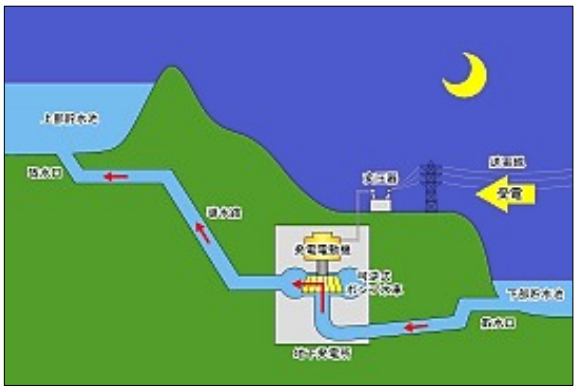
Matching supply and demand using stored water
Pumped storage hydroelectric schemes – just-in-time power

Pumped storage - how does it work?
By pumping water to a higher level, it gains potential energy; it can then generate electric power on demand. At times when more power is being generated across the country than is being used, such as at night-time when demand is low, the extra electricity is used to pump water into a high storage reservoir. Then, when the electricity is needed, the water is released to flow downhill through turbines to generate power, just-in-time.

This is particularly useful when there are sudden peaks in demand, such as when it is half time in a football cup final, and people across the land turn on their electric kettles for a hot drink. Then it can be turned on and off like a switch in just a few seconds. Other power sources such as gas-fired power stations take much longer to turn on and off. Most of the time, pumped storage schemes are not used for 'TV peaks' but simply to store energy at night and provide energy during the day.

The pumped storage principles are shown in these two diagrams of a Japanese scheme. During the day, water runs downhill from the upper reservoir, driving the turbines which drive generators to make electricity, which is then transmitted to the national grid.

At night, surplus energy from the national grid is used to drive the turbines the other way, pumping water back uphill to the upper reservoir. Then it can be used again to make power next day.



(Both diagrams Σ64 Creative Commons Attribution 4.0).

Pumped storage is an inefficient process, because more energy is used to pump the water uphill than is generated by downhill flow, but this is unimportant because it is surplus electricity which is used for the uphill pumping.

Pumped storage in the UK
There are four pumped storage schemes operating in the UK today. The largest of these is the Dinorwig Scheme in North Wales, which opened in 1984. It is the largest pumped storage scheme in Europe and is a tourist attraction called 'Electric Mountain'.

The Dinorwig scheme was built behind the abandoned Dinorwig Slate Mine. Above the slate mine is a glacial corrie (cwm in Welsh) which was deepened to form the Marchlyn Mawr reservoir, the upper reservoir, 500 metres above the Llyn Peris lake below.

Marchlyn Mawr reservoir. *(Dave Roberts, CC BY-SA 2.0).*

During the day or at times of high power demand, water flows from the upper reservoir down a tunnel into the huge turbine hall excavated deep inside the mountain. This drives six turbines to generate electricity, before the water flows out into Llyn Peris lake below.

Llyn Peris lake showing the entrance to the hydroelectric scheme, with slate mine debris in the foreground. *(Subarite, CC BY-SA 2.0).*

During the night, electricity from the national grid is used to pump water back up from Llyn Peris to the Marchlyn Mawr reservoir above.

The future for pumped storage?
Pumped storage schemes may become more important in future as countries move to including more renewable sources in their energy mix. Some of these renewable sources have variable output (such as wind turbines when there is no wind or solar when it is cloudy); this is when storing surplus power from times when they are generating electricity becomes important.

Research is being carried out on pumped storage using high density mineral-rich fluids instead of water. High density fluids would store more energy and supply more power than the same amount of water at the same height, so may be able to operate in hilly rather than mountainous areas. However, we do not yet know if this will work at large scale and there are concerns that the fluid might be highly polluting.

Your area
Do you have local mountains more than 500 metres high with glacial corries that could be deepened into reservoirs and a lake at the bottom? If so a pumped hydroelectric scheme could be built there.

Do you have local hills? If so, it might be possible to build a high-density fluid pumped storage scheme there in the future.

If one of these schemes could be built, or might be possible, should it be built there? This is a discussion for your class and would involve representatives from industry, government and the local community.

The back up

Title: Matching supply and demand using stored water.

Subtitle: Pumped storage hydroelectric schemes – just-in-time power.

Topic: A discussion of the potential for a local pumped storage scheme.

Age range of pupils: 14 years upwards

Time needed to complete activity: 30 minutes including a debate

Pupil learning outcomes: Pupils can:
- explain the principles of pumped storage;
- explain the 'just-in-time' advantage of pumped storage;
- explain how it is used to even out the supply of power over time;
- explain why pumped storage schemes may become more important in the future;
- discuss whether such a scheme might be viable locally.

Context:
Government 'net-zero' targets will affect many areas across the world. This Earthlearningidea explores how pumped storage hydroelectric schemes may make an important future contribution to government 'net-zero' targets by storing power from sources with variable output such as wind or solar.

Extra background information is provided in other 'net-zero' Earthlearningideas.

If you do not have local hills or mountains, discussion could be developed using photographs or maps instead.

Meanwhile, another proposal to store energy in a similar way, using large weights in disused mineshafts is being explored.

Following up the activity:
Virtually tour the Cruachan 'Hollow mountain' pumped storage scheme in Scotland at: https://www.visitcruachan.co.uk/

The upper and lower reservoirs of the Cruachan pumped storage scheme, Loch Awe, Scotland.
(James Hearton, CC BY-SA 2.0).

Underlying principles:
- Electricity must be produced as it is needed because the national electricity grid cannot store electricity.
- Special methods must be used to store electricity from times when there is over-production, such as during the night, for times when is needed, such as during daytime or when there are 'spikes' in demand.
- Pumped storage schemes using water or other dense liquids provide one method of storing electricity.

Thinking skill development:
Developing an understanding of how pumped storage schemes work is a construction activity. Applying that understanding to the local area involves bridging and may involve cognitive conflict and metacognition during discussions.

Resource list:

- if you live in a mountainous or hilly area, you could use a viewpoint or a view from a window; if not, photographs or maps of a mountainous or hilly area suitable for discussion could be used

Useful links:
Search 'net-zero' on the Earthlearningidea website to find other Earthlearningideas relating to climate change mitigation or adaptation, as in the table below. Use a search engine like Google to explore the internet for more information about likely global impacts of 'net-zero'.

In the UK, you can access a tool to help visualise how climate change might affect your local area at: https://www.bbc.co.uk/news/resources/idt-d6338d9f-8789-4bc2-b6d7-3691c0e7d138

Source: Chris King of the Earthlearningidea team. *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? *Also:* Hydrogen of many colours
		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? *Also* Hydrogen of many colours
		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