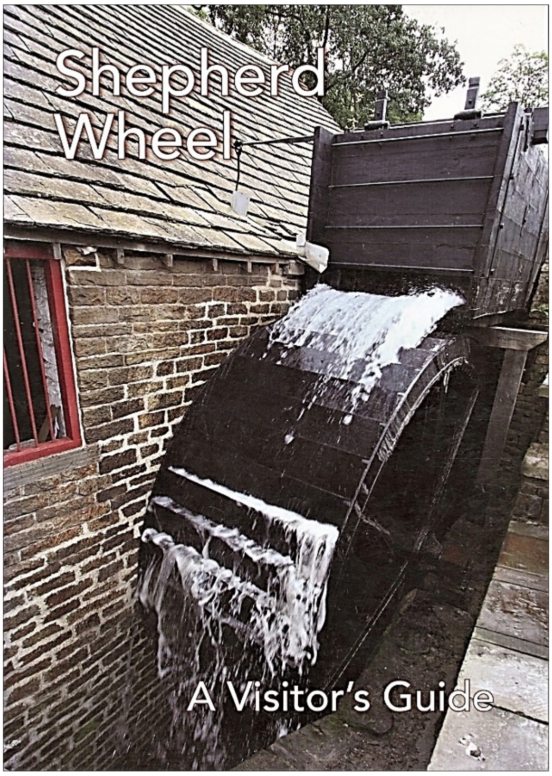
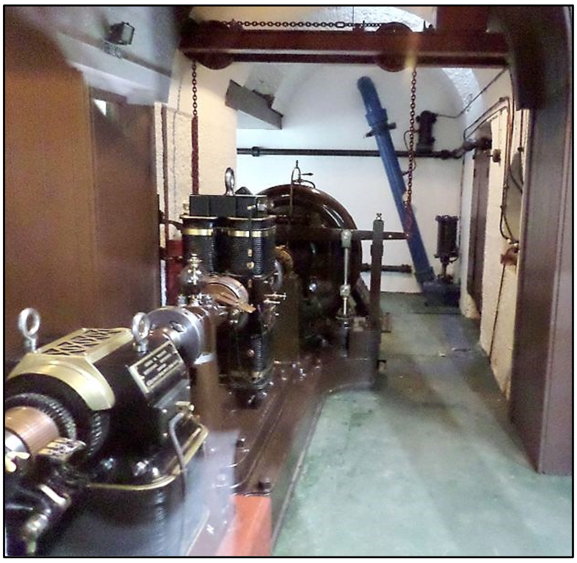
Small-scale hydroelectric power schemes
Investigating opportunities for micro-hydro

Humans have exploited the power of falling water for thousands of years, for milling grain, sawing wood, grinding edge-tools and a host of other applications.



Shepherd Wheel, Sheffield - an 18th Century mill for grinding cutlery, now an industrial museum (*Friends of the Porter Valley*)

Falling water can also be used to generate electricity, when it is referred to as hydro-electric power (HEP). The first house in the world to be powered by HEP was Cragside, the country home of an industrialist, Lord Armstrong, in Northumberland in 1878. Although a simple water wheel can be used to generate electricity, it is more efficient to use a turbine, where the blades are curved and are confined within a tubular metal casing, as at Cragside. In principle, all it needs is a reliable flow of water and a sufficient "head" of water. The head is the drop in height from the water source to the water wheel or turbine.
This small scale invention rapidly led to the development of HEP on a huge scale and it now makes a major contribution across the world. In fact, the world's top six power stations today, in terms of output, are all hydro-electric.



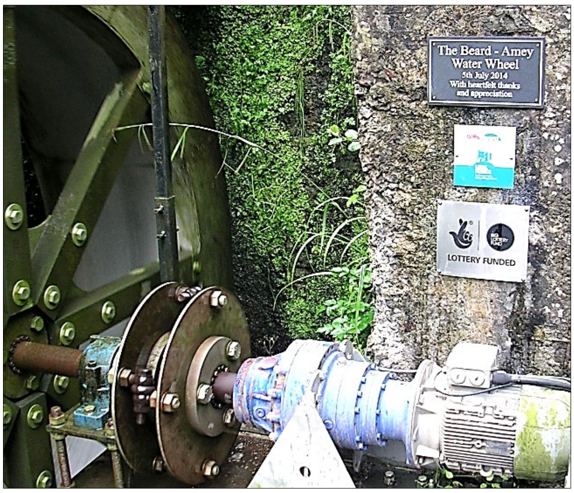
The turbine house at Cragside *(file licensed under the Creative Commons Attribution-Share Alike 4.0 International license)*

Micro-hydro.
However, there is a place for small scale schemes today. Systems suitable for installation by local community groups and villages in the developing world are now available. When the electrical output is between 5kW and 100kW, it is referred to as micro-hydro. The most common methods are water wheels and turbines and Archimedes screws.

Water wheels

Water wheel installed in 2013 at the Forest of Dean Heritage Centre, Gloucestershire (*Photo: P. Kennett*)

Estimate the head of water from the outflow of the dam to the bottom of the wheel, if the height from the lady's feet to the tip of the umbrella is about 1.7m.



Close up of the generator at the Forest of Dean
(*Photo: P. Kennett*)

The micro-hydro equipment in the photographs was installed in exactly the same place below the mill dam as an old water wheel, which had been used to drive a sawmill, before the days of electricity, and which had fallen into decay. Above the dam is a series of old ponds ensuring a good supply of water. The Trustees of the Heritage Centre raised about £50,000 to buy and install the brand new wheel and 7kW generator. The power is used in the Centre and any surplus is fed into the national electricity grid. The Trustees said: "From a green perspective we will be reducing our carbon footprint and generating around £8000 towards our energy costs per annum".
https://www.theforestreview.co.uk/article.cfm?id=942&headline=Water%20sight&sectionIs=news&searchyear=2013
How many years will it take before the generator will recoup the installation costs?

Archimedes Screws

The Archimedes screw has been used for centuries to raise water from a lower level to irrigate fields. The farmer turns a handle at the top of the screw, using human energy, and "winds" the water up. Later, somebody had the bright idea of using falling water to drive the screw in reverse, and connect it up to a generator to produce electrical energy. Such Archimedes screws may be installed below a dam providing a head of water, like the water wheel, or actually in the water of a fast-flowing river without a dam.

The Cragside Archimedes Screw: In addition to the earlier turbine at Cragside, an Archimedes screw was installed recently, fed from a series of lakes. At the time, the National Trust stated, "It will help us meet our target of halving our fossil fuel use and generating 50% of our energy from renewable sources by 2020" (Hydropower returns to Cragside | National Trust)

A new 17m long Archimedes screw installed at Cragside
(file licensed under the Creative Commons Attribution-Share Alike 4.0 International license)

The Dane Valley Archimedes Screw: The Dane Valley Community Energy scheme has installed an Archimedes screw in the river Dane, in Cheshire. There is a head of water of 4m and a steady year-round flow from the river. The total costs of the project are over £600,000, and the 65kW of electricity which it will generate has been bought by a large local firm. As a community project, £5,000 per year will also go to local charities, and provision has been made for education of local children and community groups. The pay-back time is expected to be 20 years.

The River Dane Archimedes screw under construction
(March 2021. *Photo: Peter Lane*)

Suggest some of the advantages and disadvantages of micro-hydro.
Look around your own area and see if you can spot sites where a micro-hydro scheme would work. Suggest local community groups which might get involved in fund-raising to install a water wheel, or Archimedes screw system. Perhaps your own school could build a "pico-hydro" system (Pico-hydro schemes produce from a few hundred watts up to 5kW).

The back up

Title: Small-scale hydroelectric power schemes.

Subtitle: Investigating opportunities for micro-hydro.

Topic: An introduction to electricity generation by micro-hydro schemes.

Age range of pupils: 14 years upwards.

Time needed to complete activity: 30 minutes to work through this activity, but could develop into a long-term class project.

Pupil learning outcomes: Pupils can:
- explain how falling water might be used to generate electricity;
- explain the advantages and disadvantages of micro-hydro installations;
- assess the potential of their own region if they live near flowing water or lakes and ponds.

Context: Government 'net-zero' targets will affect many areas across the world. This activity explores the benefits of cheap, small-scale hydroelectric schemes. Suggested answers to questions above are:
- *The head of water at the Forest of Dean is about 5m. It would only take six to seven years of running the system to recoup the installation costs.*
- *Advantages of micro-hydro include: efficient energy source, requiring a very low head or flow of water; relatively cheap to install; no major reservoir required; minimal environmental impact; zero-carbon operation; surplus electricity can be sold to the national electricity grid; relatively low-tech and therefore suitable for developing countries.*
- *Disadvantages include: low or no power in summer drought or winter freeze; limited scope for expanding the output; need to minimise disturbance to the ecology of the river around the construction site.*

Following up the activity: Encourage the class to undertake a survey of local micro-hydro potential within reach of the school, using non-specialist equipment, to measure flow rates and head of water in their local stream or lake, and thus calculate its potential for generation of electricity.

Underlying principles:
- Falling or flowing water has the potential to generate electricity.
- The controlling factors in power generation are the head of water and the rate of flow.
- Calculations may be made for local situations, using equations available on the internet.
- Simple measurements of flow rate and head are within the capabilities of most schools using simple equipment.
- Micro-hydro schemes are of relatively low cost and are being widely installed in developing countries. They are also being installed in developed countries by local communities or large landowners.
- In 1995, the micro-hydro capacity in the world was estimated at 28 GW. About 60% of this capacity was in the developed world, with 40% in developing areas.

Thinking skill development: Building up an understanding of the potential of micro-hydro 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 activities relating to climate change mitigation or adaptation. A full list is shown on the next page.

Also try accessing:
Micro Hydro Power (MHP) Plants - energypedia.info
https://www.renewablesfirst.co.uk/hydropower/hydropower-learning-centre/how-much-power-could-i-generate-from-a-hydro-turbine/

Resource list:
- paper copies or a screen version of this activity;
- a view from the window, or photographs of the local area.

Source: Written by Peter Kennett of the Earthlearningidea team.
This information was as accurate as possible in spring 2021.

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