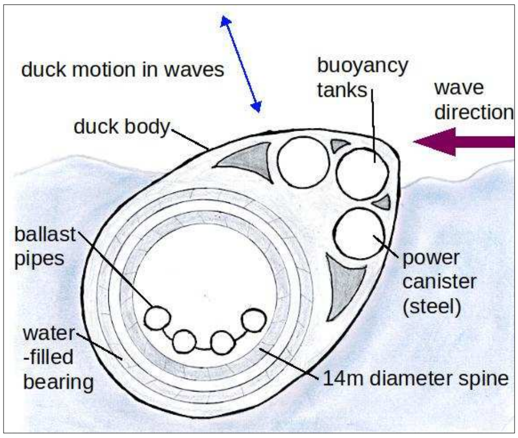
Harnessing the power of waves
Investigating the development of wave power

Ultimately, nearly all the world's energy is sourced from the Sun. We can make use of this directly via solar panels and indirectly from fossil fuels, or by renewable energy sources such as the harnessing of wind and waves. We are used to the sight of solar panels and wind turbines, the latter on both land and at sea but we are less familiar with the development of energy from wave power. Wave energy has great potential but it suffers due to high costs and the problems of damage from ocean waves when compared to other forms of renewable energy like wind and solar. Despite this, there are still a number of innovations taking place. Wave energy could have many uses other than generating electricity, e.g. desalinating water or pumping water. It can also be used in an energy mix, especially with wind turbines.

The history of using wave power goes back further than you might think. In 1799, a patent was filed in France to use waves for mechanical power. In 1910, again in France, another device was used to light and power a house near Bordeaux. More attention was given to wave technology after the oil crisis of 1973 which resulted in a dramatic increase in the price of oil. At the University of Edinburgh in 1974, Dr Stephen Salter invented a nodding 'duck' which became known as Salter's duck, (official name the Edinburgh Duck).



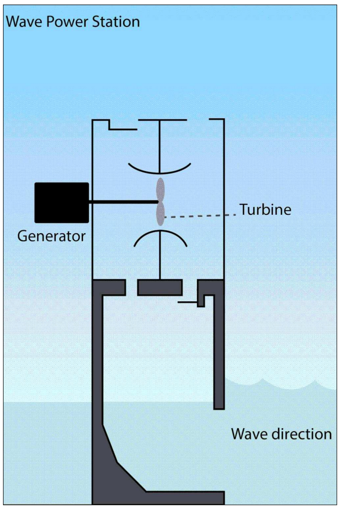
Cross section of Salter's Duck

© Maggie Harker, drawn from a diagram by Thorpe 1999

Each duck is shaped like a teardrop, and many of these 'teardrops' are attached to a long spine to make up the whole Salter's system. The nose of the teardrop faces incoming waves and bobs as they pass. Essentially, this involves a transfer, or 'capture' of the wave's energy. In theory, this bobbing action would capture as much as 90% of the wave's energy. The energy is used to keep pistons running and the pistons pressurise hydraulic oil. When sufficiently pressurised, the oil enters a hydraulic motor which generates electricity from the captured energy. In practice, the percentage of wave energy capture was lower than the predicted 90%. There was much debate about the data collected, not just about the amount of power generated but also about the cost per kWh. The cost of producing energy from wave power must be competitive with that from other sources and this was not proved by using the ducks at that stage.

Further development of wave power has not been straightforward. The world's first attempt to build a commercial wave power station off the north coast of Scotland did not end well. In 1995, a large yellow 2-megawatt generator named Osprey was wrecked by the waves that were meant to power it. A similar Australian scheme suffered in the same way.

This failure, however, led to the design and testing of other devices. Most wave power machines now operate by trapping air in a chamber above the surface of the sea. As wave crests and troughs arrive at the machine, the water level in the chamber rises and falls, blowing and sucking air through a hole in its ceiling. A turbine placed across this hole draws off power.



How one form of wave power generation works

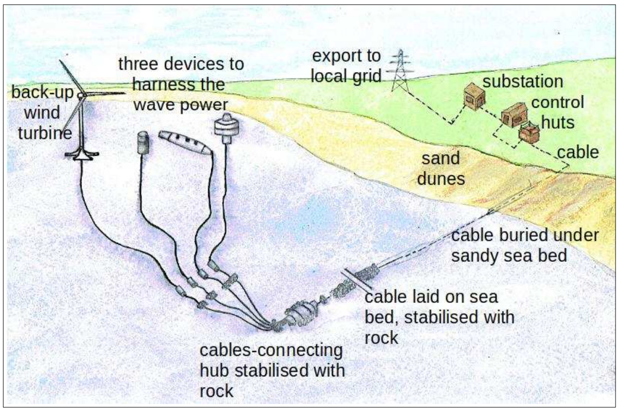
The early development of wave energy was based in Europe, but now countries including Australia, China and the USA are becoming interested. Small islands in the Caribbean and elsewhere have also turned to wave energy to replace fossil fuels.

The main challenge of building wave energy plants is ensuring the design can withstand the impact of the waves, particularly during storms. Finnish company Wello Oy's device, 'The Penguin' is one such design. The Penguin is loosely anchored to the sea bottom at a depth of 50m, with 2m visible above the surface of the water. It works by using the movement of its asymmetric-shaped hull, which rolls and heaves with each wave to drive the generator and produce electricity - very similar to Salter's duck.

Scottish company DP Power has a wave project that will combine with wind energy. If successful, the wind -wave platform will initially combine an 8MW of wind power with 3.6MW wave power, with the potential to expand to a total of 47MW.

A successful wave energy plant in operation is at Mutriku in the Bay of Biscay, Spain. The plant was officially commissioned in July 2011. It generates an output of 296kW, enough to power 250 households.

The diagram below shows a typical wave/wind power project, designed to be 16km (10 miles) from the coast. An installation such as this would have an initial capacity of 20MW, enough to provide electricity to 7,000 homes, with the potential to increase it to 50MW in the future.



Typical wave-hub plant
© Maggie Harker, drawn from a diagram in a Power Technology Newsletter

Working in groups, **ask the pupils** to find a map of a coastline they know. They should also investigate the geology of their chosen coast, (https://www.bgs.ac.uk/geological-data/opengeoscience).

Study the diagram of the wave hub plant and then decide whether such a wave hub could be built off their chosen coastline.

Factors to consider include:
- rock type (are the rocks strong or weak: is there one rock type or several);
- relief of the coastline (for siting the infrastructure);
- wave size (the largest and most regular waves are generated by the wind blowing across the widest oceans);
- weather conditions (frequency of storms which might damage the underwater equipment);
- population density near the coast;
- towns and cities nearby;
- infrastructure of the area (railways, motorways, harbours, shipping lanes).

The back up

Title: Harnessing the power of waves

Subtitle: Investigating the development of wave power

Topic: An investigation into the use of wave power to generate electricity

Age range of pupils: 14 years upwards

Time needed to complete activity: 30 minutes

Pupil learning outcomes: Pupils can:
- realise that wave movements may be used as a power source;
- explain early ideas such as Salter's Duck;
- explain how current wave energy machines work by trapping air;
- imagine a wave hub plant near a coast known to them;
- list the advantages and disadvantages of building a wave hub plant.

Context:
Wave power can be produced by the up and down motion of floating devices placed on the surface of the ocean. Put simply, energy from the Sun causes wind, wind produces waves, and then waves produce energy. As the waves travel across the ocean, devices capture the natural movements to generate power. One prediction is that, given the length of Britain's coastline, wave power could generate 50% of Britain's electricity requirements by 2040. Others are less optimistic and cite a figure of 20%.

Following up the activity:
Use the internet to explore other ideas to harness the power of waves.

Underlying principles:

- Solar energy generates wind.
- Wind blowing across the surface of bodies of water generates waves.
- The energy in the movement of waves can be used to generate electrical power.

Thinking skill development:
A pattern develops when looking at various ways to harness wave power. Discussion of the topic is metacognition. Decisions concerning building a wave hub plant on to an existing coastline involve a bridging skill. Cognitive conflict will occur when it is realised that many coastlines are not suitable for such a development; they may be very urbanised or have protected status or the geology may make construction impossible.

Useful links:
Wave Star, Denmark *(error near end - for 'tides' read 'waves')*:
https://www.youtube.com/watch?v=KOaXc3XiKbQ
8-minute video on the experimental development of the Salter's Duck:
https://www.youtube.com/watch?v=NYPdQaPyyN0
Animation of the Duck:
https://technologystudent.com/energy1/tidal7.htm

Resource list:
• access to the internet for maps of coastlines

Source:
Devised and researched by Maggie Harker and developed by the Earthlearningidea Team.

This activity was as accurate as possible in spring 2021. The full list of ELI 'net zero' emissions activities can be seen on the next page.

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