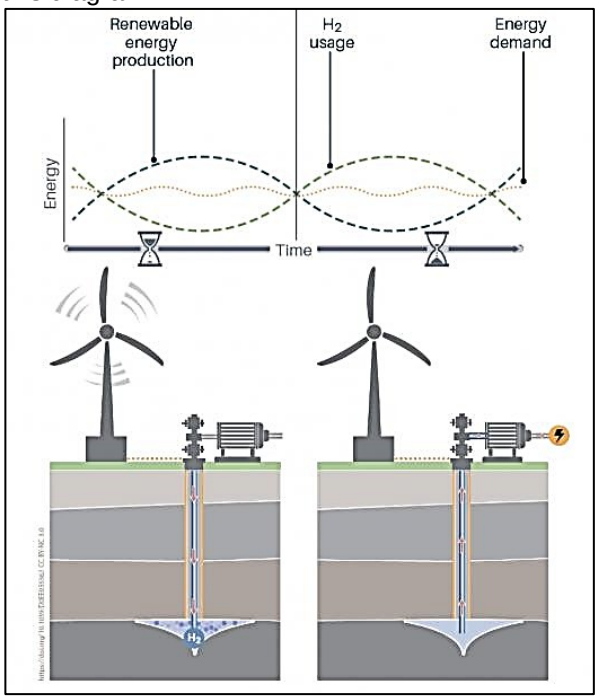
Green hydrogen used to even out renewable energy supplies?

Could 'green hydrogen' be the solution to the efficient use of renewable energy?

One of the problems with using wind turbines to generate renewable energy is that they only work when the wind blows, and when the wind is not too strong. Wind turbines are most efficient at wind speeds of between 17 and 25 m s^{-1} and must be shut down at about 25 m s^{-1} wind speeds (about 94 km/h or 58 mph) to avoid damage.

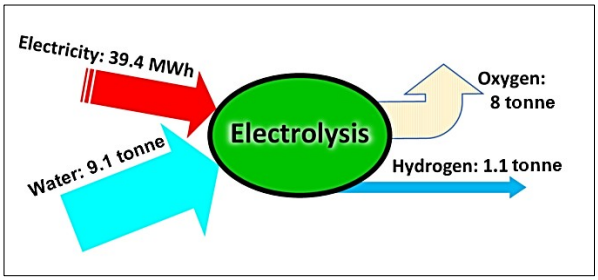
A method to even out this energy flow is shown in this diagram:



(BGS©UKRI CC BY-NC 3.0).

The graph shows that as wind increases, the turbine adds energy to the national grid until demand is reached. After that, the extra energy is used to generate hydrogen which is stored underground. Later, when the wind drops or the turbine is shut down, the stored hydrogen is burnt to generate electricity. This evens out the energy supply, shown by the dotted yellow line on the graph.

Hydrogen can be made in several different ways, but here, where it is made using renewable energy, it is called 'green hydrogen' because there are no harmful emissions involved in its manufacture. The wind turbine produces electricity, which is used for the electrolysis of water, splitting H_2O into its separate components of hydrogen gas (H_2) and oxygen gas (O_2). The process is shown in the diagram opposite:



(By Parent55 under CC0 1.0).

When the hydrogen is later burnt to produce energy the diagram above reverses. The hydrogen burns in oxygen from the atmosphere to drive a turbine to produce electricity; the only waste product is water.

The key to this technology is to be able to store hydrogen gas underground.

It is not enough to store hydrogen in pipelines or tanks, as the supply will only last a few hours or days. So the hydrogen needs to be stored within geological structures, such as salt caverns, old oil- or gasfields or underground traps where oil or gas never accumulated. Salt caverns are ideal for short or medium-term hydrogen storage, but they can only be used in parts of the country where there are salt deposits and these are quite uncommon.

Old oil- or gasfields and non-oil/gas-filled traps are many times larger than salt caverns and so offer a better long-term prospect for hydrogen storage. They need a porous and permeable reservoir rock, an impermeable cap rock and a trap structure to trap the gas underground. However hydrogen stored in underground traps may react with the fluids there or hydrogen-consuming microbes may grow. Since hydrogen has a much lower density than other underground fluids, it may also be prone to leakage or cause unwanted seismic effects too. So research needs to focus on these issues if green hydrogen is to make a real contribution to future energy supplies.

To find out if wind turbines supported by green carbon technology can one day be used in your area, you need to find out:

- whether the area is suitable for wind turbines;
- whether there are salt deposits or underground traps nearby where the hydrogen could be stored.

If this technology could be used in your area, the next question is: Should it be used there?

The back up

Title: Green hydrogen used to even out renewable energy supplies?

Subtitle: Could ‘green hydrogen’ be the solution to the efficient use of renewable energy?

Topic: A discussion of the steps necessary if green hydrogen is to be used to even out future wind-turbine-generated energy supplies.

Age range of pupils: 14 years upward

Time needed to complete activity: 30 minutes if local topographic and geological maps are examined for potential sites; much longer for investigative outdoor visits.

Pupil learning outcomes: Pupils can:
- explain why the energy supply from wind turbines is variable;
- explain how hydrogen can be recovered from the electrolysis of water;
- explain the conditions necessary for hydrogen to be stored underground;
- explain how hydrogen can be burnt to generate electricity;
- investigate local possibilities for wind turbine installation and hydrogen storage and report on their findings.

Context:
Government ‘net-zero’ targets will affect many areas across the world. This Earthlearningidea explores how the contribution of wind turbine technology coupled with green hydrogen might be used to even out renewable energy supplies.

To find out if your local area is suitable for both wind turbines and hydrogen storage you could:
- use local topographic and geological maps to evaluate the possibilities;
- visit a suitable field area to carry out these investigations.

Other issues that should be considered in this discussion are:
- hydrogen leaks very easily because its molecules are so small – much more readily than other gases;
- it is very highly flammable – more so than other gases;
- the electrolyte normally used, sulfuric acid, needs to be treated with care;
- the whole process is only about 80% efficient – the energy losses need to be taken into account.

Following up the activity:
Once generated, hydrogen can be used for other purposes as well as generating electricity to add to national grids. Other uses of hydrogen as a fuel could be explored.

Underlying principles:
- Some renewable energy sources such as wind turbines generate energy only part of the time and at other times generate energy surplus to requirements.
- One way of storing the surplus energy is to use electrolysis to generate hydrogen.
- The hydrogen can then be burnt to generate electricity, with the only waste product being water.
- There are some efficiency losses in these processes.
- This technology requires the hydrogen generated to be stored.
- The storage of hydrogen has particular safety implications.
- There are three medium- to long-term storage options for hydrogen: salt caverns in parts of the country where salt is found; old oil- or gasfields, or underground traps where oil or gas never accumulated.
- Where there are suitable local areas for wind turbines to be built and hydrogen to be stored, this technology could be installed. The next question is: Should it be installed. This question requires debate between installation companies, government and the local community

Thinking skill development:
The class will need investigative skills to apply their learning to the question of whether the method could be used locally. If the answer is positive, they will need to construct an argument to support their views, which is likely to involve both cognitive conflict and metacognition.

Resource list:
- if the exercise is to be carried out in class, topographical and geological maps of the area
- if the exercise is to be carried out in the field, a suitable field venue, taking into account all the precautions necessary for outdoor visits

Useful links:
Visit the Earthlearningidea website to find other activities relating to climate change mitigation or adaptation. The full list can be seen on page 3.

Try putting “green hydrogen” into a search engine like Google to discover more about its potential.

See: https://www.geolsoc.org.uk/hydrogen-economy for more information on hydrogen as a fuel.

Source: Chris King 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