CS06

Comprehending Science: Pumped storage hydro

The Comprehending Science series of resources uses extracts of Drax website articles, alongside comprehension questions, in topics relevant to the national curriculum. A shorter version of this resource is also available, with less text and six comprehension questions.

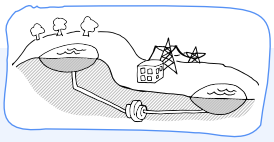
Teacher notes

Most suited to	KS3, KS4
May be suitable for	KS5
Skills	Comprehension, scientific literacy
Subject	Science, English language, geography, environmental issues
Topic	Electricity generation, sources of energy, climate change, resource use
Suggested use	Lesson activity, homework, remote provision, home learning
Resources needed	Optional internet access, paper or electronic copies of worksheet and questions
Mark schemes guidance	Suggested or model answers are provided

Feedback: https://forms.office.com/r/VkQ6FF4xxJ

Contact us: educational.resources@drax.com

- Read the text about this type of electricity generation, taken from: www.drax.com/power-generation/what-is-pumped-storage-hydro
- Write the answers to the questions in your books/on paper, as instructed. Use full sentences. The numbers in brackets help you find the line numbers you need in the text. You may need some additional science knowledge or resources for some of the short answer and challenge questions.



What's pumped storage hydro?

Pumped storage hydro (PSH) is a large-scale method of storing energy that can be converted into hydroelectric power. The long-duration storage technology has been used for more than half a century to balance demand on Great Britain's electricity grid. It accounts for more than 99% of bulk energy storage capacity worldwide.

How does it work?

The principle is simple. Pumped storage facilities have two water reservoirs at different elevations on a steep slope. When there's too much electricity on the grid compared to the level of demand, the facility uses the excess to power its reversible turbines and pump water from the lower to the upper reservoir. When demand is high, the water is released downhill into the lower reservoir, driving the turbines in the other direction to generate electricity. Pumped storage hydro plants can also provide ancillary services – such as inertia from spinning turbines – to help balance the power system. This ensures the system runs at the right frequency and reduces the risk of power cuts.

Why is PSH important in the transition to more renewable energy?

To meet their climate goals, governments around the world are shifting from fossil fuels to renewable energy sources. But renewable generation technologies such as wind and solar pose challenges for power grid operators because they're weather-dependent and the supply of power is intermittent. For example, wind farms accounted for almost a quarter of the UK's total electricity generation in 2020. However, on some days, wind met less than 10% of the country's electricity needs. Changing weather patterns and extreme weather events with prolonged periods of little wind or reduced daylight are a further threat to grid stability.

When output from renewables falls, grid operators mostly turn to gas-fired power stations to plug the gap. But in the long term, relying on fossil fuels such as natural gas to balance the grid will compromise efforts to reach net zero emissions by 2050. Pumped storage hydro facilities act as vast 'water batteries' and are a flexible, cost-effective way – at scale – of storing excess energy generated by renewables.

How can PSH capacity be increased?

As old thermal power plants are decommissioned and renewables provide an increasing share of the electricity supply, storage capacity will need to grow. This is particularly true if the world wants to meet its climate goals. Over the next two to three decades, Great Britain's energy storage capacity alone will need to increase tenfold, from 3 gigawatts (GW) to around 30 GW.

PSH power stations require very specific sites, with substantial bodies of water between different elevations. There are hundreds, if not thousands, of potential sites around the UK, including disused mines, quarries and underground caverns. But the cost of developing entirely new facilities is huge. A more cost-effective way to increase storage capacity is by expanding existing plants, such as the Cruachan Power Station in Scotland.

If you want to understand more on this topic

- Watch a video explaining how our Cruachan pumped hydro works: https://vimeo.com/566229360
- Investigate the links in the article. If you're working from a paper copy, the links in full are:
  - https://www.drax.com/power-generation/could-great-britain-go-off-grid/
  - https://www.drax.com/power-generation/why-spin-a-turbine-without-generating-power/
  - https://www.electricinsights.co.uk/#/dashboard?period=1-year&start=2020-01-01&category=weather-dependent&&_k=v7x9hy
  - https://www.drax.com/press_release/experts-issue-weather-warning-for-britains-electricity-grid/
  - https://www.drax.com/carbon-capture/what-is-net-zero/
  - https://reports.electricinsights.co.uk/q3-2019/how-much-energy-storage-will-we-need/
  - https://www.drax.com/power-generation/makes-mountain-right-energy-storage/
  - https://www.drax.com/about-us/our-projects/cruachan-2/

Feedback:

Comprehending Science: Pumped storage hydro Questions

Comprehension questions

1. For how many years has pumped storage hydro (PSH) been used? (2-3)
2. How many water reservoirs are needed for a pumped hydro facility to work? (6-7)
3. What happens when there's excess power on the grid? (8-9)
4. How does PSH generate electricity? (9-10)
5. Why are governments moving away from using fossil fuels to generate electricity? (15-16)
6. How much of the UK's total electricity in 2020 was generated by wind energy? (18-19)
7. Do solar panels generate electricity at night? (18-22)
8. What type of power station is currently relied upon to generate electricity when it's not windy? (23-24)
9. What type of energy is providing an increasing share of our electricity supply? (29-30)
10. How much does energy storage capacity need to grow by? (32-33)

Short answer questions

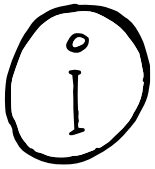
1. What's a reservoir? (6-7)
2. Name three fossil fuels (15)
3. Are wind and solar power renewable or non-renewable? (16-17)
4. What's meant by the word 'grid'? (17, 22, 25)
5. What sort of energy store is a PSH facility? (26-27)

Challenge tasks

1. Describe the problems the UK could have if we rely on wind power to generate a significant share of the electricity we need. How can PSH help to solve some of these problems? Include these key words: weather, demand, supply, storage.
2. Explain why governments want to use renewable energy sources to generate electricity, rather than continuing to use fossil fuels. Include these key words: carbon dioxide, climate change, renewable.
3. Use the drax.com website to find a diagram and photograph of a PSH facility. Draw and annotate your own diagram to explain how pumped hydro storage works.

Comprehending Science: Pumped storage hydro model answers

Comprehension questions



1. Pumped storage hydro (PSH) has been used for more than 50 years.
2. Two reservoirs are needed for a PSH facility to work (one needs to be higher than the other one).
3. When there's excess power on the grid, the facility uses it to pump water from the lower reservoir to the higher reservoir.
4. Water is released downhill to the lower reservoir; this drives the turbines that generate electricity.
5. Governments are moving away from using fossil fuels to generate electricity to meet their climate goals.
6. Almost 25% (a quarter) of the UK's total electricity in 2020 was generated by wind energy.
7. Solar panels do not generate any electricity at night.
8. Gas fired power stations are currently relied upon to generate electricity when it's not windy.
9. Renewable energy is providing an increasing share of our electricity supply.
10. Energy storage capacity in the UK needs to increase ten times from current capacity, to about 30 GW.

Short answer questions

1. A reservoir is a means of water storage, usually an artificial lake created by building a dam across a river.
2. Fossil fuels include coal, oil and gas (others include oil shales and tar sands).
3. Wind and solar power are types of renewable energy.
4. In the article, the word 'grid' means the National Grid – an electricity transmission network that distributes electricity from power stations to where it's used.
5. A PSH facility uses hydroelectrical generation and the stored energy is gravitational potential energy.

Challenge tasks

1. Wind turbines only generate electricity for supply to the grid when it's windy. It's quite hard to predict when it's going to be windy or not, and it's unlikely that there'll always be the right conditions at the right time. Sometimes, wind turbines can generate more electricity than needed, and there's no way of storing the excess. Sometimes, it's not windy at all. If the UK relied solely on wind for its power generation, there may not be enough electricity generated to meet demand. PSH is one way of helping to balance these supply and demand issues. When the weather is very windy, excess generated electricity not needed by homes and businesses is used to pump water to the upper reservoir. The water in the reservoir becomes like a giant battery of stored energy. When demand on the grid is high, but there's not enough electricity being generated (e.g. because it's not windy enough), the water is released downhill to the lower reservoir. The spinning turbines driven by the water generate electricity and help meet the gap between electricity supply and demand.
2. Many governments around the world want to try to increase electricity generation from renewable energy sources such as wind, and to reduce or stop using fossil fuels. This is because burning fossil fuels such as coal releases carbon dioxide gas into the atmosphere. Carbon dioxide is known as a greenhouse gas because it contributes to a global warming effect. Increased atmospheric carbon dioxide concentration is now widely understood to be a cause of climate change. Many governments have targets to try to reduce the amount of carbon dioxide released into the atmosphere to minimise the impacts of climate change.
3. Photographs and diagrams available on the website include those below. You could add your own annotations (labels) to them. In the first, of the turbine hall inside Cruachan's mountain chamber, the yellow vertical cylindrical turbine generators are in a row inside a large domed hall. The second photo shows the upper reservoir.