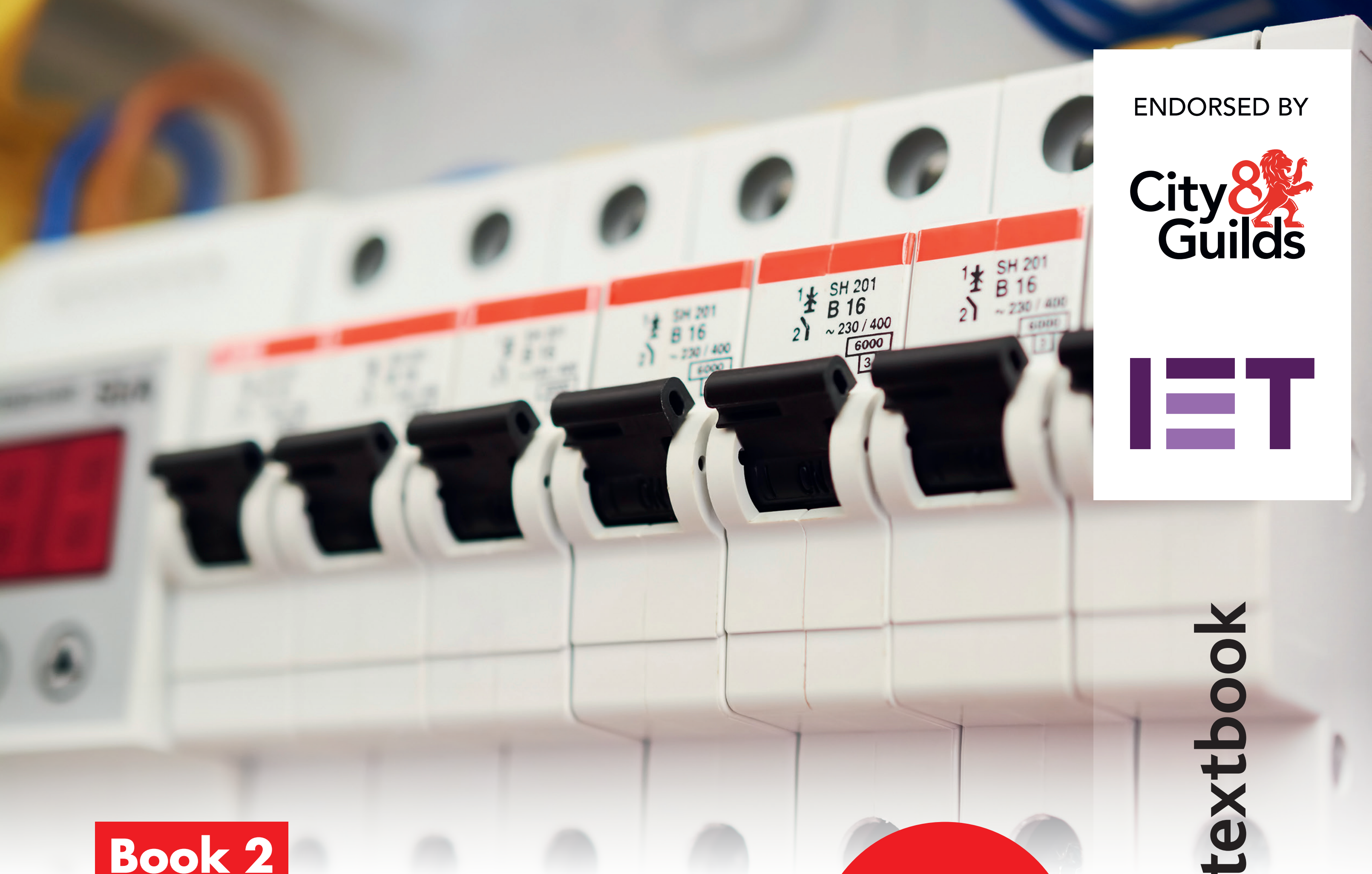

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City & Guilds

IET

Book 2

Electrical Installations

SECOND EDITION

REVISED & UPDATED EDITION

LEVEL 3 ELECTROTECHNICAL APPRENTICESHIP (5357)
LEVEL 3 ELECTROTECHNICAL IN DWELLINGS APPRENTICESHIP (5393)
LEVEL 3 ADVANCED TECHNICAL DIPLOMA (8202)
LEVEL 3 DIPLOMA (2365)
T LEVEL OCCUPATIONAL SPECIALISMS (352/353)

The City & Guilds textbook

Peter Tanner

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Contents

ENVIRONMENTAL TECHNOLOGIES

INTRODUCTION

A large number of scientific studies show that climate change is causing more frequent and more extreme weather events around our planet and CO_2 emissions are a clear contributor towards this.

The use of energy storage and generating systems, as well as renewable technologies, will help to minimise climate change or its effects by reducing emissions.

The construction industry is already going some way to reduce emissions but needs to further promote and utilise these technologies in buildings.

Much of the decline in harmful emissions is due to new technologies used in building materials, insulation and renewable energy sources. When working in the electrotechnical sector, you are very likely to come across these technologies. This chapter is intended to explain how they work.

HOW THIS CHAPTER IS ORGANISED

This chapter is divided up into four sections, each one detailing a type of environmental technology system.

Heat-producing

- Solar thermal
- Ground-source heat pump
- Air-source heat pump
- Biomass

Electricity-producing

- Solar photovoltaic
- Micro-wind
- Micro-hydro

Co-generation

- Micro-combined heat and power (heat-led)

Water conservation

- Rainwater harvesting
- Greywater re-use

▲ Figure 1.1 The environmental technology systems covered in this chapter

INDUSTRY TIP

The Office for National Statistics' website updates figures on CO_2 emissions every year. Visit their website to obtain the most current statistics.

This approach will help you to understand the working principles of each system and how they impact on the installation requirements and the regulatory requirements. The advantages and disadvantages of each technology system are also described.

Note that, for those studying the **2365** Level 3 Diploma in Electrical Installations (Building and Structures) course, you will be formally assessed on your knowledge of environmental technologies as part of the **2365** certification.

For those studying:

- **5357** Electrical Qualification (installation or maintenance) (Apprenticeship)
- **8202** Level 3 Advanced Technical Diploma in Electrical Installation
- **8710-353** Electrotechnical Engineering Specialism

you will not be formally assessed, but this chapter offers useful information because, in the future, you may be expected to install or advise on environmental technologies.

For those studying 8710 T Level Technical Qualification in Building Services Engineering for Construction, this chapter will help with the core unit content (350), especially 5.10 within Outcome 5.

▼ Table 1.1 Chapter 1 assessment criteria coverage

Topic	5357	2365	8202	5393-104/004
Regulatory requirements relating to micro-renewable energy and water conservation technologies		3.1; 3.2		
Heat-producing micro-renewable energy technologies		1.1; 2.1; 2.3; 2.4; 2.5; 3.1; 3.2; 4.1; 4.2		
Electricity-producing micro-renewable energy technologies		1.2; 2.2; 2.6; 2.7; 3.1; 3.2; 4.1; 4.2		4.4; 7.3
Micro-combined heat and power		1.3; 2.8; 3.1; 3.2; 4.1; 4.2		
Water conservation technologies		1.4; 2.9; 3.1; 3.2; 4.1; 4.2		

T Level mapping grids are available on the Hodder Education website. These map the book to the occupational specialisms: 8710-353 (Electrical Engineering) and 8710-352 (Electrical and Electronic Equipment).

REGULATORY REQUIREMENTS RELATING TO MICRO-RENEWABLE ENERGY AND WATER CONSERVATION TECHNOLOGIES

It is important to have knowledge of the planning requirements and building regulations for each technology. This section:

- explains the terminology used
- provides insight into the workings of both the planning requirements and building regulations
- explains the differences in planning regulations across different regions of the UK.

Planning and permitted development

In general, under the Town and Country Planning Act 1990, before any building work that increases the size of a building is carried out, a planning application must be submitted to the local authority. A certain amount of building work is, however, allowed without the need for a planning application. This is known as **permitted development**.

Permitted development usually comes with criteria that must be met. When building an extension, for example, it may be possible to do so under permitted development, if the extension is under a certain size, is a certain distance away from the boundary of the property and is not at the front of the property. If the extension does not meet these criteria, then a full planning application must be made.

Permitted development is intended to ease the burden placed on local authorities and to smooth the process for the builder or installer. Permitted development exists for renewable technologies, and this chapter outlines the situations where it applies.

Building Regulations

The Climate Change and Sustainable Energy Act 2006 brought **microgeneration** under the requirements of the Building Regulations.

Even if a planning application is not required, because the installation meets the criteria for permitted development, there is still a requirement to comply with the relevant Building Regulations. Local Authority Building Control (LABC) is the body responsible for checking that Building Regulations have been met. The person carrying out the building work is responsible for ensuring that approval is obtained.

Building Regulations are statutory instruments that seek to ensure that the policies and requirements of the relevant legislation are complied with. The Building Regulations themselves are rather brief and, in England, are currently divided into 18 sections, each of which is accompanied by an Approved Document. The Approved Documents are non-statutory and give guidelines on how to comply with the statutory requirements.

The 18 parts of the Building Regulations in England are:

- Part A Structure
- Part B Fire safety
- Part C Site preparation and resistance to contaminates and moisture
- Part D Toxic substances
- Part E Resistance to the passage of sound
- Part F Ventilation
- Part G Sanitation, hot-water safety and water efficiency
- Part H Drainage and waste disposal
- Part J Combustion appliances and fuel-storage systems
- Part K Protection from falling, collision and impact
- Part L Conservation of fuel and power
- Part M Access to and use of buildings
- Part O Overheating
- Part P Electrical safety

KEY TERMS

Permitted development: Allows certain projects or building work to be carried out without the need for planning permission.

Microgeneration: The small-scale generation of heat or electric power by individuals, small businesses and communities to meet their own needs, as alternatives or in addition to traditional, centralised, grid-connected power, such as power stations.

INDUSTRY TIP

For more information on what is allowed as permitted development in a typical domestic dwelling, search for the planning portal (England and Wales) or Planning Portal NI (Northern Ireland) or ePlanning Scotland.

INDUSTRY TIP

You can research the Climate Change and Sustainable Energy Act 2006.

- Part Q Security in dwellings
- Part R High-speed electronic communications networks
- Part S Infrastructure for charging electric vehicles
- Document 7 Materials and workmanship.

Compliance with Building Regulations is required when installing renewable technologies. Not all of the Building Regulations will be applicable, however, and different technologies will have to comply with different Building Regulations. The Building Regulations applicable to each technology are indicated in this chapter.

HEAT-PRODUCING MICRO-RENEWABLE ENERGY TECHNOLOGIES

Some technologies produce heat using natural energy sources, such as the Sun or energy from the ground, as an alternative to burning gas or oil or using electricity.

Solar thermal (hot-water) systems

A solar thermal hot-water system uses solar radiation to heat water, directly or indirectly.

Working principles

The key components of a solar thermal hot-water system are:

- a solar thermal collector
- a differential temperature controller
- a circulating pump
- a hot-water storage cylinder
- an auxiliary heat source.

ACTIVITY

What would be an auxiliary heat source from the diagram shown in Figure 1.2?

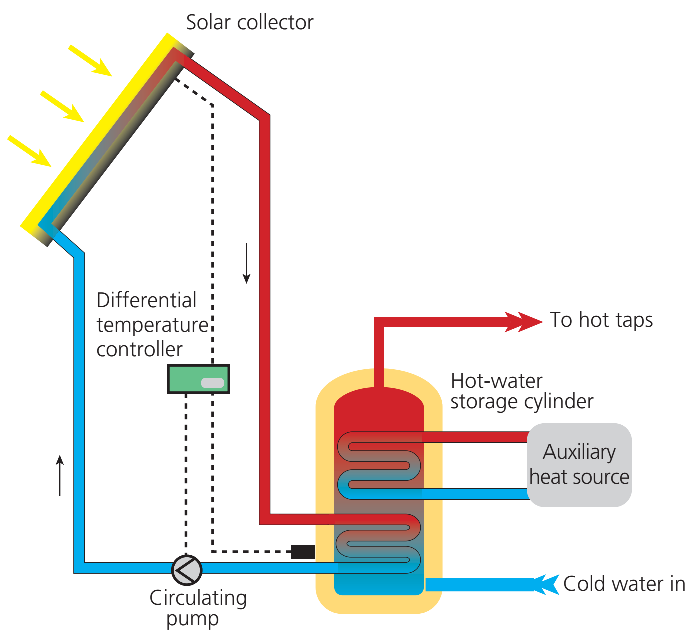


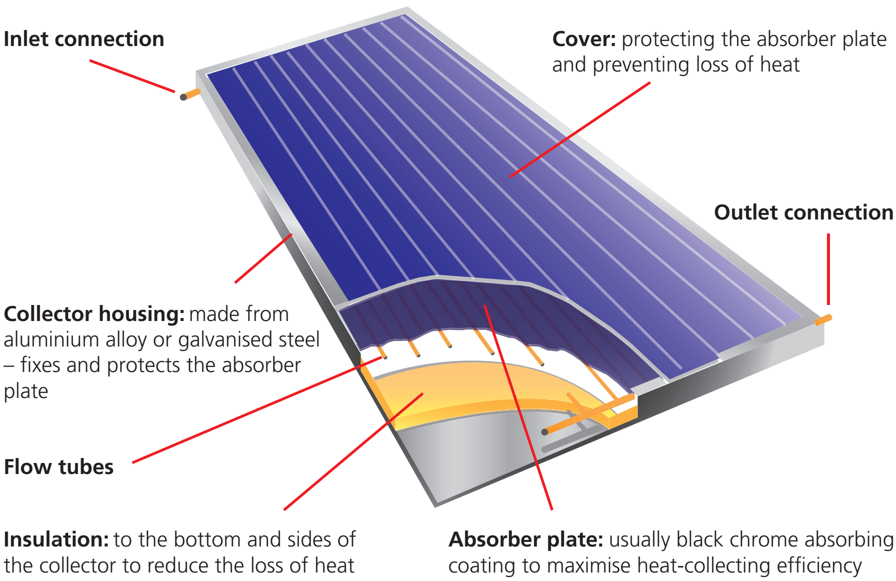
Figure 1.2 Solar thermal hot-water system components

Solar thermal collector

A solar thermal collector is designed to collect heat by absorbing heat radiation from the Sun. The energy from the Sun heats the heat-transfer fluid contained in the system. There are two types of solar thermal collector:

- flat-plate collectors
- evacuated-tube collectors.

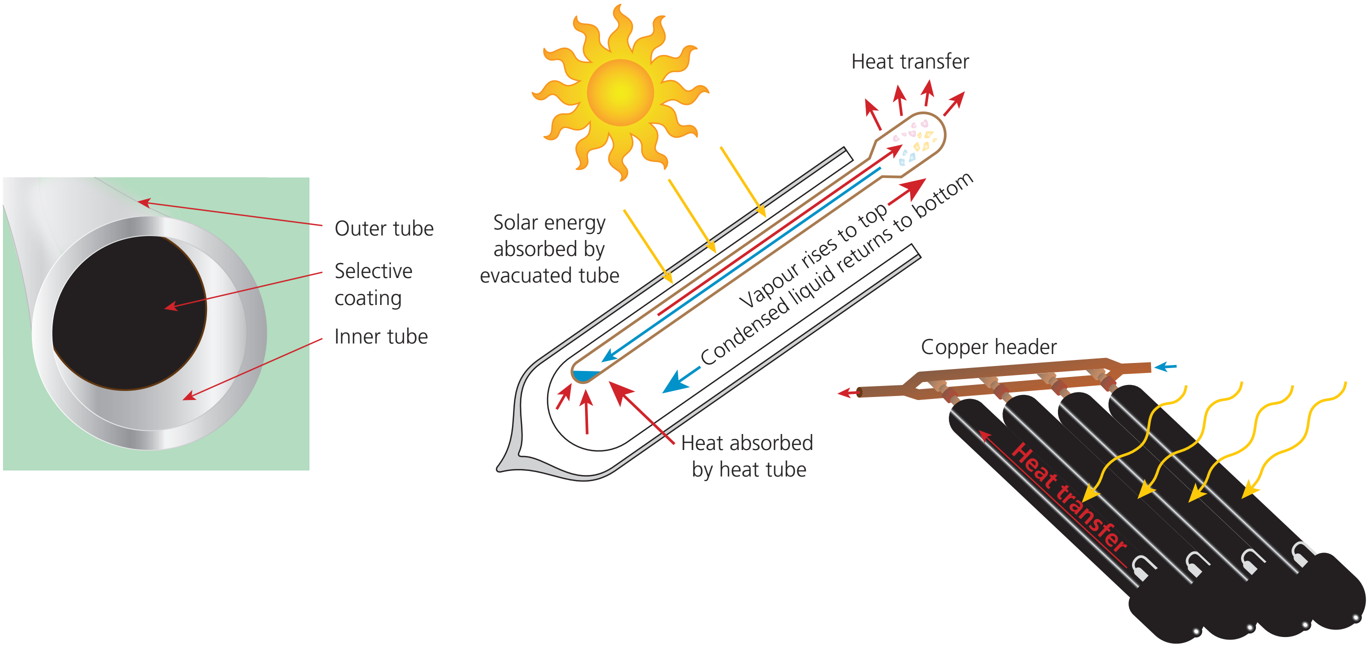
Flat-plate collectors are less efficient but cheaper than evacuated-tube collectors. With a flat-plate collector, the heat-transfer fluid circulates through the collectors and is directly heated by the Sun. The collectors need to be well insulated to avoid heat loss.



▲ Figure 1.3 Cutaway diagram of a flat-plate collector

Evacuated-tube collectors are more efficient but more expensive than flat-plate collectors.

An evacuated-tube collector consists of a specially coated, pressure-resistant, double-walled glass tube. The air is evacuated from the glass tube to aid the transfer of heat from the Sun to a heat tube that is housed within the glass tube. The heat tube contains a temperature-sensitive medium, such as methanol, that, when heated, vaporises. The warmed gas rises within the glass tube. A solar collector will contain several evacuated tubes in contact with a copper header tube that is part of the solar heating circuit. The heat tube is in contact with the header tube. The heat from the methanol vapour in the heat tubes is transferred by conduction to the heat-transfer fluid flowing through the solar heating circuit. This process cools the methanol vapour, which condenses and runs back down to the bottom of the heat tubes, ready for the process to start again. The collector must be mounted at a suitable angle to allow the vapour to rise and the condensed liquid to flow back down the heat tubes.



▲ Figure 1.4 Evacuated-tube collector

Differential temperature controller

The differential temperature controller (DTC) has sensors connected to the solar collector (high level) and the hot-water storage system (low level). It monitors the temperatures at the two points. The DTC turns the circulating pump on when there is enough solar energy available and there is a demand for water to be heated. Once the stored water reaches the required temperature, the DTC shuts off the circulating pump.

Circulating pump

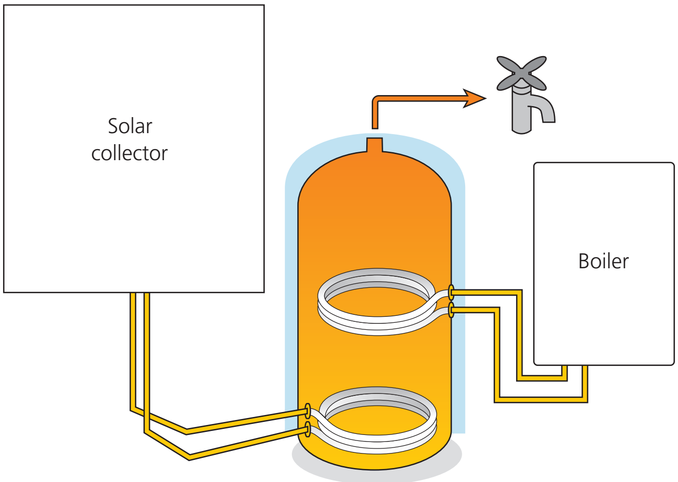
The circulating pump is controlled by the DTC and circulates the system's heat-transfer fluid around the solar hot-water circuit. The circuit is a closed loop between the solar collector and the hot-water storage tank. The heat-transfer fluid is normally water-based but, depending on the system type, usually also contains antifreeze (glycol) so that at night, or in periods of low temperatures, it does not freeze in the collector.

Hot-water storage cylinder

The hot-water storage cylinder enables the transfer of heat from the solar collector circuit to the stored water. Several different types of cylinder or cylinder arrangement are possible.

Twin-coil cylinder

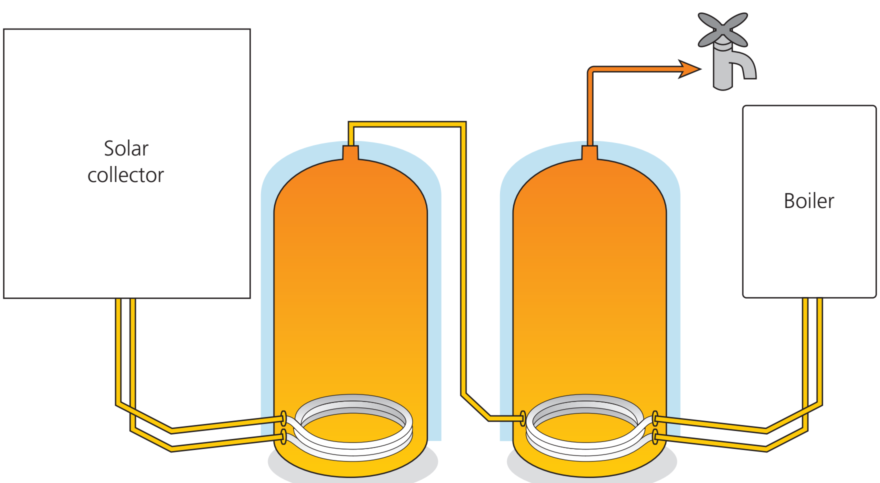
With this type of cylinder, the lower coil is the solar heating circuit and the upper coil is the auxiliary heating circuit. Cold water enters at the base of the cylinder and is heated by the solar heating coil. If the solar heating circuit cannot meet the required demand, then the boiler will provide heat through the upper coil. Hot water is drawn off, by the taps, from the top of the cylinder.



▲ Figure 1.5 Twin-coil cylinder

Alternatives

An alternative arrangement is to use one cylinder as a solar preheat cylinder, the output of which feeds a hot-water cylinder. The auxiliary heating circuit is connected to the second cylinder.



▲ Figure 1.6 Using two separate cylinders

The two arrangements that have been described are indirect systems, with the solar heating circuit forming a closed loop.

Direct system

A direct system is an alternative to an indirect system. In direct systems, the domestic hot water that is stored in the cylinder is directly circulated through the solar collector and is the same water that is drawn off at the taps. Owing to this fact, antifreeze (glycol) cannot be used in the system, so it is important to use freeze-tolerant collectors.

Auxiliary heat source

In the UK there will be times when there is insufficient solar energy available to provide adequate hot water. On these occasions an auxiliary heat source will be required. Where the premises have space heating systems installed, the auxiliary heat source is usually this boiler. Where no suitable boiler exists, the auxiliary heat source will be an electric immersion heater.

Location and building requirements

The following factors should be considered when deciding whether or not a solar thermal hot-water system is suitable for particular premises.

The orientation of the solar collectors

The optimum direction for the solar collectors to face is due south. However, as the Sun rises in the east and sets in the west, any location with a roof facing east, south or west is suitable for mounting a solar thermal system, although the efficiency of the system will be reduced for any system not facing due south.

The tilt of the solar collectors

During the year, the maximum elevation or height of the Sun, relative to the horizon, changes. It is lowest in December and highest in June. Ideally, solar collectors should always be perpendicular to the path of the Sun's rays. As it is generally not practical to change the tilt angle of a solar collector, a compromise angle has to be used. In the UK, the angle is 35°; however, the collectors will work, but less efficiently, from vertical through to horizontal.

Shading of the solar collectors

Any structure, tree, chimney, aerial or other object that stands between the collector and the Sun will block the Sun's energy. The Sun shines for a limited time and any reduction in the amount of heat energy reaching the collector will reduce the collector's ability to provide hot water to meet the demand.

▼ Table 1.2 Degree of shading of solar collectors

Shading	% of sky blocked by obstacles	Reduction in output
Heavy	> 80%	50%
Significant	> 60–80%	35%
Modest	> 20–60%	20%
None or very little	≤ 20%	No reduction

The suitability of the structure for mounting the solar collector

The structure has to be assessed as to its suitability for the chosen mounting system. Consideration needs to be given to the strength and condition of the structure and the suitability of fixings. The effect of wind must also be taken into account. The force exerted by the wind on the collectors, an upward force known as 'wind uplift', affects both the solar collector fixings and the fixings holding the roof members to the building structure.

In the case of roof-mounted systems on blocks of flats and other shared properties, the ownership of the structure on which the proposed system is to be installed must be considered.

The space needed to mount the collectors is dependent on the demand for hot water. The number of people occupying the premises determines the demand for hot water and, therefore, the number of collectors required, and the space needed to mount them.

Compatibility with the existing hot-water system

Solar thermal systems provide stored hot water rather than instantaneous hot water. Premises using under/over-sink water heaters and electric showers will not be suitable for the installation of a solar thermal hot-water system; neither will premises using a combination boiler to provide hot water, unless substantial changes are made to the hot-water system.

Planning permission

Permitted development applies where a solar thermal hot-water system is installed:

- on a dwelling house or block of flats
- on a building within the grounds of a dwelling house or block of flats
- as a stand-alone system in the grounds of a dwelling house or block of flats.

However, there are criteria to be met in every case.

The criteria that must be met for **building-mounted systems** are that:

- the solar thermal system cannot protrude more than 200 mm from the wall or the roof slope
- the solar thermal system cannot protrude past the highest point of the roof (the ridge line), excluding the chimney.

The criteria that must be met for **stand-alone systems** are that:

- only one stand-alone system is allowed in the grounds
- the array cannot exceed 4 m in height
- the array cannot be installed within 5 m of the boundary of the grounds
- the array cannot exceed 9 m^2 in area
- no dimension of the array can exceed 3 m in length.

The criteria that must be met for both **stand-alone and building-mounted systems** are that:

- the system cannot be installed in the grounds, or on a building within the grounds, of a listed building or a scheduled monument
- if the dwelling is in a conservation area or a World Heritage Site, then the array cannot be closer to a highway than the house or block of flats.

In every other case, planning permission will be required.

Compliance with Building Regulations

The Building Regulations applicable to the installation of solar thermal hot-water systems are outlined in Table 1.3.

ACTIVITY

Conduct research to investigate:

- how much water an average person uses in one day in the UK
- how much of this is hot water
- how much is returned as waste water.

▼ Table 1.3 Building Regulations applicable to solar thermal hot-water systems

Part	Title	Relevance
A	Structure	Where equipment and components can put extra load on the structure of the building, or the fabric requires modifications such as chases, suitability of the structure must be considered.
B	Fire safety	Where holes for pipes are made, this may reduce the fire resistance of the building fabric.
C	Site preparation and resistance to contaminates and moisture	Where holes for pipes and fixings for collectors are made, this may reduce the moisture resistance of the building and allow ingress of water.
G	Sanitation, hot-water safety and water efficiency	Hot-water safety and water efficiency must be considered.
L	Conservation of fuel and power	Energy efficiency of the system and the building as a whole must be considered.
P	Electrical safety	The installation of electrical controls and components must be considered.

Other regulatory requirements to consider

Other regulatory requirements to consider regarding the installation of solar thermal hot-water systems are:

- **BS 7671: 2018 (2022)** The IET Wiring Regulations, 18th Edition including amendments
- Approved Document Part G3: Unvented hot-water storage systems
- Water Regulations (WRAS).

The advantages and disadvantages of solar thermal hot-water systems

The advantages of solar thermal hot-water systems are that they:

- reduce CO_2 emissions
- reduce energy costs
- are low maintenance
- improve the energy rating of the building.

The disadvantages of solar thermal hot-water systems are that they:

- may not be compatible with the existing hot-water system
- may not meet demand for hot water in the winter
- have high initial installation costs
- require a linked auxiliary heat source.

▲ Figure 1.7 A heat pump moves heat from one location to another, just as a water pump like this one moves water from one location to another

Heat pumps

A water pump moves water from a lower level to a higher level, through the application of energy. Pumping the handle draws water up from a lower level to a higher level, through the application of kinetic energy. As the name suggests, a heat pump moves heat energy from one location to another, through the application of energy. In most cases, the applied energy is electrical energy.

Working principles

Heat energy from the Sun exists in the air that surrounds us and in the ground beneath our feet. At absolute zero or 0 K (kelvin), there is no heat in a system. This temperature is equivalent to –273°C so, even with an outside temperature of –10°C, there is a vast amount of free heat energy available.

▲ Figure 1.8 Heat energy exists down to absolute zero (0 K ≈ –273°C)

Using a relatively small amount of energy, that stored heat energy in the air or in the ground can be extracted and used in the heating of living accommodation.

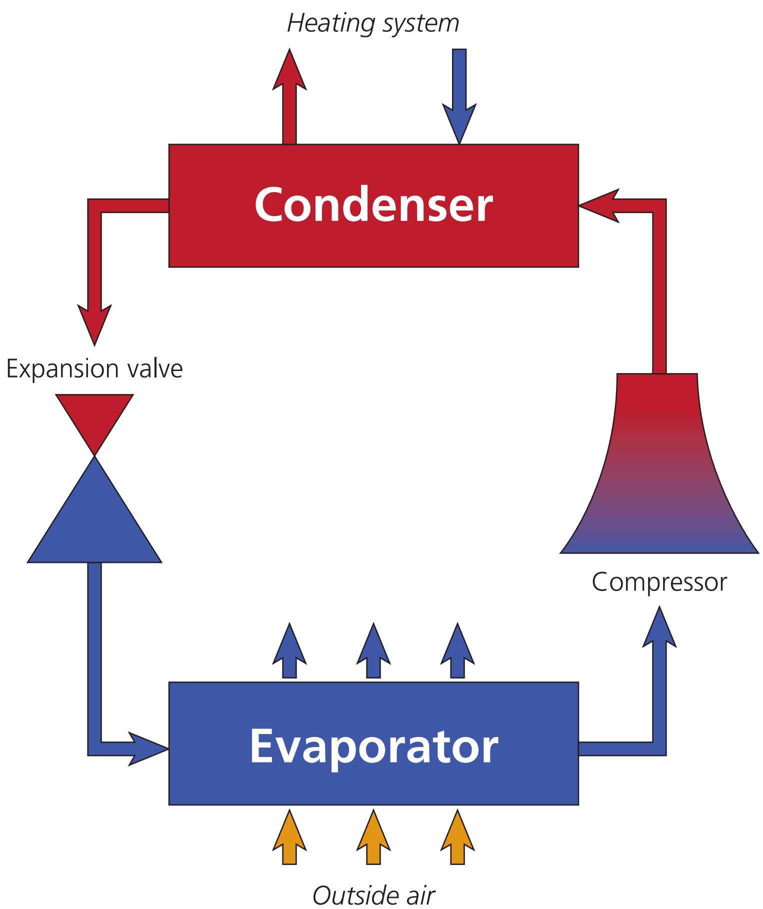
Heat pumps extract heat from outside and transfer it inside, in much the same way that a refrigerator extracts heat from the inside of the refrigerator and releases it at the back of the refrigerator via the heat-exchange fins.

A basic rule of heat transfer is that heat moves from warmer spaces to colder spaces.

A heat pump contains a refrigerant. The external air or ground is the medium or heat source that gives up its heat energy. The heat pump operates as follows.

- When the refrigerant is passed through the heat source, the refrigerant is cooler than its surroundings and so absorbs heat.
- The compressor on the heat pump then compresses the refrigerant, causing the gas to heat up.
- When the refrigerant is passed to the interior, the refrigerant is now hotter than its surroundings and gives up its heat to the cooler surroundings.
- The refrigerant is then allowed to expand, which converts it back into a liquid.
- As the refrigerant expands, it cools, and the cycle starts all over again.

The only energy needed to drive the system is the energy required by the compressor. The greater the difference in temperature between the refrigerant and the heat-source medium from where heat is being extracted, the greater the efficiency of the heat pump. If the heat-source medium is very cold, then the refrigerant will need to be colder, to be able to absorb heat, so the harder the compressor must work, and the more energy is needed to accomplish this.



▲ Figure 1.9 The refrigeration process

▲ Figure 1.10a The efficiency of an electric panel heater

▲ Figure 1.10b The efficiency of an A-rated condensing gas boiler

▲ Figure 1.10c The efficiency of an air-source heat pump

Two main types of heat pump are in common use. They are:

- ground-source heat pumps (GSHPs)
- air-source heat pumps (ASHPs).

Heat pumps extract heat energy from the air or the ground, but the energy extracted is replaced by the action of the Sun. It is not uncommon for heat pumps to have efficiencies in the order of 300%; for an electrical input of 3 kW, a heat output of 9 kW is achievable. If we compare this with other heat appliances (see Figures 1.10 a–c), we can see where the savings are made.

The efficiency of a heat pump is measured in terms of the coefficient of performance (COP), which is the ratio between the heat delivered and the power input of the compressor.

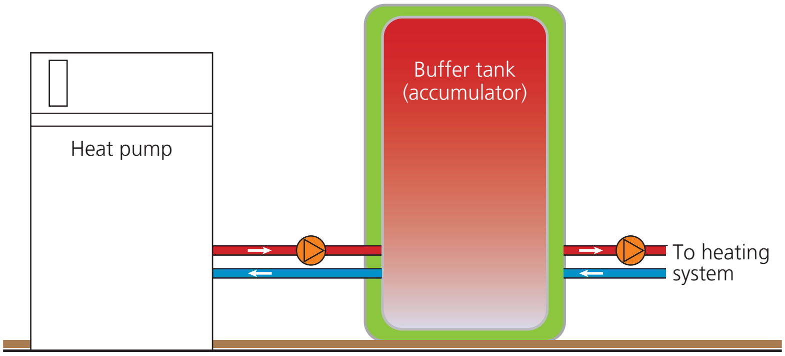
$$\text{COP} = \frac{\text{heat delivered}}{\text{compressor power}}$$

The higher the COP value, the greater the efficiency. Higher COP values are achieved in mild weather than in cold weather because, in cold weather, the compressor has to work harder to extract heat.

Storing excess heat produced

Heat pumps are not able to provide instant heat and so therefore work best when run continuously. Stop–start operations will shorten the lifespan of a heat pump. A buffer tank, simply a large water-storage vessel, is incorporated into the circuit so that, when heat is not required within the premises, the heat pump can 'dump' heat to it and thus keep running. When there is a need for heat, this can be drawn from the buffer tank. A buffer tank can be used with both ground-source and air-source heat pumps.

> **INDUSTRY TIP**
>
> Air-source heat pumps are not just used to warm the inside of buildings; they can also cool the inside of buildings during hot days.



▲ Figure 1.11 Storing heat in a buffer tank

Ground-source heat pumps

A ground-source heat pump (GSHP) extracts low-temperature free heat from the ground, upgrades it to a higher temperature and then releases it, where required, for space heating and water heating.

Working principles

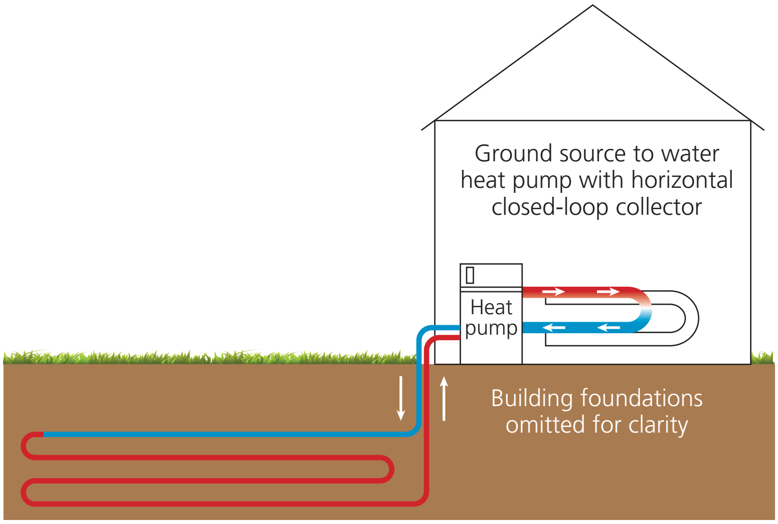
The key components of a GSHP are:

- heat-collection loops and a pump
- a heat pump
- a heating system.

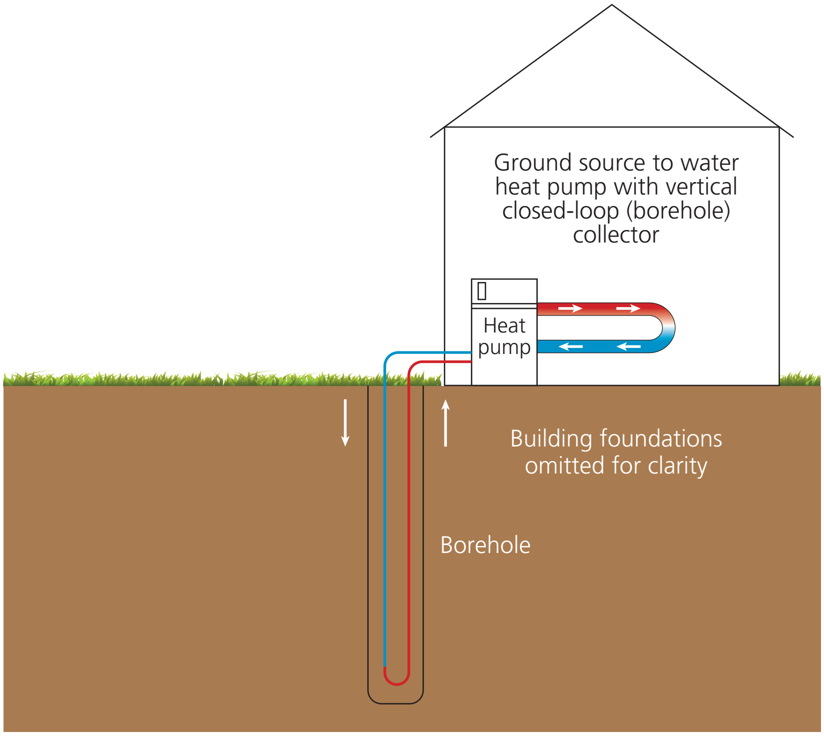
The collection of heat from the ground is accomplished by means of pipes that are buried in the ground and contain a mixture of water and antifreeze. This type of system is known as a 'closed-loop' system. Three methods of burying the pipes are used. Each method has its advantages and disadvantages.

Horizontal loops

Piping is installed in horizontal trenches that are generally 1.5–2 m deep. Horizontal loops require more piping than vertical loops – around 200 m of piping for the average house.



▲ Figure 1.12 Horizontal ground loops



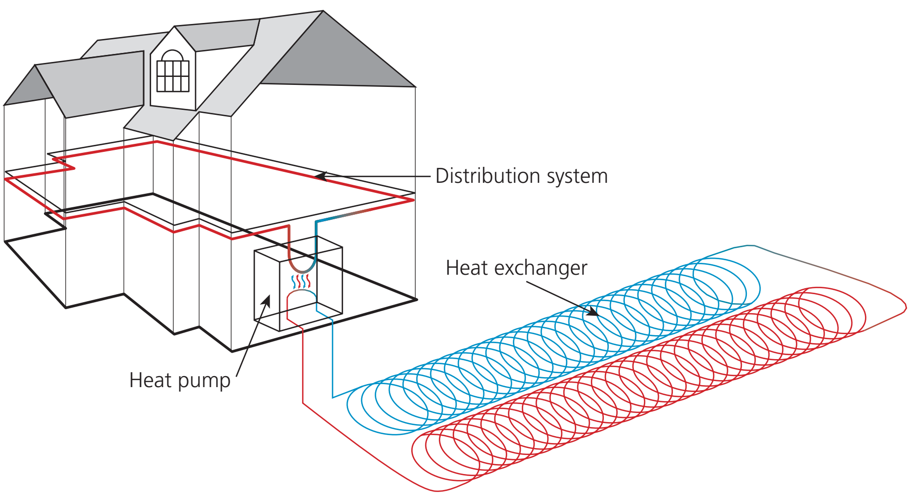
▲ Figure 1.13 Vertical ground loops

Vertical loops

Most commercial installations use vertical loops. Holes are bored to a depth of 15–60 m, depending on soil conditions, and spaced approximately 5 m apart. Pipe is then inserted into these bore holes. The advantage of this system is that less land is needed.

Slinkies

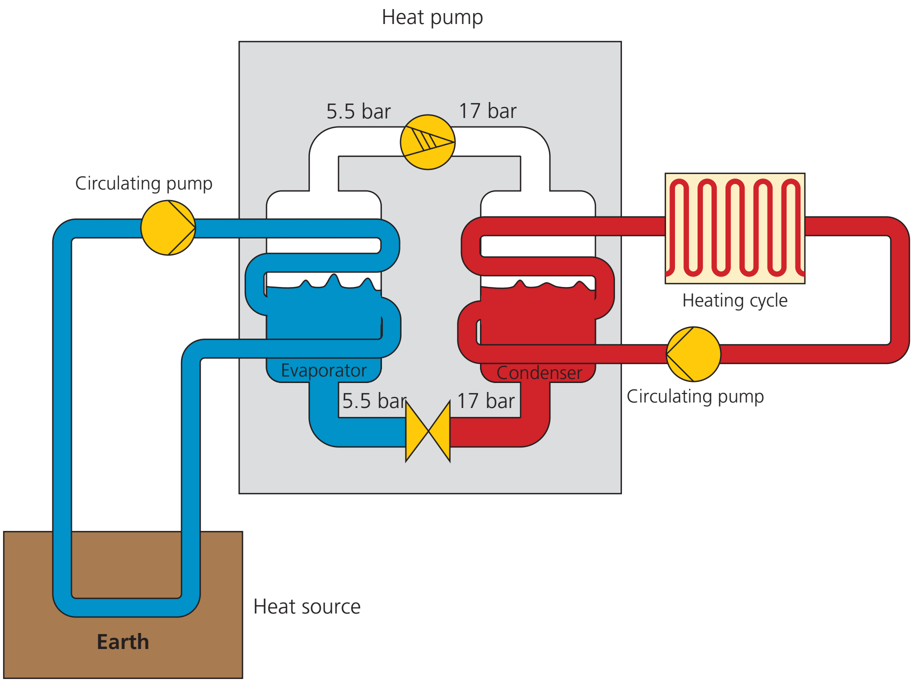
Slinky coils are flattened, overlapping coils that are spread out and buried, either vertically or horizontally. They are able to concentrate the area of heat transfer into a small area of land. This reduces the length of trench needing to be excavated and therefore the amount of land required. Slinkies installed in a 10 m long trench will yield around 1 kW of heating load.



▲ Figure 1.14 Slinkies

▲ Figure 1.15 Slinkies being installed in the ground

The water–antifreeze mix is circulated around these ground pipes by means of a pump. The low-grade heat from the ground is passed over a heat exchanger, which transfers the heat from the ground to the refrigerant gas. The refrigerant gas is compressed and passed across a second heat exchanger, where the heat is transferred to a pumped heating loop that feeds either radiators or under-floor heating.



▲ Figure 1.16 Ground-source heat pump operating principle

Final heat output from the GSHP is at a lower temperature than would be obtained from a gas boiler. The heat output from a GSHP is at 40°C, compared with a gas boiler at 60–80°C. For this reason, under-floor heating, which requires temperatures of 30–35°C, is the most suitable form of heating arrangement to use with a GSHP. Low-temperature or oversized radiators could also be used.

A GSHP system, in itself, is unable to heat hot water directly to a suitable temperature. Hot water needs to be stored at a temperature of 60°C. An auxiliary heating device will be necessary in order to reach the required temperatures. A GSHP is unable to provide instant heat and, for maximum efficiency, should run all the time. In some cases, it is beneficial to fit a buffer tank to the output so that any excess heat is stored, ready to be used when required. By reversing the refrigeration process, a GSHP can also be used to provide cooling in the summer.

Location and building requirements

For a GSHP system to work effectively, and as the output temperature is low, the building must be well insulated.

A suitable amount of land has to be available for trenches or, alternatively, land that is suitable for bore holes. In either case, access for machinery will be required.

Planning permission

The installation of a GSHP is usually considered to be permitted development and will not require a planning application to be made.

If the building is a listed building or in a conservation area, the local area planning authority will need to be consulted.

Compliance with Building Regulations

The Building Regulations applicable to the installation of GSHPs are outlined in Table 1.4.

▼ Table 1.4 Building Regulations applicable to ground-source heat pumps

Part	Title	Relevance
A	Structure	Where equipment and components can put extra load on the structure of the building, or the fabric requires modification such as chases, suitability of the structure must be considered.
B	Fire safety	Where holes for pipes are made, this may reduce the fire resistance of the building fabric.
C	Site preparation and resistance to contaminates and moisture	Where holes for pipes and fixings for equipment are made, this may reduce the moisture resistance of the building and allow ingress of water.
E	Resistance to the passage of sound	Where holes for pipes are made, this may reduce the soundproof integrity of the building structure.
G	Sanitation, hot-water safety and water efficiency	Hot-water safety and water efficiency must be considered.
L	Conservation of fuel and power	Energy efficiency of the system and the building as a whole must be considered.
P	Electrical safety	The installation of electrical controls and components must be considered.

INDUSTRY TIP

The GOV.UK website provides guidance on the qualifications required to work on equipment containing F (fluorinated) gas.

Other regulatory requirements to consider

Other regulatory requirements to consider regarding the installation of GSHPs are:

- **BS 7671: 2018 (2022)** The IET Wiring Regulations, 18th Edition including amendments
- F (fluorinated) gas requirements, if working on refrigeration pipework.

Furthermore, you must be qualified in order to work on refrigeration pipework.

The advantages and disadvantages of ground-source heat pumps

The advantages of GSHPs are that they:

- are highly efficient
- are cheaper to run than electric, gas or oil boilers, leading to a reduction in the cost of energy bills
- reduce CO_2 emissions
- generate no CO_2 emissions on site
- are safe, because no combustion takes place and there is no emission of potentially dangerous gases
- are low maintenance compared with combustion devices
- have a long lifespan
- do not require fuel storage, so less installation space is required
- can be used to provide cooling in the summer
- are more efficient than air-source heat pumps.

The disadvantages of GSHPs are that:

- the initial costs are high
- they require a large area of land

- the design and installation are complex tasks
- they are unlikely to work efficiently with an existing heating system
- they use refrigerants, which could be harmful to the environment
- they are more expensive to install than air-source heat pumps.

Air-source heat pumps

An air-source heat pump (ASHP) extracts free heat from low-temperature air and releases it, where required, for space heating and water heating.

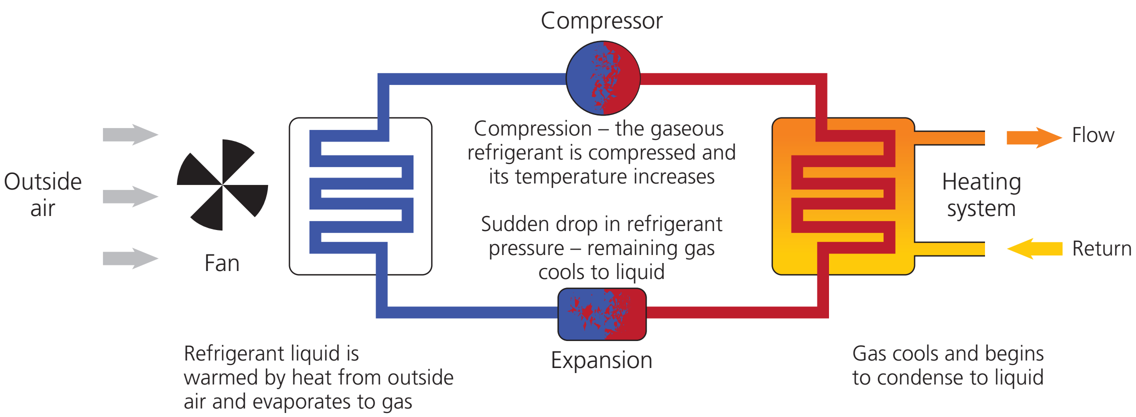
The key components of an ASHP are:

- a heat pump containing a heat exchanger, a compressor and an expansion valve
- a heating system.

Working principles

An ASHP works in a similar way to a refrigerator, but the cooled area becomes the outside world and the area where the heat is released is the inside of a building. The steps involved in the ASHP process are as follows.

- The pipes of the pump system contain refrigerant that can be a liquid or a gas, depending on the stage of the cycle. The refrigerant, as a gas, flows through a heat exchanger (evaporator), where low-temperature air from outside is drawn across the heat exchanger by means of the unit's internal fan. The heat from the air warms the refrigerant. Any liquid refrigerant boils to gas.
- The warmed refrigerant vapour then flows to a compressor. Here, the refrigerant vapour is compressed, causing its temperature to rise further.
- Following this pressurisation stage, the refrigerant gas passes through another heat exchanger (condenser), where it loses heat to the heating-system water, because it is hotter than the system water. At this stage, some of the refrigerant has condensed to a liquid. The heating system carries heat away to heat the building.
- The cooled refrigerant passes through an expansion valve, where its pressure drops suddenly and its temperature falls. The refrigerant flows once more to the evaporator heat exchanger, continuing the cycle.



▲ Figure 1.17 Air-source heat pump operating principle

There are two types of ASHP in common use. These are:

- air-to-water pumps
- air-to-air pumps.

An air-to-water pump is the pump described above, and it can be used to provide both space heating and water heating. An air-to-air pump is not suitable for providing water heating.

The output temperature of an ASHP will be lower than that of a gas-fired boiler. Ideally, the ASHP should be used in conjunction with an under-floor heating system. Alternatively, it could be used with low-temperature radiators.

Location and building requirements

The following factors should be considered when deciding whether or not an ASHP is suitable for particular premises.

- The premises must be well insulated.
- There must be space to fit the unit on the ground outside the building or to mount it on a wall. There will also need to be clear space around the unit to allow an adequate airflow.
- The ideal heating system to couple to an ASHP is either under-floor heating or warm-air heating.
- An ASHP will pay for itself in a shorter period of time if it replaces an electric, coal or oil heating system rather than a gas-fired boiler.

Air-source heat pumps are an ideal solution for new-build properties, where high levels of insulation and under-floor heating are to be installed.

Planning permission

Permitted development applies where an ASHP is installed:

- on a dwelling house or block of flats
- on a building within the grounds of a dwelling house or block of flats
- in the grounds of a dwelling house or block of flats.

There are, however, criteria to be met, mainly due to noise generated by the ASHP.

- The ASHP must comply with the Microgeneration Certification Scheme (MCS) Planning Standards or equivalent.
- Only one ASHP may be installed on the building or within the grounds of the building.
- A wind turbine must not be installed on the building or within the grounds of the building.
- The volume of the outdoor unit's compressor must not exceed 0.6 m^3.
- The ASHP cannot be installed within 1 m of the boundary.
- The ASHP cannot be installed on a pitched roof.
- If the ASHP is installed on a flat roof, it must not be within 1 m of the roof edge.
- The ASHP cannot be installed on a site designated as a monument.

- The ASHP cannot be installed on a building that is a listed building, or in its grounds.
- The ASHP cannot be installed on a roof or a wall that fronts a highway, or within a conservation area or World Heritage Site.
- If the dwelling is in a conservation area or a World Heritage Site, then the ASHP cannot be closer to a highway than the house or block of flats.

Compliance with Building Regulations

The Building Regulations applicable to the installation of ASHPs are outlined in Table 1.5.

▼ Table 1.5 Building Regulations applicable to air-source heat pumps

Part	Title	Relevance
A	Structure	Where equipment and components can put extra load on the structure of the building, or the fabric requires modification such as chases, the suitability of the structure must be considered.
B	Fire safety	Where holes for pipes are made, this may reduce the fire resistance of the building fabric.
C	Site preparation and resistance to contaminates and moisture	Where holes for pipes and fixings for equipment are made, this may reduce the moisture resistance of the building and allow ingress of water.
E	Resistance to the passage of sound	Where holes for pipes are made, this may reduce the soundproof integrity of the building structure.
G	Sanitation, hot-water safety and water efficiency	Hot-water safety and water efficiency must be considered.
L	Conservation of fuel and power	Energy efficiency of the system and the building as a whole must be considered.
P	Electrical safety	The installation of electrical controls and components must be considered.

Other regulatory requirements to consider

Other regulatory requirements to consider regarding the installation of ASHPs are:

- **BS 7671: 2018 (2022)** The IET Wiring Regulations, 18th Edition including amendments
- F (fluorinated) gas regulations, if working on refrigeration pipework.

The advantages and disadvantages of air-source heat pumps

The advantages of ASHPs are that they:

- are highly efficient
- are cheaper to run than electric, gas or oil boilers, leading to reductions in the cost of energy bills
- reduce CO_2 emissions
- generate no CO_2 emissions on site
- are safe, because no combustion takes place and there is no emission of potentially dangerous gases
- are low maintenance compared with combustion devices
- do not require fuel storage, so less installation space is required

- can be used to provide cooling in the summer
- are cheaper and easier to install than ground-source heat pumps.

The disadvantages of ASHPs are that they:

- are unlikely to work efficiently with an existing heating system
- are not as efficient as ground-source heat pumps
- have high initial costs
- are less efficient in the winter than in the summer
- generate noise from the fans
- have to incorporate a defrost cycle to stop the heat exchanger freezing in the winter.

Biomass

The major difference between biomass and fossil fuels, both of which are derived from the same source, is time. Fossil fuels, such as gas, oil and coal, have taken millions of years to form. Demand for these fuels is outstripping supply and replenishment. **Biomass** is derived from recently living organisms. As long as these organisms are replaced by replanting, and demand does not exceed replacement time, the whole process is sustainable. Biomass is therefore rightly regarded as a renewable energy technology.

KEY TERM

Biomass: The biological material from living or recently living organisms; biomass fuels are usually derived from plant-based material but could be derived from animal material. Fuel pellets can be made from woodworking offcuts, cereals or grain products, oils, animal fats and waste fish products.

VALUES AND BEHAVIOURS

Where possible, the use of sustainable fuel sources should be encouraged. Biomass fuel products are much more readily available and significantly faster to produce, so offer a viable and sustainable alternative to fossil fuel consumption.

However, be mindful of the fact that biomass fuels still produce greenhouse gas emissions, which have a detrimental effect on the environment.

Both fossil fuels and biomass fuels are burned to produce heat, and both fuel types release CO_2 as part of this process. Carbon dioxide is a greenhouse gas that has been linked to global warming. During their lives, plants and trees absorb CO_2 from the atmosphere, to enable growth to take place. When these plants are burned, the CO_2 is released once again into the atmosphere.

Biomass fuels have two main carbon advantages over fossil fuels.

- Fossil fuels absorbed CO_2 from the atmosphere millions of years ago and have trapped that CO_2 ever since. When fossil fuels are burned, they release the CO_2 from all those millions of years ago and so add to the present-day atmospheric CO_2 level.
- Biomass absorbs CO_2 when it grows, reducing current atmospheric CO_2 levels. When biomass is turned into fuel and burned, it releases the CO_2 back into the atmosphere. The net result is that there is no overall increase in the amount of CO_2 in the atmosphere.

Book 2

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