Energy Resources - Renewables, Teachers Notes KS4/S4-5

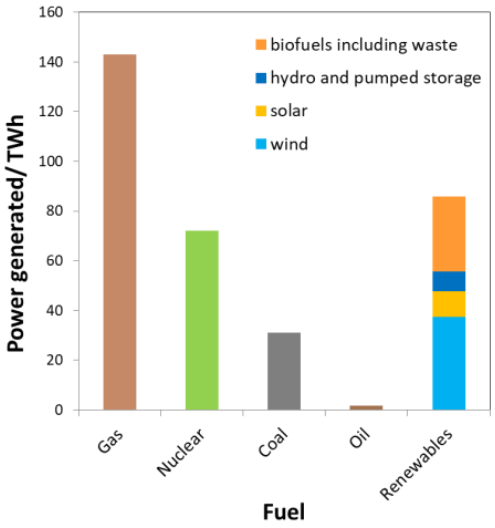
Learning outcomes

- Understand that the UK uses a mixture of non-renewable and renewable energy resources for its energy supply
- Understand that to mitigate climate change, renewables must be incorporated into energy supply.
- Understand and give examples of why, where and how wind, solar, hydroelectric power, geothermal and biofuels are used as renewable energy resources.
- Understand and be able to give examples of renewable energy schemes in other countries to provide sustainable energy

Presenter notes

Some suggested notes for each slide and information for the presenter. Questions the presenter could ask students are highlighted in bold. The Geological Society gives permission for presentations and notes to be adapted to suit the presenter's needs.

Renewable energy resources

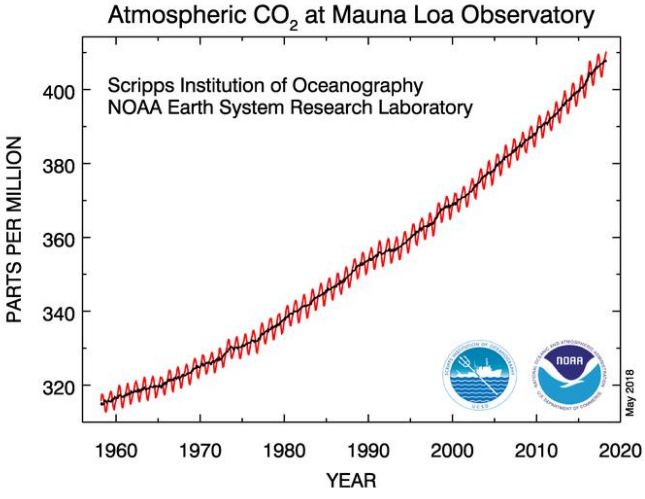


Unlike non-renewable energy sources such as oil, gas and coal, renewable energy sources such as wind power, solar power, wave power and geothermal power will not run out. They can be reused again and again and do not contribute largely to global warming.

24.5% of UK electricity is generated from renewable energy resources largely from wind and biofuels. However most of the UKs power, at 42%, is generated from gas (data from Department of Business, Energy and Industrial Strategy).

Utilizing renewable energy resources is crucial for being able to reduce the amount of CO_2 we are pumping into the atmosphere and oceans so we can try to mitigate dangerous levels of climate change. With an ever increasing energy demand especially in newly developing countries we need to look for different ways of producing energy that is sustainable for future generations and environmentally friendly.

Climate change quick facts (Source: NASA)



Global warming – the Earth's average temperature has risen by 1.1°C since the late 19th century – most of this warming has occurred in the last 35 years at the fastest rate in recorded history. Global warming occurs when carbon dioxide and other greenhouse gases collect in the atmosphere and absorb sunlight and solar radiation that have bounced off the Earth's surface. Normally, this radiation would escape into space—but these pollutants, which can last for years to centuries in the atmosphere, trap the heat and cause the planet to get hotter - the greenhouse effect.

Ocean acidification – CO_2 reacts with ocean water to produce acid ($H_2O + CO_2 \rightarrow H_2CO_3$ (carbonic acid)) lowering the pH of the ocean. When conditions are too acidic corals cannot absorb the calcium carbonate they need to maintain their skeletons and they dissolve and expel the zooxanthella that live within the corals. This is known as coral bleaching and results in the loss of vital reef habitats home to thousands of

species of marine life. Carbon absorbed by ocean surface layers is increasing by 2 billion tonnes every year and coral reefs are suffering ever increasing levels of bleaching.

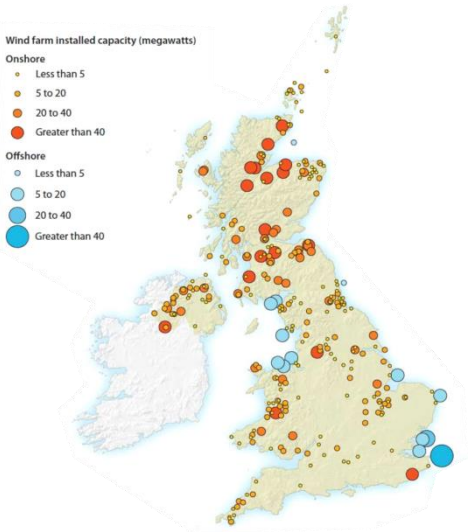
Sea level rise – 3.2mm each year, due to melting ice sheets and thermal expansion of water

Ice sheet mass – Greenland and Antarctic ice sheets are decreasing by 413 gigatonnes each year. Arctic ice - decreasing in mass by 13% each decade

Glacier retreat – glaciers are retreating around the world particularly in the Alps, Himalayas, Andes, Rockies, Alaska and Africa

Wind

Wind turbines are built to harness the kinetic energy of wind. When the wind blows the blades move and spin a turbine connected to a generator which produces electricity. Engineers do a lot of measurements and calculations before they build wind turbines to figure out the best areas to place them. The wind doesn't blow all the time but the important thing is how much the wind blows on average. In order to create enough energy capable of powering thousands of homes, energy companies build large wind farms either offshore or onshore with lots of wind turbines. The UK currently has 8,680 wind turbines (2018) with a capacity for 18.4 gigawatts of power making it the 6th largest producer of wind power in the world. In 2017 17% of UK electricity was generated from wind power. One major issue that people have with wind turbines is that they can ruin the look of the landscape; they can also be harmful to birds that might fly into them.

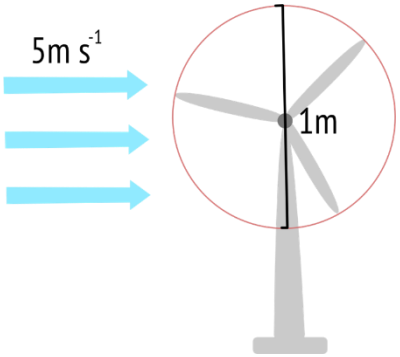


The amount of power, and therefore electricity, a wind turbine can produce is largely based on wind velocity using this equation:

Power (Watts) = ½ ρAV^3

ρ = air density; ~1 kg m^{-3}
A = swept area (π r^2)
V = velocity (m s^{-1})

0.5((π × 0.5^2)(5^3)) = 49.1 W
0.5((**π** × 0.5^2)(10^3)) = 392.7 W

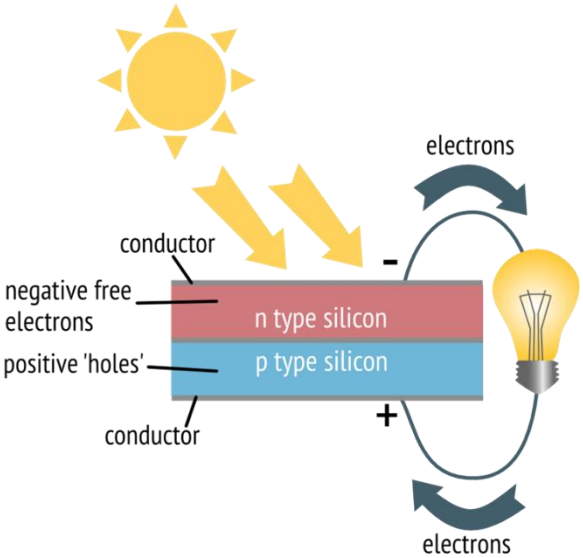


Note because the velocity is cubed in this equation, doubling wind speed causes an eight-fold increase in power.

Solar

Solar power is generated directly from sunlight (photons). Solar thermal panels are filled with water which heats up in the sunlight. The heated water is then pumped through a tank heating the water that is connected to the taps in the house.

Solar photovoltaic (PV) cells use the suns energy to convert are made from two layers of silicon crystal. When photons hit the top layer of silicon they 'excite' the negatively charged electrons in the silicon atoms giving

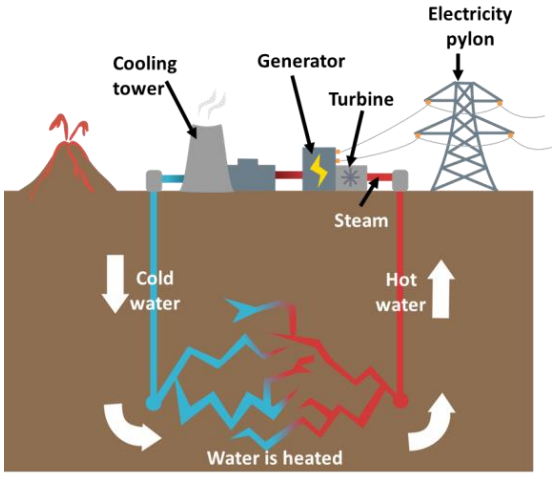


them enough energy to move towards the positively charged lower layer, inducing an electrical current.

In 2017 3.4% of electricity generated in the UK was done so using Solar PV (11,479 GWh)– electricity generated by renewables in total was 29%. UK solar potential - the south of the UK has comparable sunlight with that of central European countries, including Germany, which generates about 7% of its total electricity from solar power.

Solar power has no fuel costs, does not produce greenhouse gases and can provide electricity to remote areas. However, because PV cells require rare metals like cadmium and indium, they are very expensive. The average house in the UK uses around 3kW of energy each year – you would need between 12-15 PV cells to generate this much power. And although more efficient PV cells are being developed, currently they can only process 15-25% of the sun's energy into electricity, making electricity generated from solar power expensive.

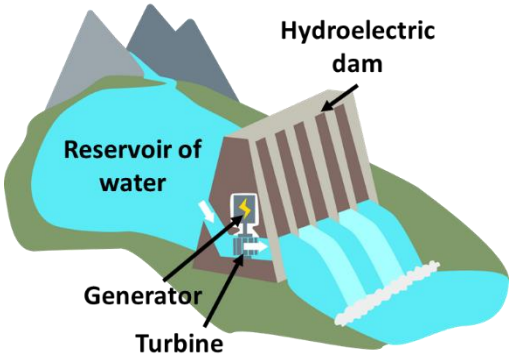
Geothermal



Geothermal energy is heat energy from the Earth generated by the decay of radioactive elements and residual heat from the Earth's formation 4.5 billion years ago. Hot springs have been used since Palaeolithic times for bathing and the Romans harnessed geothermal energy for underfloor heating and to heat their public baths, however nowadays geothermal energy is better known for electricity generation. To use geothermal energy water is pumped down into hot rocks through pipes where is it heated. When this water and steam comes back up to the surface it can be used directly to heat people's homes, buildings, greenhouses etc., or the steam can be used to generate electricity through spinning turbine connected to a generator. Geothermal energy can only be harnessed where the rocks are hot enough. This initially was only at plate boundaries as hot rocks tend to be much closer to the surface in these situations e.g. in Iceland, New Zealand, Japan, the Philippines, Indonesia and Italy. However technology improvements in the last 20 years have increased the geographical range so that electricity generation by geothermal energy is no longer limited to plate boundaries.

Geothermal in Cornwall Hot granite beneath Cornwall, known as the Cornubian Batholith (formed around ~280 million years ago in the Variscan orogeny) gives Cornwall the highest heat flow in the UK - the granite at 4.5km beneath Cornwall is ~ 190 ˚C . The United Downs Geothermal Energy Project has secured funding to build a pilot geothermal energy plant in Cornwall (£10.6 million - European Regional Development Fund, £2.4 million - Cornwall Council, £5 million - private investors). It is estimated that it will be able to produce 10MW of electricity and 55MW of renewable heat. Geothermal energy beneath Cornwall could meet all of Cornwall's demand for electricity and up to 20% of the UK's demand so it is an important area of research.

Hydroelectric



Hydroelectric power harnesses kinetic energy from running water. Hydroelectric dams are built to store large amounts of water in reservoirs made from flooding river valleys.
When electricity is needed, water is let out through pipes in the dam. The water flows downwards under the influence of gravity and turns turbines linked to generators to generate electricity. Hydroelectric power is more reliable than wind and solar power, although they are expensive and depend on finding a suitable valley site to build and flood. This in turn effects the people and animals living there as well as impacting on the migration patterns of fish. Mountainous regions like the Scottish highlands and North Wales are good for hydroelectric power because they have steep topography and high rain fall. The UK currently generates about 1.5% of its electricity from hydroelectric schemes - most of which are in the Scottish Highlands.

Biofuels

Biofuels are fuels produced from biomass either directly from plants or indirectly from agricultural, commercial, domestic and/or industrial waste. Biofuels can be made quickly so they are considered renewable energy resources. The two main types of biofuel produced are bioethanol and biodiesel:

- Bioethanol is an alcohol made by fermentation of crops such as corn, sugarcane and sweet sorghum. It is used as a petrol additive to increase octane and lower carbon emissions or can be used directly as a fuel.
- Biodiesel is an oil-based biofuel produced from vegetable fats such as rapeseed, sunflower seed, soya bean and palm oil. It is used to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles or directly to fuel vehicles.

In 2015, biofuels accounted for 4% of total transportation fuels worldwide. The global production of biofuels is dominated by the US and Brazil – producing 72% of all biofuels in 2015 – followed by Europe (EU–28), which produced 12%.

Theoretically biofuels could be carbon neutral - they absorb as much carbon dioxide from the atmosphere whilst they are growing as they give off when they are burnt. However, at present, because fossil fuels are used in the production of biofuels (producing fertilizer, fuelling farm equipment) they are not carbon neutral, although they do still release less CO_2 and other GHGs than burning fossil fuels directly. There are ethical issues surrounding the use of biofuels

- issues with food competition and security as crops that could be used to feed people are being used to provide the raw materials for biofuels.
- Deforestation of rainforest to make space for large scale biofuel crops
- land-use change reduces biodiversity and can lead to an increase in pests

The main sources of biofuel in the UK are wheat and used cooking oil. In 2016, 93,000 ha of land was used to produce crops for biofuels, 41,000 ha of this land was to grow wheat (source: DEFRA). If all the extra emissions involved in changing land use to grow wheat were accounted for, biofuel based on wheat was actually worse for the environment than regular petrol or diesel in 2016 (Sustainability of liquid biofuels, Royal Academy of Engineering). The UK produces 16 million tonnes of waste each year – Royal Academy of Engineering suggest that it should focus on using waste fuels like chip fat, landfill gas, forest and sawmill residue, whiskey manufacturing dregs and even sewer 'fatbergs' instead of wheat. RAE recommends that the UK government set a cap for all crop-based biofuels to limit the use of farmland for wheat.

Case studies: Iceland

Iceland lies on the Mid Atlantic Ridge, a region of sea floor spreading at a divergent plate margin. Due to it's tectonic setting Iceland is very volcanic and the rocks beneath its surface are hot. Iceland also gets high rainfall, much of which filters down into the Earth's crust through cracks and pores. hereit is naturally heated by the hot surrounding rocks and it then travels upwards to the surface. Sometimes this hot water explodes out as geysers other times it creates hot springs like the Blue Lagoon. Iceland has over 200 extinct and active volcanoes (~30), 600 hot springs and 20 high-temperature steam fields that are at least 150 °C. Iceland currently generates over 85% of heating and 27% of its electricity from geothermal energy. Iceland's mountainous and glacial geography also means that it can also generate 70% of its electricity from hydropower from glaciers and rivers in the interior of the country.

The move from oil-based heating to geothermal heating saved Iceland an estimated $8.2 billion from 1970 to 2000 and lowered the carbon dioxide emissions by 37%. However Iceland is still dependent on fossils fuels for its shipping boats, cars and buses – this reliance actually makes it one of the highest emitters of CO_2 per capita (because of its very small population of ~320,000). Research is underway into using hydrogen fuel cells to power buses and cars – so that Iceland can be 100% renewable.

Costa Rica

Costa Rica has a high concentration per capita of rivers, dams, and volcanoes, and 4th highest rainfall per capita: average 2,926 mm/year, excellent features for renewable energy generation. The elimination of Costa Rica's military in 1948 freed up millions of dollars which is now invested in social programs and renewable energy generation. In 2017 renewable energy supplied 99% of electricity in Costa Rica, 78% of which was HEP. For 300 days in 2017 Costa Rica generated all of its electricity from renewable energy sources. Lake Arenal Dam, built in 1979, was Costa Rica's first dam intended solely for hydroelectric power usage. It provides enough electricity to power 12% of Costa Rica.

Whilst 99% electricity in Costa Rica is from renewables which but 70% energy consumption in Costa Rica is from transport which runs on petroleum. Costa Rica has 287 cars per 1,000 people, greater than the world and Latin American average. Growth in car ownership has also made San José, the capital of Costa Rica, the most congested city in Latin America. Costa Rica hosts more than 5% of the world's species biodiversity despite a landmass that covers 0.03% of the planet. While dams provided the majority of the country's electricity, they can have destructive environmental and social consequences, such as affecting previously healthy rivers, disrupting wildlife and displacing indigenous communities.

Brazil

Sugarcane has been grown in Brazil for hundreds of years and at present Brazil is the 2nd largest producer of bioethanol after the US. In 2016 Brazil produced 7.295 billion US gallons of ethanol from sugarcane, making up 27.4% of the world's total ethanol production. Brazil has replaced 42% of its gasoline needs with bioethanol and 90% of new cars sold today in Brazil are 'flex fuel', meaning they can run on either gasoline or pure ethanol, due to consumer demand. Since 2003, the combination of sugarcane ethanol and flex fuel vehicles has reduced Brazil's emissions of carbon dioxide by more than 350 million tons.

Growing sugar cane for ethanol has resulted in greater demand for rainforest land raising concerns about deforestation and biodiversity. Ethanol was badly hit in the global recession of 2008 as the Brazilian government gave subsidies to petrol - but is now recovering. Direct emissions from bioethanol are up to 90% lower than those of gasoline or diesel fuels but indirect emissions associated with production and land clearing for sugarcane cropping vary greatly and can be significant. Sugarcane production use lots of water - up to 4 litres of water are needed to produce 1 litre of ethanol produced.

Other useful resources

Energy resources – non-renewable energy presentation: www.geolsoc.org.uk/Education-and-Careers/Resources/Activity-Sheets-And-Presentations

Energy resources activity: www.geolsoc.org.uk/Education-and-Careers/Resources/Activity-Sheets-And-Presentations

Energy factsheets: www.geolsoc.org/factsheets

NASA YouTube video showing planet warming: www.youtube.com/watch?time_continue=9&v=s3RWTTtPg8E

Current UK power being generated by wind - www.thecrownestate.co.uk/energy-minerals-and-infrastructure/offshore-wind-energy/offshore-wind-electricity-map/