes in floor joists and studs - if in doubt, ask a chartered engineer to check the proposed installation.

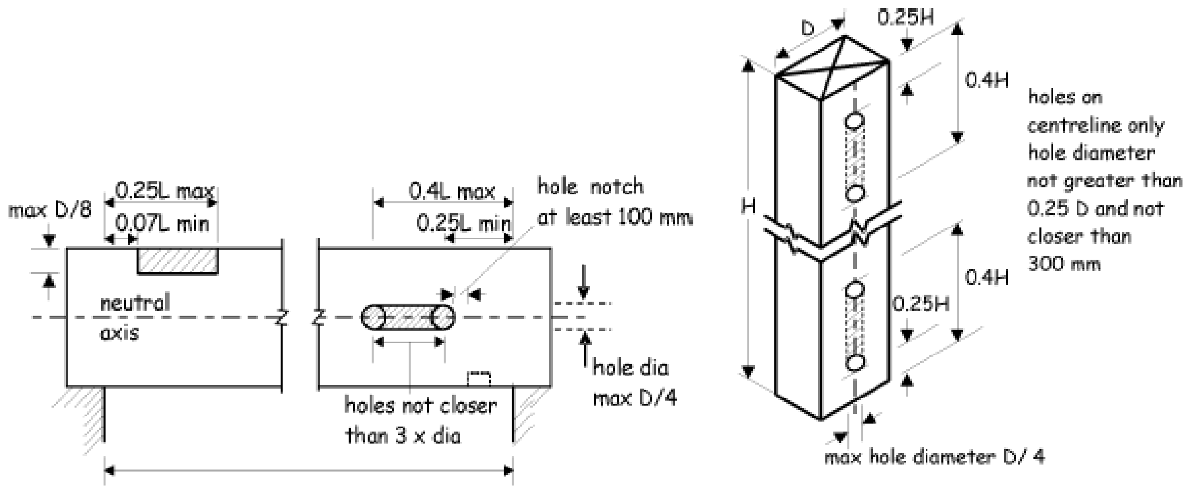

Figure 9: Notches and hole locations in timber floor joists and studs
Source: Domestic Technical Handbook, Section 1 Annexes E and F

3.2.3 Section 2 Fire

Section 2 aims to ensure that the risk of fire is reduced and if a fire does occur, there are measures in place to restrict growth and the spread of fire and smoke to enable the occupants to escape safely and fire-fighters to deal with fire safely and effectively.

Care should be taken to limit the risk of fire starting inside framed construction and to avoid the spread of fire through gaps in walls, floors, or ceilings, particularly within dwellings, between compartments, between cavities, and between cavities and any other room or space in the building.

- separating walls made of combustible materials should not contain any pipes or wiring, for instance timber frame separating walls, although pipes and ducts (other than a ventilating duct) can pass through such walls;
- cavity barriers should not be compromised by the ductwork or pipes associated with the heat pump unit or the distribution system – particular care should be taken not to disturb cavity barriers separating roof spaces in two dwellings, including boxed eaves, or at the head of a cavity wall;
- the heating system and any ventilation associated with the heat pump should have safeguards to avoid the spread of fire and smoke throughout the building: this may involve smoke detection to automatically operate in a fire control mode or alternatively shut down the system.
- casings to ductwork within a compartment should have the fire resistance duration of the compartment concerned. For example a section of ductwork in different

compartments should have the same fire resistance duration as required for each consecutive compartment that the ductwork passes through. Providing automatic smoke activated fire and smoke dampers is an alternative for ductwork that does not have a sufficient fire resistance duration where it passes through a ceiling wall, floor, cavity barrier, or through a protected route of escape. For penetrations other than ventilation ducts such measures are not required. These situations are listed in the Domestic and Non-Domestic Technical Handbook guidance;

- care should be taken to limit the size of any hole in a separating wall or floor, and to seal air gaps around pipes and ducts, for instance with intumescent mastic, to avoid reducing the fire resistance duration of the wall, floor, ceiling or cavity barriers;
- any penetrations through a protected escape route; or separating wall, floor, ceiling or cavity barrier; should not reduce the required fire resistance of the compartment.

The risk of fire associated with electrical installations is covered in Section 4 Safety.

3.2.4 Section 3 Environment

Section 3 aims to ensure that buildings do not pose a threat to the environment, and that people in and around buildings are not placed at risk from various sources, including the effects of moisture in various forms.

For any work where pipes are laid underground, which could include both ground source and water source heat pump systems, particular care should be taken to identify and avoid damage to any underground installations through digging trenches or boring holes, including:

- any filling, sealing, or other treatments used on contaminated land;
- drainage systems, including field drains, sustainable urban drainage systems (SUDS), sewers, and wastewater treatment systems;
- fuel feed systems, such as pipes from oil storage tanks;
- any measures to protect from radon gas, methane gas and carbon dioxide.

For ground or water source heating systems, particular care should be taken to avoid moisture damage to the building:

- pipes or fixings that penetrate the external walls should be properly weather protected to prevent the ingress of rainwater or dampness, for instance by caulking small gaps around pipes and in a way that any moisture collecting on a pipe in a cavity is shed to the outside of a wall;
- pipes or fixings that penetrate the walls should be installed in a way that does not adversely affect any existing damp proof, waterproof or breather membranes - if a membrane is damaged or disturbed, it should be reinstated;
- installations should not cause bridging of the damp proof course: for an outdoor unit installed close to an external wall at ground level, provision should be made to keep the gap beside the unit clear of debris, such as a lightweight protective cage;
- condensation produced by the heat pump should be disposed of to drainage systems:
    - for outdoor heat pumps, the condensate should be diverted to a mains drain or soakaway, through an insulated pipe to limit the risk of freezing;
    - for indoor units the condensate can be drained into the same drainage system as the sink or washing machine. The system should be protected by a trap to prevent unwanted smells..

Installations should not interfere with measures used to comply with the ventilation standard:

- if draught-proofing measures are used to limit the risk of frost damage to an indoor unit located in a garage, permanent ventilators should be installed to compensate for the loss of uncontrolled air infiltration.

Care must also be taken not to interfere with the ventilation of any combustion appliances.

- If the heat pump is near a fixed combustion appliance, there must be adequate ventilation for both appliances and if the heat pump is near a boiler flue, the fan must not interfere with the safe removal of the products of combustion.

3.2.5 Section 4 Safety

Section 4 aims to ensure that the risk of harm to users of a building is limited to an acceptable level by identifying hazards in and around buildings.

For ground or water source heating systems, particular care should be taken to avoid risks of burns and scalding, of legionella, and of electrocution and fire:

- unvented hot water systems are used to avoid the need for a cistern at high level and allow mains water to be supplied directly to the storage cylinder, but present risks of burns and scalds. So if an unvented system is used:
    - systems should incorporate appropriate safety devices and controls to regulate temperature and pressures within the system;
    - installations should be carried out by people with appropriate training and practical experience, usually members of a registration scheme operated by a recognised professional body such as the Scottish and Northern Ireland Plumbing Employers Federation (SNIPEF).
- to control the risk of legionella and similar pathogens, a secondary heat source, typically an immersion heater coil, is needed to raise the temperature of the stored water, once a week for a short time, to at least 60°C, in accordance with guidance to the Water Byelaws;
- as in any system where stored water is heated to control the risk of pathogens, provision must be made to prevent scalding, with a device such as a thermostatic mixing valve to limit the temperature of water delivered to a bath or bidet;
- to avoid the risk of electrocution and fire, the air source heat pump system should be installed in accordance with BS 7671, also known as the Institute of Electrical Engineers (IEE) Wiring Regulations 17th edition.

In addition, care should be taken so that an installation does not encroach on the requirements of accessibility in Standard 4.1

3.2.6 Section 5 Noise

Section 5 aims to limit the transmission of noise to a dwelling from another dwelling, other parts of the same building or an attached building, to a level that will not threaten the health of residents:

- the installation of heat pump and distribution pipe-work should not adversely affect the existing sound insulation of a separating wall or separating floor:
    - for instance, it is advisable not to mount units that incorporate a fan, pump. or compressor directly onto separating walls between flats or attached houses, or directly onto separating floors between flats.

3.2.7 Section 6 Energy

Section 6 aims to ensure that effective measures for the conservation of fuel and power are incorporated into buildings, and that emissions of carbon dioxide are limited.

Installation of a ground or water source heat pump and distribution system should not prejudice the energy performance of the building:

- if insulation within the walls, ground floor, or roof, and on pipe work is disrupted it should be reinstated;
- if membranes and seals that contribute to the airtightness of the building are disrupted, they should be repaired and the junctions around pipes or ductwork made airtight;
- gaps should be filled where any pipes or ducts penetrate external walls, incorporating insulating material to limit thermal bridging.

Various measures can help to ensure that the installation of the heat pump and distribution system is energy efficient:

- pipes and ducts within the system should be well insulated to minimise heat loss (see BS 5422: 2001 'Methods for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range – 40°C to + 700°C); for example a 22mm diameter copper pipe should be insulated with 23mm of insulation with a thermal conductivity of 0.035 W/mK;
- in addition to standard controls for a space or water heating system, heat pump unit controls should include:
    - control of water temperature for the distribution system,
    - control of water pumps (integral or otherwise),
    - protection for water flow failure,
    - protection for high water temperature,
    - protection for high refrigerant pressure, and
    - a weather compensating controller.
- further, ancillary controls are recommended:
    - timer to optimise operation of the heat pump;
    - room thermostats to regulate the space temperature, interlocked with the heat pump unit to ensure that the heat pump only operates when there is demand for heat;

   - zoning with thermostatic controls for heating systems in large buildings (with the floor area of each zone not exceeding 150 m^2) to limit unnecessary demand for heat.

- the whole system, including any supplementary heating or electricity generation, must be properly commissioned to achieve optimum energy efficiency:
   - there should be access to enable inspection, testing and commissioning;
   - commissioning should raise the system from a level of static completion to full working order and achieve the levels of energy efficiency that the component manufacturers expect from their products, at the same time with a view to ensuring safe operation.
- written information must be made available for the use of the occupier of the building on the operation and maintenance of the heating and hot water system,
   - information is intended to encourage the building user to optimise energy efficiency and the use of fuel;
   - a logbook should be provided for non-domestic buildings, with information presented in a manner similar to that recommended in CIBSE Technical Memorandum 31.

Although some heat pump systems can be used for cooling as well as heating, it is always preferable to adopt passive measures rather than using energy for cooling:

- buildings should incorporate passive measures that avoid or at least minimise the use of energy for cooling; measures might include:
   - designing the proportions and orientation of glazing to limit internal temperatures and adding external solar shading where appropriate, but taking account of the need for adequate daylighting;
   - very efficient lighting and daylight dimming controls to limit the generation of heat;
   - natural ventilation, including passive stack, cross-ventilation and night cooling;
   - incorporation of thermal mass in walls, floors, and ceilings;
   - passive chilled beams.
- In any new building or conversion, an assessment should be made of the risk of over-heating, using CIBSE Technical Memorandum 37 (TM37) for non-domestic buildings, or Appendix P to SAP 2005; this is also good practice whenever the use of mechanical cooling is contemplated.

4 Additional guidance

In addition to the issues covered by the Technical Handbooks, the following good practice guidance will optimise the performance of a ground or water source heat pump system.

4.1 Design and installation of ground source collector loops

Collector loop installations should be carefully designed:

- the sizes of the collector, the heat pump, and the distribution system should be matched carefully in order to work efficiently and minimise the use of electricity;
- an undersized loop will result in poor efficiency and comfort levels, with a risk that the pump will shut down or that heating is predominantly supplied by the back-up heater;
- an over-sized loop may make the installation uneconomic and if linked with an oversized heat pump, the pump will tend to work inefficiently, cycling frequently.

All health and safety risks should be properly assessed in relation to ground loops of whatever form:

- there is a particular risk to safety when digging a trench in close proximity to others.

Each type of loop has different design requirements, but some requirements are common:

- the loop must be of sufficient size to collect the required heat energy;
- the design should minimise pumping losses that occur through friction;
- all parts of the horizontal loop must be well spaced so that the return pipe doesn't take heat from the supply pipe and the pipes do not cause excessive cooling of the ground; the minimum distance varies, but is typically 1m.

Careful backfilling of horizontal trenches is needed to ensure that the collector loops are not damaged and work efficiently:

- backfill for horizontal and slinky® loops should be the excavated material graded to remove any large or sharp stones;
- where the excavated material consists of large clods (which might lead to air gaps around the pipes, causing poor heat conduction) or sharp flints (which could damage the pipe) top soil or sand should be used to backfill until the pipe is covered and then excavated material used;
- backfilling in layers can help avoid air gaps;
- protect the loop from being crushed or split during backfilling and after installation, for instance by carefully selecting backfill materials and ensuring sufficient cover;
- clearly indicate the location of the collector loop after installation so that it can be protected in future.

Similarly, vertical borehole collectors need to be backfilled carefully:

- the space between the borehole wall and the collector pipe should be backfilled, from the bottom up, with a suitable grout material to provide full thermal contact, such as bentonite, silica sand, cement, superplasticiser and water.

Separate control of each collector loop is needed with multiple borehole installations:

- each borehole should be individually connected to a manifold with valves located in a manifold pit (see figure 10). This design enables flow balancing and in the event of a borehole failure, an individual borehole can be isolated without the loss of the entire ground loop.

Figure 10: A typical manifold pit for horizontal loops, slinkies or bore hole systems
Source: EarthEnergy Ltd

4.2 Installation of water source collector loops

The nature of the water source affects the efficiency of the system:

- in still water, greater efficiencies are achieved when the volume of the body of water is larger;
- in rivers, greater efficiencies are gained from higher flow rates, although securing pipes or plates in moving water can be a difficult exercise.

Water temperatures vary considerably near the surface, but variations decrease with depth. Loops should be installed deep enough to avoid freezing:

- depths necessary to avoid freezing will vary according to the local climate, but typically in still water, the loop should be submerged at least 1m from the water's surface.

4.3 Location of heat pump units

The heat pump unit associated with ground or water source collector loops are generally designed for indoor use. In the placing of units, manufacturers' design recommendations should be followed due to the weather resilience of the unit, its mounting requirements, the amount of air it handles and its provision for disposal of condensate.

The building regulations cover noise transmission between parts of attached buildings by use of separating construction but do not control noise from services. However, any indoor installation of a unit that contains a fan, pump, or compressor, should take account of the potential impacts of noise and vibration.

To find a location for the heat pump unit that limits the risk of noise nuisance and prevent damage to the appliance, the following measures are recommended:

- ideally, the heat pump should be in a separate room such as a plant room or utility room that is not adjacent to sleeping areas, to prevent the transmission of unwanted noise and vibration;

- the unit should be within a heated area of the building, to limit the risk of frost and dampness that can damage the appliance;
- use anti-vibration pads or brackets that incorporate anti-vibration pads, to isolate the unit from the structure of the building and prevent the transmission of noise and vibration to other parts of the building.
- for ground-standing units, the heat pump should be installed on a firm, level and substantial base that will absorb vibrations;

4.4 Pipework and fittings

Certain measures can limit the risks arising from pipework and fittings of damage due to condensation and nuisance due to noise or vibration:

- as well as insulating to maximise energy efficiency, it is good practice to insulate pipe-work and fittings to avoid condensation damage to the building, or frost damage;
- the heat pump can be fixed on anti-vibration mountings to limit the risk of transmitting noise or vibrations;
- pipe connections to the heat pump using flexible hoses can limit noise transmission through pipework.

5 Making the most of a ground source or water source heat pump

Manufacturers describe the efficiency of a heat pump as the Coefficient of Performance (COP). This is the ratio of the number of units of heat output for each unit of electricity input used to drive the heat pump. The higher the COP the better.

When an energy performance certificate (EPC) is produced using RdSAP, SAP or SBEM software, the calculations ascribe a standard efficiency of 320% to ground source heat pumps, decreased to 300% if there is an auxiliary heater. The standard efficiency for a water source heat pump is 300% (equivalent to a COP of 3). This assumes the use of underfloor heating, but the efficiency decreases where the system supplies all the domestic hot water or the radiators used have a low surface area, or where no compensation is made for the weather.

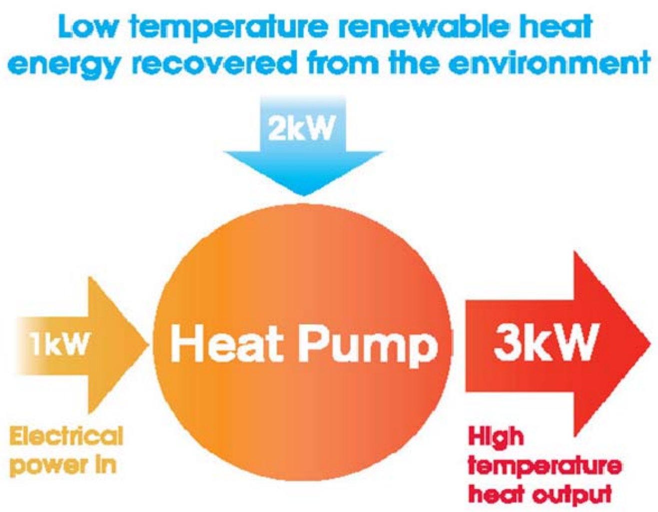

Figure 11: Example Coefficients of performance
Source: Mitsubishi Electric Europe B.V.

It may be possible to achieve much higher efficiencies in practice than is allowed for in EPC calculations, but this depends on the quality of the installation as well as the specification of the equipment and distribution system. The non-domestic calculation software allows for higher than default efficiencies to be input for a verifiable system design. This flexibility is currently being considered for SAP software too. At the same time, it is likely that the manufacturer's statement of the COP for the heat pump, which is based on test conditions, will be different from practice, which can be affected by a number of factors:

Using Ground or Water Source Heat Pumps	
more energy efficient	**less energy efficient**
✓ building has a high standard of insulation and airtightness	× building has poor insulation and unintentional air leakage
✓ extra insulation below underfloor heating with solid or screeded floors	× carpets, timber flooring above underfloor heating
✓ all pipes are well insulated	× heating pipes are uninsulated
✓ correctly sized collector loop	× over-sized collector loop
✓ correctly sized heat pump	× over-sized heat pump
✓ underfloor heating or low temperature, large surface radiators	× standard radiators that operate at higher temperatures
✓ allowing the heat pump to run continuously over a long period – but some systems work well with thermostatic radiator valves (TRVs)	× stopping and starting the heat pump by setting controls incorrectly
✓ a horizontal collector in moist packed soil	× a horizontal collector in dry loose soil
✓ vertical bore hole collectors backfilled with high conductivity grout	× vertical bore hole collectors backfilled with low conductivity grout
✓ vertical bore hole collectors in hard rock, such as granite or quartz	× vertical bore hole collectors in soft rock, such as limestone
✓ deep, moving water source	× shallow, still water source
✓ the occupants understand how to use the building and the heat pump system in an energy efficient way	× occupants leave windows open while the heating is on, set the controls so that the heat pumps keeps cycling.

Fuel costs for a ground source or water source heat pump system will vary with the price of grid electricity, unless the electricity is generated on site. Some systems can partly operate on off-peak tariffs, for instance for heating water with an immersion heater.

6 Product standards

6.1 European and British Standards

There are a number of European and British Standards that are relevant to ground or water source heat pump systems. These include those listed below, but this list should not be regarded as exhaustive.

Only those that **are** cited in the relevant section of 2009 Technical Handbooks have an asterisk by their number reference.

6.1.1 Standards for collector loops

There are no British Standards specifically for collector loops, nor for the installation of such loops.

BS EN 15450:2007	Heating systems in buildings. Design of heat pump heating systems.
	(includes some guidance such as commissioning of ground loops)

The Illustrated Guide to Renewable Technologies (BG 1/2008) by BSRIA (The Building Services Research and Information Association) contains guidance on ground loops.

6.1.2 Standards for heat pumps

BS EN 378	Refrigerating systems and heat pumps. Safety and environmental requirements.
Part 1:2008	Basic requirements, definitions, classification and selection criteria
Part 2:2008	Design, construction, testing, marking and documentation
Part 3:2008	Installation site and personal protection
Part 4:2008	Operation, maintenance, repair and recovery
BS EN 14511	Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling.
Part 1:2007	Terms and definitions
Part 2:2007	Test conditions
Part 3:2007	Test methods
Part 4:2007	Requirements

6.1.3 Standards for hot water storage vessels, buffer tanks, and associated fittings

BS 1566: Part 1: 2002 * Part 2: 1984 (1990) *	Copper indirect cylinders for domestic purposes – Open vented copper cylinders – Requirements and test methods Specification for single feed indirect cylinders.
BS 3198: 1981 *	Specification for copper hot water storage combination units for domestic purposes.
BS 5422: 2001 *	Methods for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range – 40°C to + 700°C
BS 6283: Part 2:1991 *	Safety devices for use in hot water systems - Specification for temperature relief valves for pressures from 1 bar to 10 bar.
BS 7206: 1990 *	Specification for unvented hot water storage units and packages.
BS EN 1490: 2000 *	Building valves. Combined temperature and pressure relief valves, tests and requirements.
BS EN 1491: 2000	Building valves. Expansion valves. Tests and requirements.
BS EN 12102: 2008	Air conditioners, liquid chilling packages, heat pumps and dehumidifiers with electrically driven compressors for space heating and cooling. Measurement of airborne noise. Determination of the sound power level.

6.1.4 Standards for heating systems

BS 6700: 2006	Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages. (BS 6700: 1997 is cited in the Technical Handbook)
BS EN 15316-1	Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies.
BS EN 15316-4-2: 2008	Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating generation systems, heat pump systems.
BS EN 15450: 2007	Heating systems in buildings. Design of heat pump heating systems.

6.2 European eco label

A new EU Ecolabel can be awarded to those models of heat pump which are more energy efficient and which minimise their environmental impacts (see Decision 2007/742/EC[1]). It sets out various criteria, with testing to BS EN 14511:2004 . These include the minimum efficiency of the heat pump expressed as the coefficient of performance (COP) for specified

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:301:0014:0025:EN:PDF Commission decision of 9 November 2007 establishing the ecological criteria for the award of the Community eco-label to electrically driven, gas driven or gas absorption heat pumps *(notified under document number C(2007) 5492)*

inlet and outlet temperatures of the heat source and any wet distribution loop, as appropriate.

The label requires testing and display of the sound power levels (dB(A)) and does not allow the use of certain heavy metals and flame retardants. It requires suitable training to be available for installers, and spare parts to be available for 10 years from the date of sale. A maintenance, installation, and operation manual must be supplied that conforms to EN 378:2000.

Suppliers must also provide suitable tools, computer programs, appropriate climatic data and guidance so that competent installers are able to calculate the performance parameters, such as seasonal performance factor, seasonal energy efficiency ratio, primary energy ratio and annual emissions of carbon dioxide.

Information must be provided for installers and customers, available at points of sale. As well as giving information about the system, there must be advice on reducing heat loss and solar gain, probably starting with improving insulation but possibly also reducing solar gain. It requires that if retrofitting to existing heating systems, the heat pump should be selected to match the existing distribution system.

The Scottish
Government