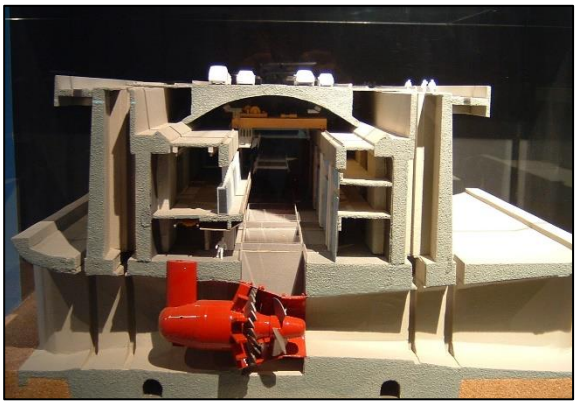
Tidal energy
Can the tides be harnessed to produce green energy?

For many years, water flowing down from the hills has been used to generate electricity – hydroelectricity. However, every day, across the planet, vast masses of water are moved to and fro by the gravitational effect of the Moon and the Sun acting upon the Earth. We call this movement of water, tides. The difference between high and low tide may be up to nearly 12 metres in really exceptional places (e.g. Bay of Fundy, Canada*).* Strong tidal currents also exist where water flows along the coast, and may be used to generate tidal stream energy. This is currently thought viable in places with peak flow speeds over about 2.5 m/s (9 km/h or 5.6 mph)**.** In most places there are two high and two low tides a day, so four tidal flows per day along each coastline. How can this daily movement of water along our coasts and up and down estuaries be harnessed?

There are three main ways in which tidal energy can be converted to electricity:

Tidal barrage:
A barrage is a long wall built across a tidal estuary where there is a good rise and fall of the tide. La Rance Barrage, 750m long, was built right across the estuary of the Rance River in Brittany, Northern France and has been generating up to 240 Megawatts (MW) of electricity since 1966. The average tidal range here is around 8m. The incoming tide is allowed through sluice gates in the barrage. When it reaches its peak the gates are closed, and it is held while the water level outside the barrage falls. When there is enough gap between the two, the water inside is allowed to flow out through turbines, generating electricity as it goes. The electricity is produced by 24 turbines, set in the barrage. It has been estimated that La Rance Tidal Power Station supplies 0.012% of the total power demand of France.

Aerial view of the barrage across La Rance Estuary, Brittany.



3D model of La Rance Barrage with a turbine in position below the water level.

Tidal lagoon:
A tidal lagoon works on the same principle as a barrage, as water passes through turbines on the rising or falling tide. A lagoon of water is created behind a very long breakwater built out from the coast. The world's biggest example at the moment is the Sihwa Lake Tidal Power Station, in South Korea, which opened in 2011. The huge breakwater, 12.5km long, had already been built in 1994, to reduce flooding and to create agricultural land, so there were no further costs for building that part of the project. The average tidal range is 5.6m and the generating capacity is up to 254MW.

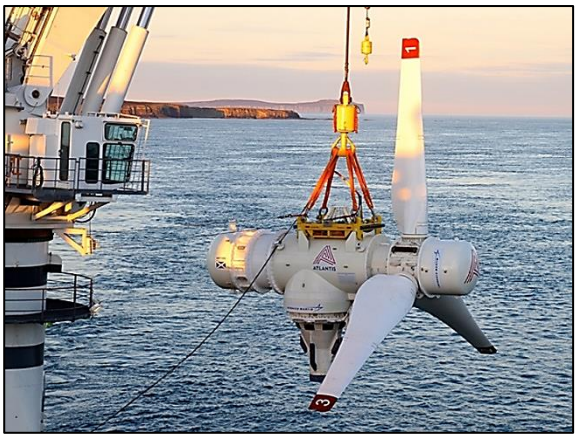
Aerial view of the Sihwa Lake Tidal Lagoon.

The turbine housings and power station at Sihwa Lake (©Arne Müseler).

Tidal Stream generator:

Map of the location of the MeyGen Tidal Power Project in the Pentland Firth, Scotland.

The tidal current between the north coast of Scotland and the Isle of Stroma in the Pentland Firth is one of the fastest in the U.K. and flows at speeds of up to 5m/s (11 mph) – certainly enough to be felt on the boat crossing to the Orkney Islands! There is no need for a barrage, but the turbines are fixed to the rocky sea floor and generate electricity when the current passes either way across them. The project is designed to deliver up to 400MW and its first phase (1A) began generating commercially at 6MW in 2017. Phase 1A of the project comprises four 1.5 megawatt turbines. These can generate the electricity needs of 3800 “typical” homes in the U.K.



One of the MeyGen turbines being lowered onto its base on the sea bed

As with any source of energy, we must consider the advantages and disadvantages of generating electricity from the tides. Look at the following lists and tick in the boxes where you think advantages or disadvantages apply to the three case studies above. Then write a summary of your findings.

Advantages	La Rance Barrage	Sihwa Tidal Lagoon	MayGen Tidal Stream
Tidal power produces renewable energy.			
Once constructed, tidal energy systems are zero carbon.			
Tidal power stations take up less space than a wind farm or solar panel farm generating the same amount of electricity.			
Tide times and heights or flow speeds are predictable throughout the year, so electricity generation can be predicted.			
Water is denser than air and it is claimed that water can generate electricity at much lower speeds than wind.			
Barrages and breakwaters can last more than four times as long as wind turbines and solar panels.			

Disadvantages	La Rance Barrage	Sihwa Tidal Lagoon	MayGen Tidal Stream
Construction costs are very high in the short term.			
Tide heights and flow speeds vary from week to week.			
There is always a time in each tidal cycle when there is no movement of water.			
Predicted power generation may not match up with times of demand.			
Structures may obstruct shipping.			
Structures may interfere with the migration of eels, salmon and other marine life.			
Structures affect the exposure and nutrient levels of mudflats, which shellfish, worms, waders and other birds depend upon.			
Noise from turbines can cause disturbance to whales and dolphins.			
Electro-magnetic impulses from turbines and undersea cables could damage sensitive marine life.			
Building and equipping a 15km long barrage or breakwater would emit considerably more carbon dioxide during construction than a tidal stream system			

If you live in a coastal area, investigate whether the conditions might be suitable for the construction of a tidal power station there. Could it be built? Should it be built?

If you live inland, search for an example of an actual or proposed tidal power station on the internet and answer the same two questions. A good example is the proposed tidal barrage across the estuary of the River Severn in England.

The location of the proposed Severn Barrage

See: http://www.tidalenergy.eu/severntidalbarrage.html

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The back up

Title: Tidal energy

Subtitle: Can the tides be harnessed to produce green energy?

Topic: A discussion of the reasons for and against tidal power, using three case studies of operational tidal power stations.

Age range of pupils: 14 years upwards

Time needed to complete activity: from 30 minutes upwards depending on the levels of discussion, the potential of the local area and the extent to which internet research is carried out.

Pupil learning outcomes: Pupils can:

- explain how the tides might be used to generate electricity;
- explain why there are so many points in favour and so many against the construction of a tidal power station;
- assess the potential of their own region if they live near a coast, or explain national decisions about the continuation or rejection of a tidal power station project if they do not.

Context: Government 'net-zero' targets will affect many areas across the world. This Earthlearningidea explores what the impacts might be in a coastal area, while extra background information is provided in other Earthlearningideas.

Possible answers are:

Advantages	**La Rance Barrage**	**Sihwa Tidal Lagoon**	**MayGen Tidal Stream**
Tidal power produces renewable energy.	√	√	√
Once constructed, it is zero carbon.	√	√	√
Take up less space than a wind farm or solar panel farm generating the same amount of electricity.			√
Tide times and heights or flow speeds are predictable.	√	√	√
Water can generate electricity at lower speeds than wind.	√	√	√
Lasts a long time.	√	√	

Disadvantages	**La Rance Barrage**	**Sihwa Tidal Lagoon**	**MayGen Tidal Stream**
Construction costs are very high.	√	√	
Tide heights and flow speeds vary from week to week.	√	√	√
There is no tidal movement at times during the tidal cycle.	√	√	√
Predicted generation may not match up with times of demand.	√	√	√
Structures may obstruct shipping.	√		
Structures may interfere with the migration of marine life.	√	√	
Structures affect the exposure and nutrient levels of mudflats.	√	√	

Noise from turbines may cause disturbance to whales and dolphins.	√	√	√
Electro-magnetic impulses could damage marine life.			√
Building and equipping a 15km long barrage or breakwater would emit considerably more carbon dioxide during construction than a tidal stream system		√	

Following up the activity:
If the Severn Estuary Barrage is not used in the lesson, it may be used for follow up at home. Other Earthlearningidea 'net-zero' activities will enable a wider discussion about renewable energy.

Underlying principles:
- The Earth's climate is changing.
- Most scientists believe that the emission of carbon to the atmosphere by human activity is causing an enhanced greenhouse effect, contributing to climate change.
- Many governments are setting target dates to become 'net-zero' contributors of carbon to the atmosphere in the fairly near future.
- These targets will affect the Earth both globally and locally.
- Tides in most areas cause four flows per day, which are particularly strong in carefully chosen places.
- Local potential impacts can be explored and evaluated.

Thinking skill development: Building up an understanding of the potential of tidal energy in general is a construction activity. Discussing its impact from different perspectives will cause cognitive conflict and explanations will involve metacognition. Applying these ideas to the local environment or a different case study involves bridging.

Useful links: Search 'net-zero' on the Earthlearningidea website to find other Earthlearningideas relating to climate change mitigation or adaptation. 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

A good starting point for pupils' research is https://en.wikipedia.org/wiki/List_of_tidal_power_stations which has many links to other sites.

Resource list: For coastal areas, the view from the window may suffice, otherwise photographs of nearby coastal scenery.

Source: Written by Peter Kennett of the Earthlearningidea Team. Thanks to Dr. Simon Waldman (Hull University) and Ed Land for technical advice.
On 30th July 2021 the media reported that a new 2MW tidal stream generator had entered service. It is a floating system in the Fall of Warness – where a strong tidal current flows between some of the Orkney Islands.
https://electrek.co/2021/07/30/the-worlds-most-powerful-tidal-turbine-is-now-generating-power/

This information was as accurate as possible in August 2021.

Image credits:
Aerial view of La Rance Barrage: https://commons.wikimedia.org/wiki/File:Barrage_de_la_Rance.jpg Public domain

3D Model of La Rance Barrage: https://upload.wikimedia.org/wikipedia/commons/2/25/Coupebarrage_Rance.jpg GNU Free Documentation License

Sihwa lake turbine housings: This file is licensed under the Creative Commons Attribution 2.0 Korea license
File:Sihwa Lake Tidal Power Station 01.png - Wikimedia Commons

Aerial view of Sihwa Lake Tidal lagoon: Arne Müseler / arne-mueseler.com / CC-BY-SA-3.0 (linked to: https://creativecommons.org/licenses/by-sa/3.0/de/deed.de)

MeyGen turbine: Image-2-Meygen-tidal-power-project-Pentland-Firth-Scotland..jpg (800×600) (nsenergybusiness.com)

MeyGen location map; Wiki Creative Commons Attribution-ShareAlike 4.0 license

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