Teacher Guide

Energy storage

How geology can help to balance supply and demand

British Geological Survey

How to use these resources

These resources consist of a teacher guide, an introductory video, 3 worksheets and a class certificate. While it is intended that you use all of these resources, you may wish to pick and choose the most relevant parts to suit your class and lesson needs.

The lesson is interdisciplinary and includes elements of numeracy and literacy. We have included a curriculum link in the lesson outline, but the lesson is relevant to many parts of the curriculum.

You can share feedback on the resources by emailing BGSengage@bgs.ac.uk

What is the British Geological Survey?

The British Geological Survey is a world-leading geological survey and global geoscience organisation, focused on public-good science for government and research to understand earth and environmental processes.

Our vision is for a safer, more sustainable and prosperous planet and a future based on sound geoscientific solutions.

Why have we created this lesson?

Delivering clean energy at the scale required to achieve net zero by 2050 in the UK requires world-class science.

The British Geological Survey, on behalf of UK Research and Innovation, has set up the UK Geoenergy Observatories, which are platforms for world-class geoscience, unlocking evidence and knowledge for future and current generations.

In particular, the UK Geoenergy Observatories have been set up to understand how geothermal energy, hydrogen, carbon capture and storage, and storage solutions for wind, solar and tidal energy can reduce our carbon emissions.

This lesson is intended to support teachers with curriculum-relevant materials while enthusing, exciting and inspiring pupils with the research of the UK Geoenergy Observatories.

What is energy storage?

Energy storage is the capture of energy produced at one time for use at a later time.

On a small scale, the rechargeable batteries in smartphones are an example of energy storage. This has the benefit that we can use a smartphone on-the-go without it being plugged in to mains electricity.

On the other hand, large-scale energy storage can solve different problems. Energy storage can play a vital role in the sustainable supply of electricity, heat and fuel for transport.

What is the need for large-scale energy storage?

The UK is committed to reducing greenhouse gas emissions to net zero by 2050. One way to achieve this target is to increase the use of low carbon, renewable energy.

However, many sources of renewable energy are variable or intermittent. For example, there can be days with little sunshine or wind. This means there is potential for the demand for energy to outstrip supply from renewable sources.

Large-scale energy storage allows surplus energy (at times of low demand or plentiful renewable energy) to be stored until it is needed. This helps to prevent blackouts and ensures a consistent, reliable supply of energy.

As the contribution from renewable sources grows, the need for energy storage increases.

What are large-scale energy storage technologies?

In the UK today, over 90 per cent of the energy storage capacity comes from pumped storage hydroelectric schemes.

To help meet the target of net zero by 2050, additional technologies are being explored.

Pumped storage hydroelectricity

Water is pumped to a higher elevation for storage during periods when energy is cheap (such as during night-time when there can be a surplus of energy). When electricity is needed, the stored water is released through a turbine to spin a generator. It provides almost-instantaneous power but is limited by the size of the reservoirs.

Hydrogen storage

Hydrogen is a clean fuel that releases energy in a hydrogen fuel cell, producing only water. It is an energy carried that can be used to store, move and deliver energy produced from other sources. Large quantities of hydrogen can be stored underground in suitable geological formations such as caverns of halite salt. Hydrogen can be produced through different methods, including from natural gas as well as from renewable and biological processes.

Thermal Storage

Energy is stored in rocks, salts, water or other materials by heating them and keeping them in insulated environments either underground or in artificial containers. The stored energy can be used directly as heat or converted to electricity by creating steam to spin turbines. Thermal storage can help to balance heat energy demand (see below).

Compressed air energy storage

Air is pumped into an underground cavern when energy is cheap. When energy is needed, the compressed air is released to spin a turbine to drive a generator that generates electricity. Due to the physics of compressed gases, the compressed air needs to be heated as it is released, often using natural gas.

Battery systems

Various battery technologies including lithium-ion, lead-acid, flow and solid state, are being explored for large-scale grid storage. The batteries are recharged when energy is cheap and discharged at times of peak demand.

Flywheels

A motor stores energy in a flywheel by accelerating the heavy wheel to very high rates. Later, the motor can use the stored energy to generate electricity by going into reverse. Flywheels are not suitable for long-term energy storage but are effective for short-term balancing of supply and demand.

What is seasonal thermal energy storage?

Thermal energy storage allows thermal energy to be collected for later use. This can be hours, days or many months later and is achieved with different technologies.

Thermal energy storage can be valuable and applicable for an individual building, a large building as a school or hospital, local area and even a complete town.

With the help of thermal energy storage, energy demand can be balanced between day and night or summer and winter. For example, summer heat can be stored for winter heating, and winter cold can be stored for summer cooling.

Heat energy can be stored in rocks and water underground. Old mines can be useful geological features for the storage of surplus heat/cold as they are often flooded with water, which can be easily warmed and cooled. It is estimated that a quarter of the UK's population live above abandoned coal mines so there is huge potential for this technology.

What is the role of geology in energy storage?

Geology is key to the success of many forms of energy storage.

Useful geological features include beds of halite salt which could be developed for cavern storage for hydrogen and compressed air. Abandoned mines can be used as thermal stores. Permeable rocks and caverns could be developed for underground pumped hydro projects.

What are the UK Geoenergy Observatories?

Climate change means that there's never been a more important time to understand the natural environment.

In the UK, a network of observatories has been established to deliver essential new data from underground. The scientific data can help us to understand how geothermal energy, hydrogen, carbon capture and storage, and storage solutions for wind, solar and tidal energy can reduce our carbon emissions.

Each observatory in Cheshire, Glasgow and elsewhere delivers a different body of knowledge. The UK Geoenergy Observatories inform how geoenergy can help to deliver clean economic growth.

Publicly run, owned and funded, each observatory contributes to world-class science that puts the UK at the forefront of delivering clean energy at the scale required to achieve net zero by 2050.

You can find out more at ukgeos.ac.uk

Lesson Outline

Energy storage

How geology can help to balance supply and demand

British Geological Survey

Learning Intention

To investigate how renewable energy can be stored, using the context of home heating.

Curriculum links

National Curriculum > Key stage 3 >Geography > Human and physical geography
Pupils should be taught to understand, through the use of detailed place-based exemplars at a variety of scales, the key processes in human geography relating to the use of natural resources.

Curriculum for Excellence > Third level > Science > Planet Earth > Energy sources and sustainability
By investigating renewable energy sources and taking part in practical activities to harness them, I can discuss their benefits and potential problems.
SCN 3-04b

Resources

- Teacher guide
- Introductory video
- Worksheet 1 – The changing seasons
- Worksheet 2 – Storing heat in old mines
- Home activity – Home sweet home
- Class certificate
- Answer sheets for worksheets

Energy storage solves the challenge of variable renewable energy.

Hook into the lesson

Play the introductory video.

The video introduces large-scale energy storage as a solution to the challenges of balancing the UK's energy demand with the variable and intermittent supply from renewable energy resources.

The video asks the following questions, providing an opportunity to pause and discuss:

At what time of day does the UK use most electricity?
How can we use wind power when the wind is not blowing?

Activity

Give pupils **Worksheet 1 – The changing seasons.**

Pupils draw a bar chart from temperature data and then analyse the chart to work out the most efficient way of running a hypothetical energy storage system.

Ask pupils:

What would be the advantages of installing an underground thermal storage system?

Prompt pupils to think about:

- The problems associated with the ways we typically warm and cool our homes today (such as natural gas, electricity, air conditioning).
- The potential savings in energy and cost by storing free, surplus heat when it is available.

Extension activity

Give pupils **Worksheet 2 – Heat from old mines.**

Pupils develop their mapping skills by using six-figure grid references to determine the proximity of abandoned coal mines to areas of proposed housing.

Prompt a class discussion using the final question in the worksheet:

Which housing development would be easier to connect to an abandoned coal mine? Why do you think that?

Plenary

On the board draw a 3x3 bingo grid with each of the following words in a square: renewable, finite, energy demand, intermittent, hydrogen storage, pumped hydro, underground thermal storage, geology and greenhouse gas.

Ask pupils to tell you something they have learned about each word in order to cross them off and win the class game of bingo.

To celebrate the completion of the lesson, you can display the class certificate, which states **'our class rocks!'**.

Home activity

Give pupils **Home activity – Home sweet home**.

Pupils interview a grown-up about the past, present and future of home heating.

Worksheet 1

Energy storage

The changing seasons

British Geological Survey

Name: ______________________ **Date:** ______________

You are going to examine seasonal temperatures to work out the best way to supply heat to a community.

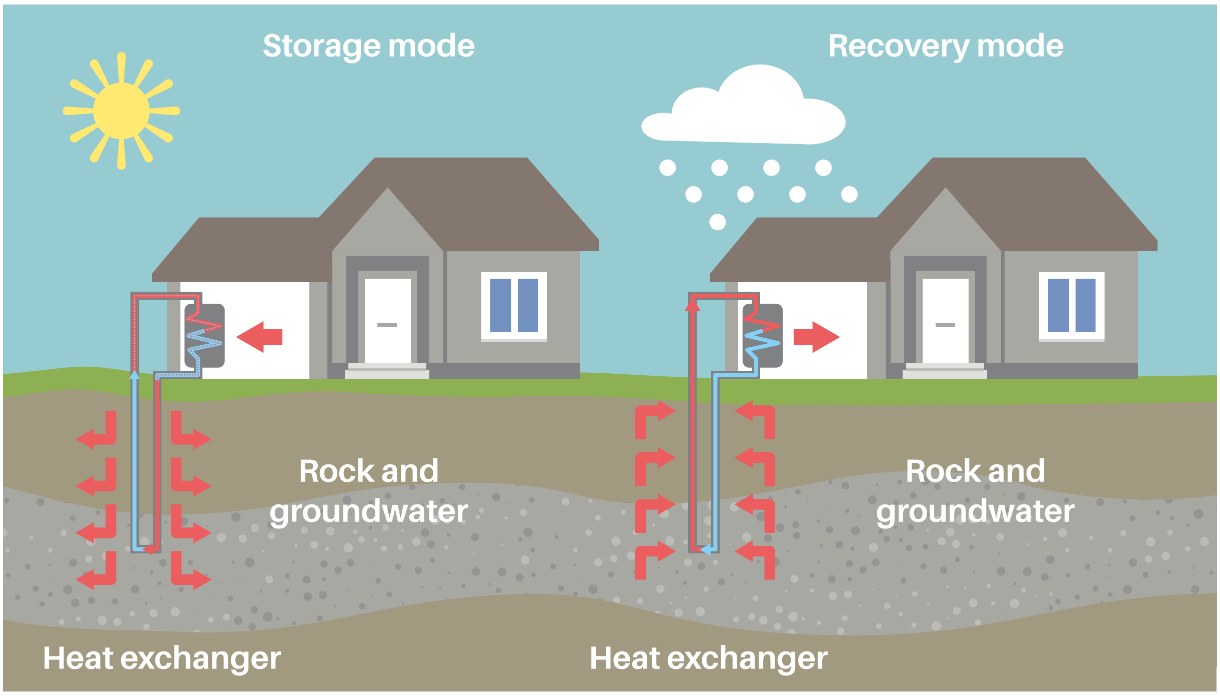
Congratulations! You are now the proud operator of the Lyell Company Thermal Storage system.

The system uses two wells that extend to a depth of 37 metres below the surface. The wells use machines called heat exchangers to move heat around, using water.

The heat exchangers run in one of two modes:

In storage mode, the system takes heat from buildings and moves it underground. This could be used in summer when the building is hot. The summer heat would be stored in the underground rock and groundwater so it can be released later.

In recovery mode, the system takes stored heat from the underground rock and groundwater and moves it up to the building. This could be used in winter to warm up a building when outside air temperatures are low.



Activity

Your goal is to program the hypothetical Lyell Company Thermal Storage system for a community in London's East End.

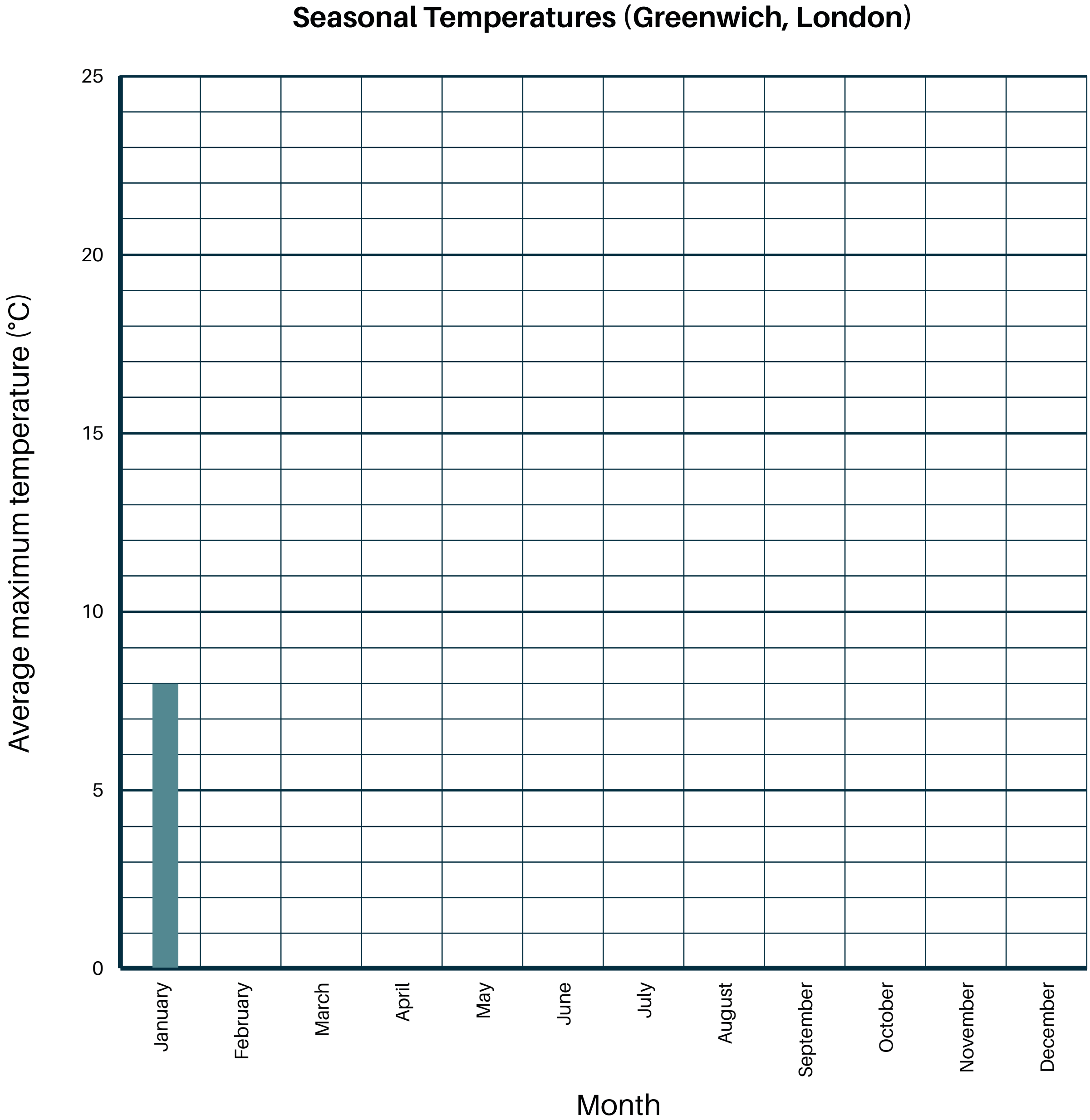
You can set the system to run in either 'storage mode' or 'recovery mode' for each month of the year. If you program it wisely, you can reduce the community's reliance on fossil fuels for heating, leading to a reduction in emissions of greenhouse gases.

Seasonal temperatures

Complete the bar chart using the data.

Month	Average maximum temperature for Greenwich, London (°C)
January	8
February	9
March	12
April	15
May	18
June	21
July	23
August	23
September	20
October	16
November	11
December	8

Bar chart



Comfortable temperatures

Humans need the interiors of buildings to be within a range of temperatures for comfort and health reasons. The World Health Organisation recommends a minimum of 18 °C.

Draw a line on your graph showing 18 °C across all 12 months.

Programming the system

If the outside air temperature is higher than 18 °C, the Lyell Company Thermal Storage System should be set to 'recovery mode'. This means the system will move stored heat energy from underground and supply it to the buildings to provide central heating.

If the outside air temperature is lower than 18 °C, the Lyell Company Thermal Storage System should be set to 'storage mode'. This means the system will take some of the heat from the buildings to be stored underground. This has the effect of cooling the buildings, ensuring they do not get too hot for residents.

Use this information and the graph to complete the table.

Month	Outside temperature is higher/lower/same than 18 °C	Recommended system mode (storage/recovery/off)
January	Lower	Recovery
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		

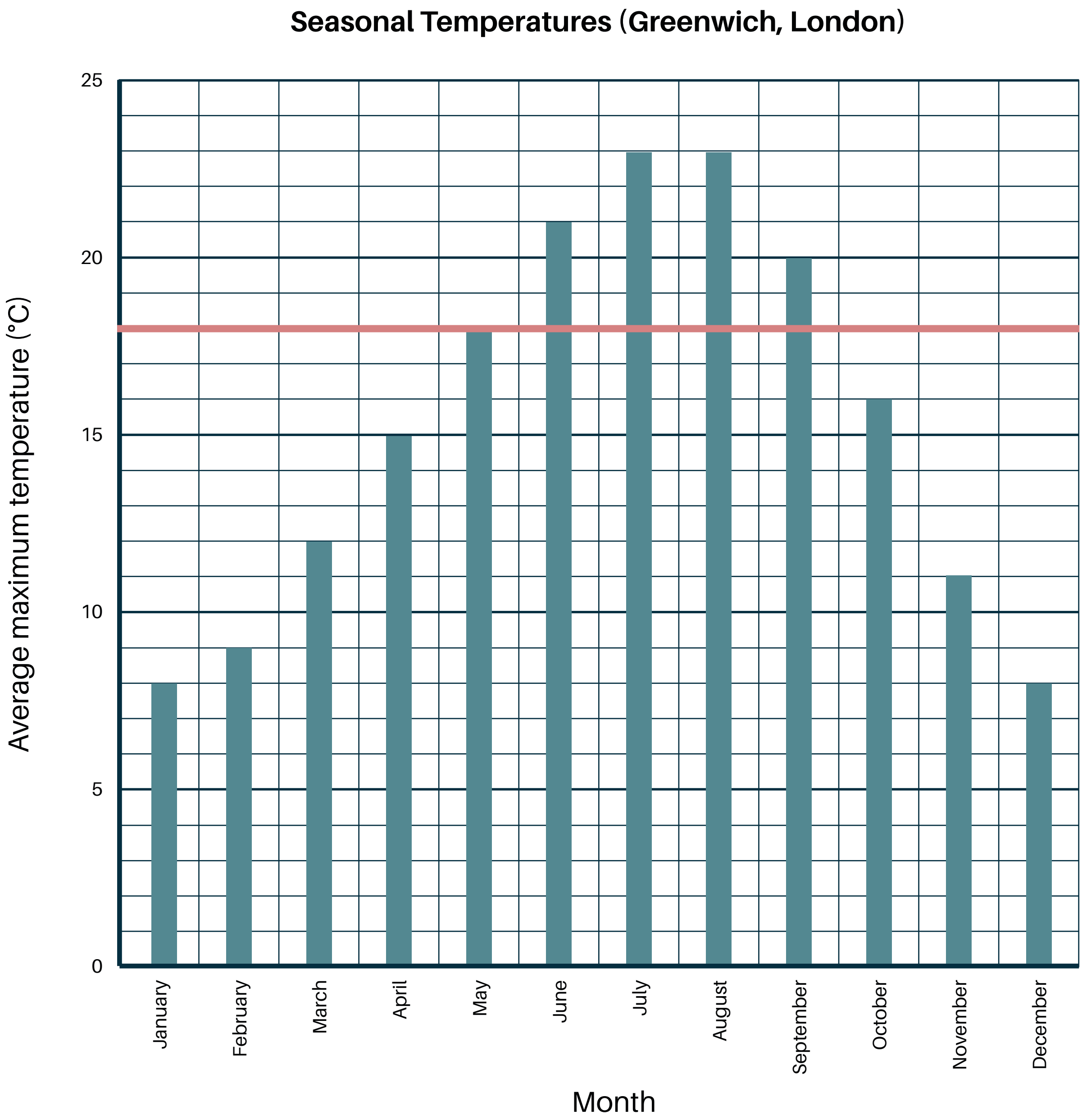
Worksheet 1 - Answers

Energy storage

The changing seasons

British Geological Survey

Bar chart



Worksheet 1 - Answers

Energy storage

The changing seasons

British Geological Survey

Programming the system

Month	Outside temperature is higher/lower/same than 18 °C	Recommended system mode (storage/recovery/off)
January	Lower	Recovery
February	Lower	Recovery
March	Lower	Recovery
April	Lower	Recovery
May	Same	Off
June	Higher	Storage
July	Higher	Storage
August	Higher	Storage
September	Higher	Storage
October	Lower	Recovery
November	Lower	Recovery
December	Lower	Recovery

Worksheet 2

Energy storage

Storing heat in old mines

British Geological Survey

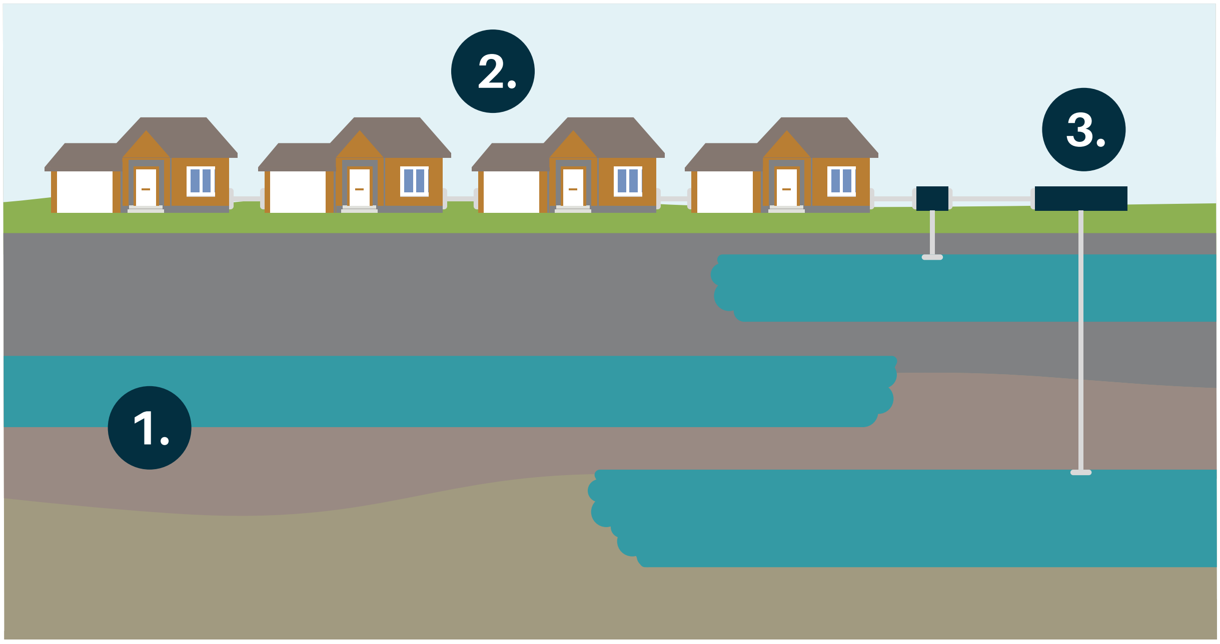
Name: ______________________ **Date:** ______________

You are going to plot locations on a map to determine whether the geology is suitable for installing a thermal energy storage system.

Thermal energy storage

It is estimated that a quarter of the UK's population live above abandoned coal mines. These remnants of the industrial revolution could provide the ideal geology to supply and store heat energy in the 21st century.

For example, a thermal energy system could store summer heat from the sun underground so it can be used to heat buildings in the winter.

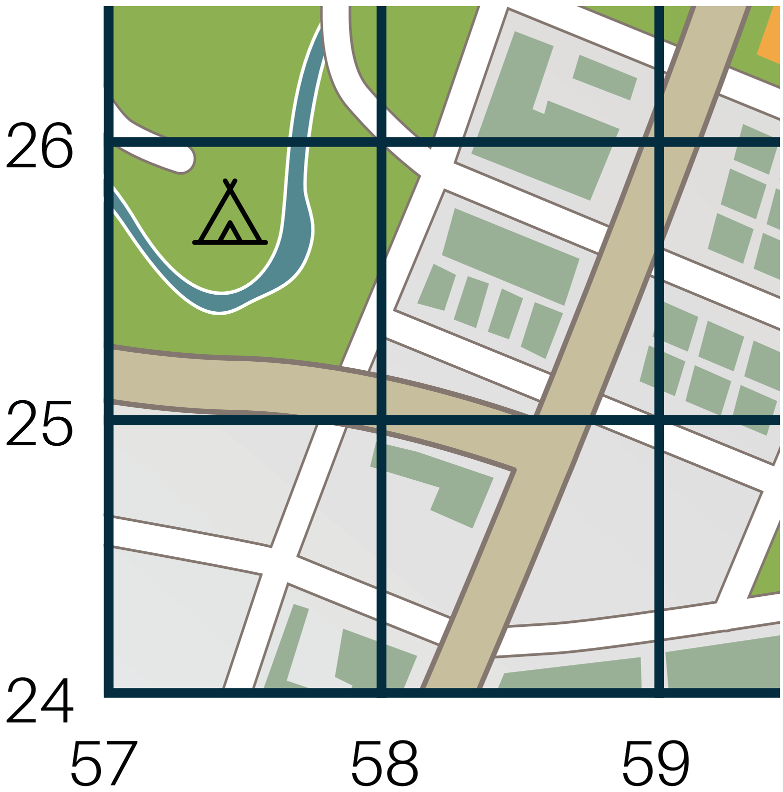


1. Abandoned mine workings tend to be flooded. The water can act as a giant heat battery, where heat energy can be stored for long periods.
2. Homes and businesses are connected to a heat network, which means heat energy can be moved between buildings.
3. Wells extend into the mines and machines called heat exchangers can either store or recover heat energy from the mine water.

Reading a map

Four-figure grid references

Some maps use four-figure grid references to help pinpoint locations within a square.



For example, the campsite marked as  is in square 5725.

To get the first two numbers, start at the left of the map and go east until you find the bottom-left corner of the square that features the campsite.
Here it is 57.

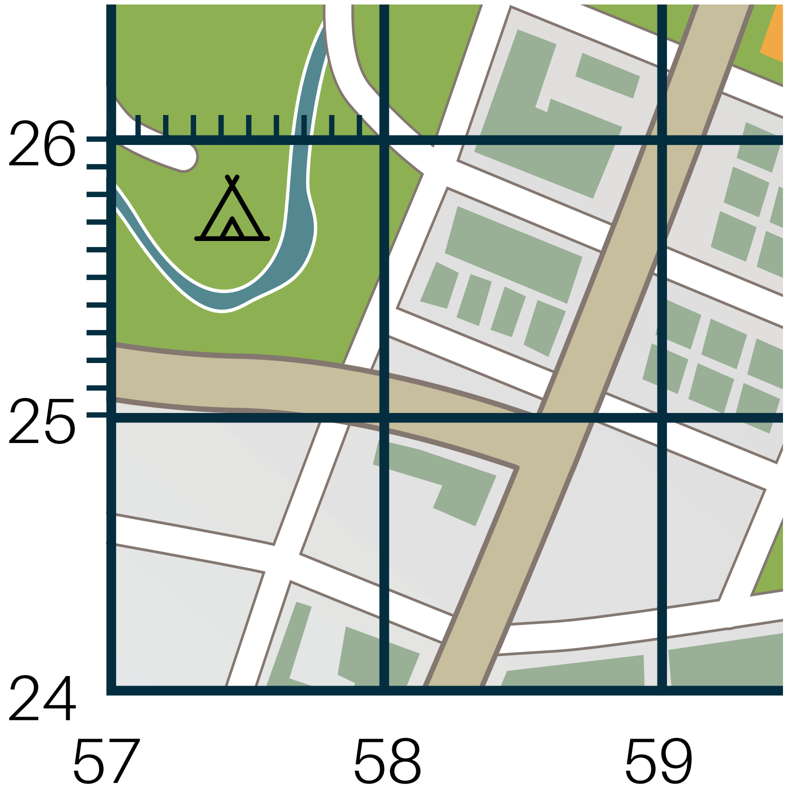
To get the second two numbers, start at the bottom of the map and go north until you find the bottom-left corner of the same square.
Here it is 25.

Reading a map

Six-figure grid references

Sometimes a four-figure grid reference is not accurate enough. A six-figure grid reference is more accurate.

Imagine each square is divided into 100 tiny squares. The distance between one grid line and the next is divided into tenths.



To find the six-figure grid reference for the campsite :

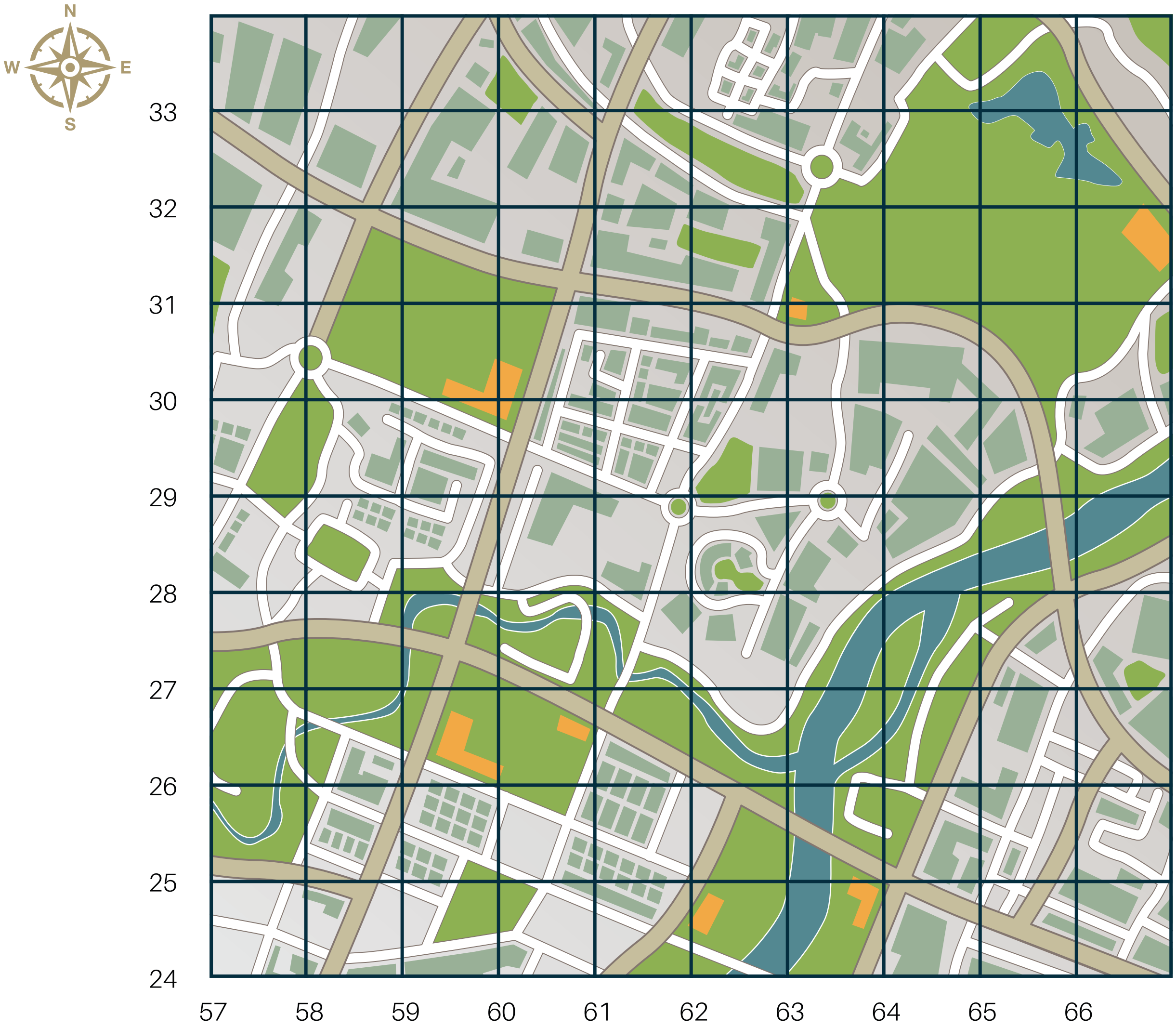
First find the four-figure grid reference but leave two spaces, for example 57_25_.

Measure how many tenths across the square the campsite symbol is.
Here the campsite is 4 tenths across. You write this in the first space, so 57425_.

Now measure how many tenths up the square the campsite symbol is.
Here it is 7 tenths up.

The six-figure grid reference for the campsite is 574257.

Town Map



Plot the following locations on to the town map. Use a cross symbol **+** for a coal mine and a circle symbol **O** for a housing development.

Location Name	Location Type	Grid Reference
Eastfield	Abandoned coal mine	587308
The Meadows	Abandoned coal mine	625245
Smithylane	Abandoned coal mine	646331
Old Springs	Abandoned coal mine	598312
Crossroads	Housing development	615287
Riverview	Housing development	654267

Questions

Which abandoned coal mine is closest to the Crossroads housing development?

Which abandoned coal mine is closest to the Riverview housing development?

Which housing development would be easier to connect to an abandoned coal mine? Why do you think that?

Worksheet 2 - Answers

Energy storage

Storing heat in old mines

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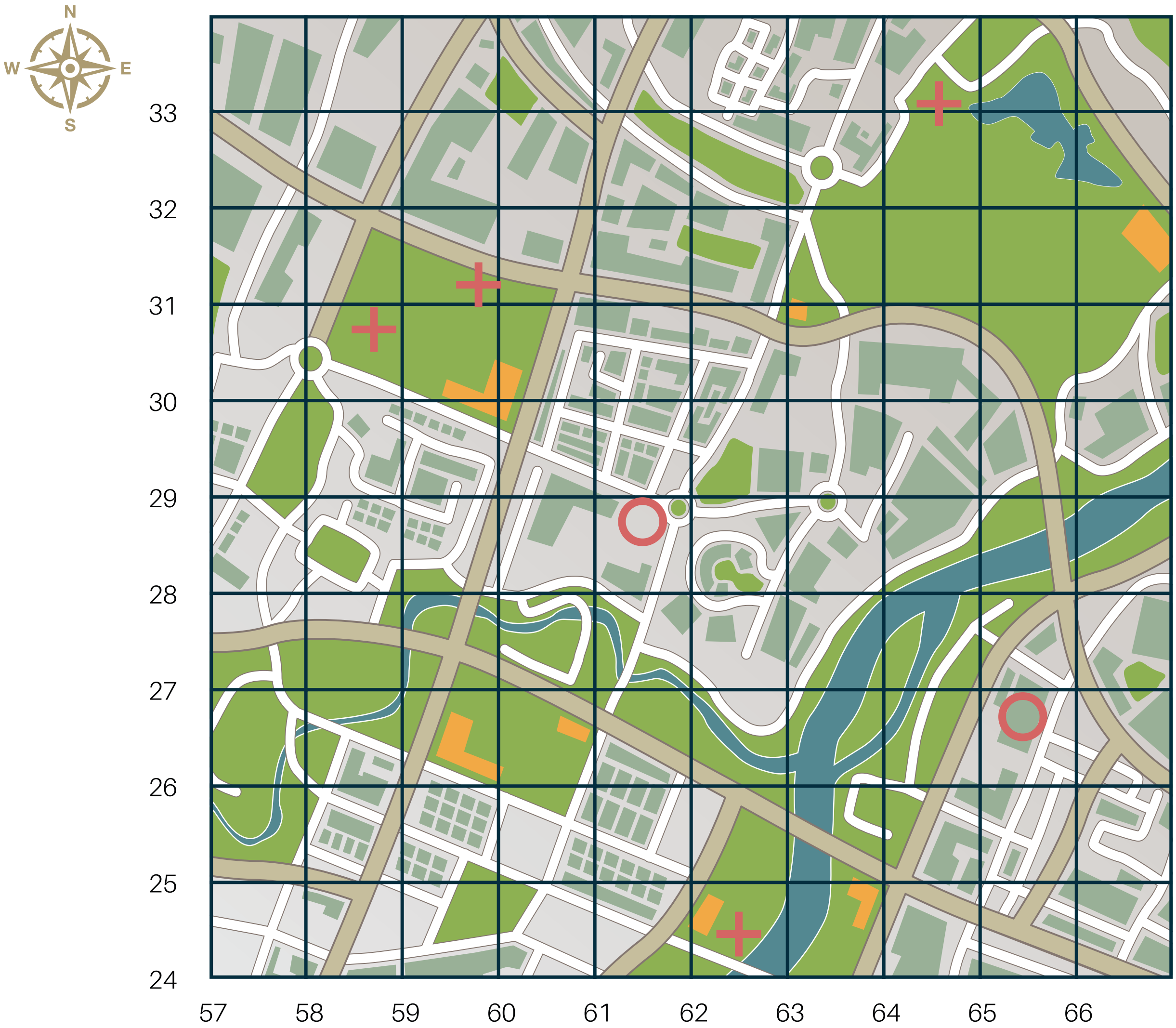
Town Map



Which abandoned coal mine is closest to the Crossroads housing development?

Old Springs

Which abandoned coal mine is closest to the Riverview housing development?

The Meadows

Which housing development would be easier to connect to an abandoned coal mine? Why do you think that?

Either housing development would be an acceptable answer, but Crossroads is more likely to be easier to connect to an abandoned coal mine. Justifications may include the relative distance between the mine and housing development, and geographical obstacles such as rivers, roads and buildings that may make connecting the mine and housing difficult.

Home activity

Energy storage

Home sweet home

British Geological Survey

Name: ______________________ **Date:** ______________

Read the background information then interview a grown-up to find out about their experiences.

Home heating

In 2021, over 85% of UK households said they used gas central heating to warm their property during the winter. Other heating methods included electricity, oil, wood and coal.

Each of these heating methods can release greenhouse gases either directly (in the case of fossil fuels and wood) and indirectly (in the case of the generation of electricity). Greenhouse gases are driving climate change, which poses a threat to places, animals and the way people live.

Past, present and future

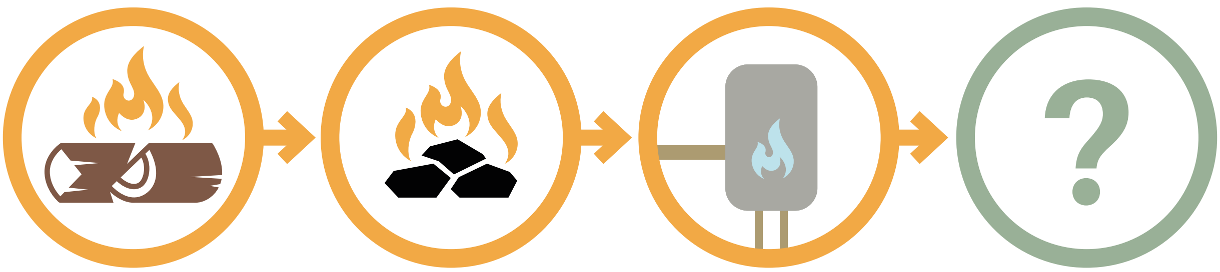
The ways that humans have heated their dwellings has changed throughout history.

Fire using wood provided our human ancestors with a source of warmth.

Coal became a major source of energy in the UK during the Industrial Revolution.

Gas central heating became dominant in the 1980s.

How will we heat our homes in the future?



Your family history

Ask these questions to a grown-up and write the answers as complete sentences.

Name of the person you are interviewing

"When you were my age, how was your home heated during the winter?"

"How is your home today heated during the winter?"

"How do you think homes of the future will be heated?"