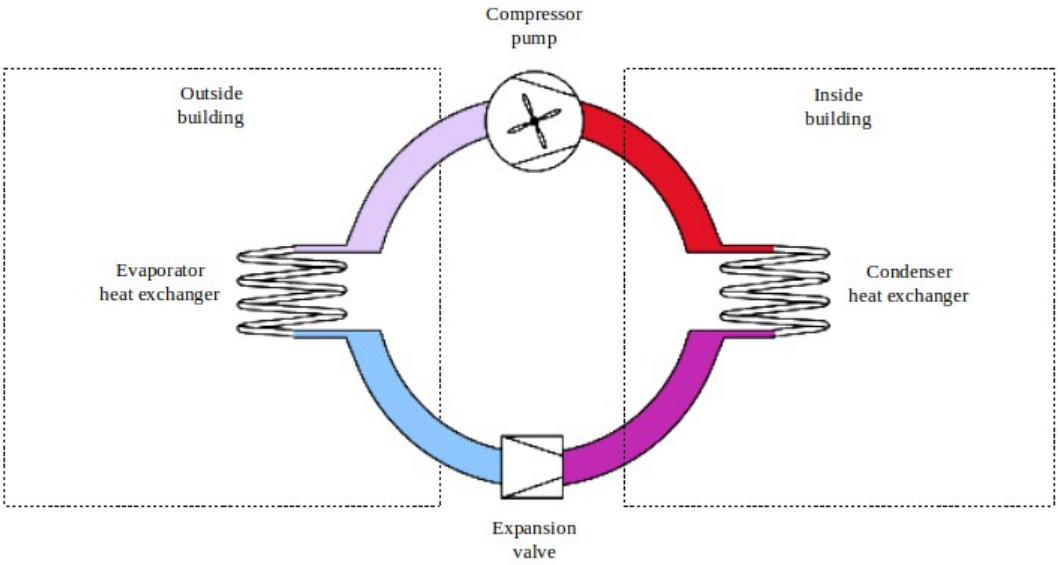
Heat from the Earth
Investigating ground source heat pumps



How a ground source heat pump works © *Chris King, ESEU*

Ground source heat pumps (GSHPs) use pipes that are buried, horizontally or vertically, to extract heat from the ground. This heat can then be used to heat homes and office blocks and to provide hot water.

Closed loop system:

- the system is filled with a fluid (the refrigerant) that changes from liquid to vapour and back to liquid as it is circulated;
- in the compressor pump, the refrigerant (entering as a cool vapour) is compressed so the temperature rises. Hot vapour results;
- the hot vapour moves to the condenser heat exchanger;
- the vapour condenses to a liquid, releasing latent heat that warms the building;
- the warm liquid moves to the expansion valve where the pressure is rapidly decreased, so the temperature falls;
- the cold liquid now moves to the evaporator heat exchanger;
- the liquid evaporates to vapour and absorbs latent heat of vaporisation from the surroundings, either in pipes buried in trenches (*photos opposite*) or in vertical pipes in the ground;
- the cool vapour now moves to the compressor pump where the process begins again.

Around 98% of the heat absorbed from the ground in ground source heat pumps is solar energy (renewable energy from the Sun). Only around 2% is geothermal energy from the Earth.

First trench dug In Jurassic limestone. It was then lined with clay to provide a good heat conductor

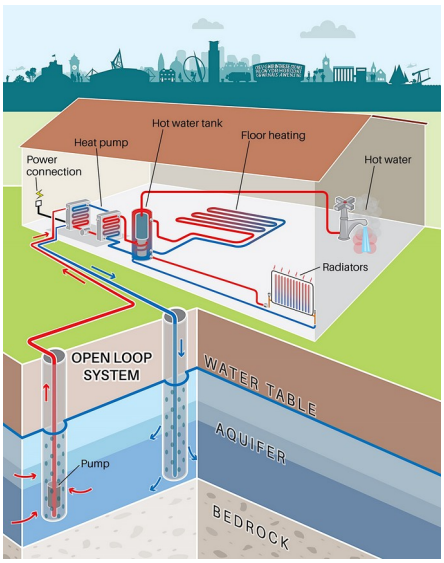
GSHP installation In Wiltshire

Mary Rumble

Pipes laid In trench in above installation. 8 trenches were dug in total.

Mary Rumble

Open- loop system
This works in a similar way to the closed-loop system except that the water moves in the aquifer between the pipes.



Pipes immersed in an underground reservoir rock (an aquifer).
© British Geological Survey

Note: Air source heat pumps also work in a similar way, but heat is taken from the surrounding air. Ground source heat pumps are more efficient than air source heat pumps because the heat is transferred through the ground via the movement of water, and water has a greater capacity to hold heat than air. Amazingly, heat pumps can extract heat from the air at temperatures down to minus 10°C or below, maybe even down to minus 25°C.

Go with your group to a local area where you have a good view of the surrounding region or just look out of the window, or study a view on a screen. If you are in an area where there are old mine workings below the surface, you could use the Earthlearningidea 'A new use for old coal mines; a potential source of energy from beneath our feet.

Discuss the following:
Could GSHPs be used in this area?
List the **advantages** of using GSHPs

Possible answers -
- *lower carbon emissions than burning fossil fuels;*
- *no fuel deliveries;*
- *minimal maintenance required but regular checks by a professional every 3 - 5 years are advisable. GSHPs can be expected to last for 20 years;*
- *the temperature of most of the ground is about 10 - 13°C all year round so GSHPs are efficient throughout the year, and unaffected by seasonal changes;*
- *cost effective when added to new building costs;*
- *once installed the pipes do not affect the garden or surrounding area;*
- *GSHPs can deliver about four times as much energy as is required to operate them from the electricity mains.*

List the **disadvantages** of using GSHPs
Possible answers -
- *the ground loop required can be installed in two ways - vertically or horizontally. The former requires boreholes which add to the installation cost and the latter requires a large area of land e.g. half an acre (0.2ha) for a 300m^2 (c. 3000 sq.ft) property. With horizontal pipes, the more houses to be heated, the more ground is required;*
- *the vertical system costs more to run than the horizontal, because it uses more electricity and requires more maintenance;*
- *initial costs are high but in the UK, grants are available; once installed GSHPs will reduce fuel bills;*
- *the property must be well insulated and draught-proof as GSHPs produce heat at a lower temperature than traditional boilers. GSHPs are best used with underfloor heating, so are better suited to new-builds.*
- GSHPs require electricity to run, so will not operate during power failure.

Once the discussion has taken place, ask the group to organise a **debate** about the advantages and disadvantages of GSHPs. Are they a good idea and which system would be recommended for:
a) individual houses;
b) a small block of flats;
c) a high rise building;
d) a small office block;
e) a skyscraper?

The back up

Title: Heat from the Earth

Subtitle: Investigating ground source heat pumps

Topic: Discussion about the advantages and disadvantages of ground source heat pump installations for a variety of buildings

Age range of pupils: 14 years upwards

Time needed to complete activity: from 15 minutes to two hours depending on what the potential of the local area is and the levels of discussion.

Pupil learning outcomes: Pupils can:
- explain how ground source heat pumps work;
- explain that shallow geothermal energy is mostly provided by solar power;
- list the advantages and disadvantages of GSHPs in houses;

- discuss the advantages and disadvantages of a variety of GSHP installations in various sizes of buildings.

Context:
Governments 'net-zero' targets will affect many areas across the world. This Earthlearningidea explores the advantages and disadvantages of GSHP installations. Other mitigation and adaptation measures are discussed in other Earthlearningideas.

Following up the activity:
Evaluate the possibilities for energy sources alternative to fossil fuels using the Earthlearningidea, 'What is/are the least bad option(s) for plugging the future global energy gap?' at
https://www.earthlearningidea.com/PDF/343_Plugging_energy_gap.pdf
for other ideas of what could be developed in your area.

Refer to the Earthlearningidea 'Finding the Earth in the UN Sustainable Development Goals'
https://www.earthlearningidea.com/PDF/319_Sustainable_development.pdf

Underlying principles:
- Ground source energy refers to any heat derived from the ground up to 200m
- the temperature up to 200m depth is between 10 and 17°C
- Low-grade heat stored in the shallow subsurface (<200 m) is largely derived from solar radiation (c.98%) that is absorbed by the ground and distributed via natural groundwater systems and artificial structures such as flooded coal mines. The ground acts as a solar battery and heat pumps are required to be able to use it.
- This low grade shallow source of heat is renewable and reliable.
- Only about 2% is actually geothermal, or heat from the Earth, arising mainly from radioactive decay of the rocks beneath.
- Advantages and disadvantages of GSHP installations can be explored and evaluated.
- The availability of different types of GSHP systems (closed-loop; open-loop; hybrid; mine water systems) and flexible design options mean that deployment of these systems is feasible almost anywhere in the UK.
- Ground source heat pumps can be used for heating, cooling or both, i.e. heating during winter and cooling during summer.

Thinking skill development:
Understanding the principle of operation of GSHPs involves skills of construction. Discussing their advantages and disadvantages from different perspectives will cause cognitive conflict and explanations will involve metacognition. Applying these ideas to the local area involves bridging.

Resource list:
- a view, either from a hill, a window or on a screen

Useful links:
In collaboration with the Environment Agency, the British Geological Survey has developed a web-based tool within a GIS that maps the potential for open-loop, ground source heat pump installations (heating/cooling output >100 kW) in England and Wales at 1:250000 scale and provides an indication of whether these conditions exist in a given area.
https://www.bgs.ac.uk/geology-projects/geothermal-energy/open-loop-gshp-screening-tool/
Search 'net-zero' on the Earthlearningidea website to find other Earthlearningideas relating to climate change mitigation or adaptation. The full list is on page 4.
Use a search engine like Google to explore the internet for more information about likely global impacts of 'net-zero'. You can access a tool to help visualise how climate change might affect your local area in the UK at:
https://www.bbc.co.uk/news/resources/idt-d6338d9f-8789-4bc2-b6d7-3691c0e7d138
Video clip explaining GSHPs:
https://energysavingtrust.org.uk/advice/ground-source-heat-pumps/

Source: Elizabeth Devon of the Earthlearningidea Team using material from ESEU and from the British Geological Survey

This information was as accurate as possible in spring 2021

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The ‘How will the ‘net-zero’ target affect your local area?’ series of Earthlearningideas

Topic			Earthlearningidea title
Introduction			How will the ‘net-zero’ target affect your local area?
Possible mitigation measures	Use alternative energy sources	Solar	Harnessing the power of the Sun
		Wave	Harnessing the power of waves
		Wind	Farming the wind: through onshore and offshore windfarms
		Tidal	Tidal energy
		Nuclear	Nuclear power - harnessing the energy of the atom
		Nuclear waste	Nuclear waste disposal
		Biofuel	Liquid biofuels: keeping our wheels turning into the future
		‘Blue’ hydrogen	Blue hydrogen: the fuel of the future?
		Geothermal – hot rocks	Deep geothermal power from ‘hot dry rocks’: an option in your area?
		Geothermal – flooded mines	A new use for old coal mines
		Hydro – small scale	Small-scale hydroelectric power schemes
		Heat pumps	Heat from the Earth
		Waste – incineration	Energy from burning waste
		Waste – methane	Energy from buried waste
	Stop fuels releasing greenhouse gases	Carbon capture	Capturing carbon?
	Store energy from sources that give irregular energy supplies	Batteries	Nuclear batteries: the future?
		‘Green’ hydrogen	Green hydrogen used to even out renewable energy supplies?
		Hydro – storage	Matching supply and demand using stored water
		Compressed gas	Storing gas underground: What can we store? How can we do it? How will it help?
	Provide raw materials for new technologies	Electric vehicles	Electric vehicles: the way to go?
		Insulation	How do I choose the best insulation?
	Remove carbon form the atmosphere	Enhanced weathering	Speeding up nature to trap carbon dioxide
		Tree planting	Let’s plant some trees
Possible adaptation measures		Coastal flooding	How will rising sea level affect our coastlines?
		Inland flooding	Inland flooding: a Sheffield case study
		Landslides	Landslide danger
		Agriculture	The future for global agriculture