WJEC (Wales) Physics GCSE

1.2: Generating Electricity

Detailed Notes

(Content in **bold** is for higher tier **only**)

Energy Sources

Over the last 200 years the demand for electricity has **increased exponentially** as the world has become more developed. This electricity is mainly produced from **non-renewable** sources, however, as stores of these become **depleted**, we require more **renewable** energy sources to supply the electricity required.

Non-Renewable Sources

These energy sources will eventually **run out** as they are not being replaced at a fast rate.

Fossil Fuels

Coal, oil and gas are common non-renewable resources known as **fossil fuels**. When burned, fossil fuels transfer stored **chemical** energy into **heat** energy that produces steam to drive turbines for generating electricity.

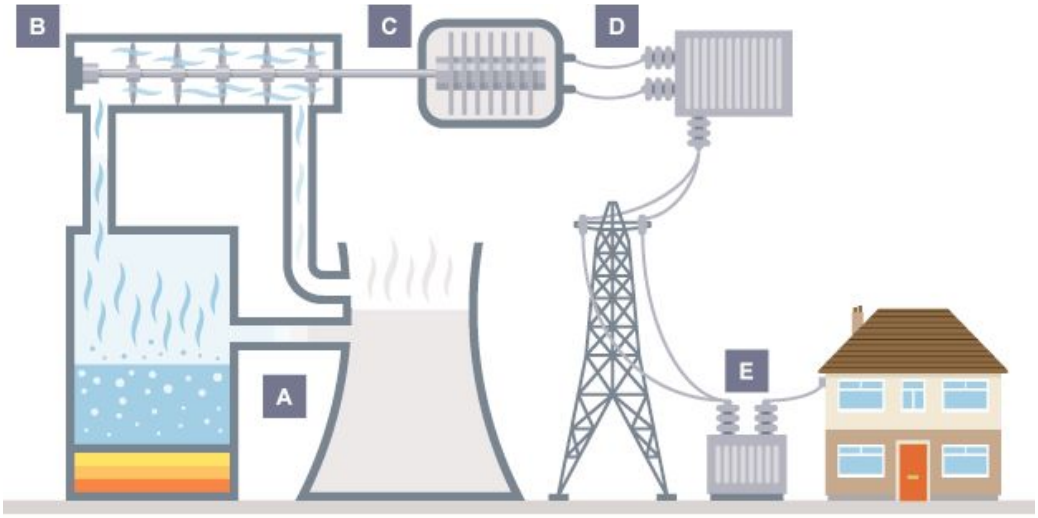


Diagram explaining how fossil fuels can be burnt to produce electricity (bbc.co.uk)

Advantages

- Release **lots of energy** when burned.
- A lot of the world's infrastructure is built to rely on them.

Disadvantages

- **Not sustainable**.
- Release **toxic gases** into the atmosphere which are harmful for the environment.

- Release **greenhouse gases** such as **carbon dioxide** into the atmosphere promoting **Global Warming**.

Nuclear Power

Nuclear power stations use **unstable (radioactive) elements** such as plutonium and uranium undergoing **nuclear decay (fission)** to heat water. This water produces steam which can turn electricity generators. Similar to burning fossil fuels, **heat energy** is produced which facilitates the transport of hot gas (**kinetic energy**) that drives turbines generating electricity (**electrical energy**). Although the energy source of nuclear power is itself renewable, the **waste products** produced are dangerous and cannot be easily treated or safely stored. Therefore it is generally considered to be **non-renewable**.

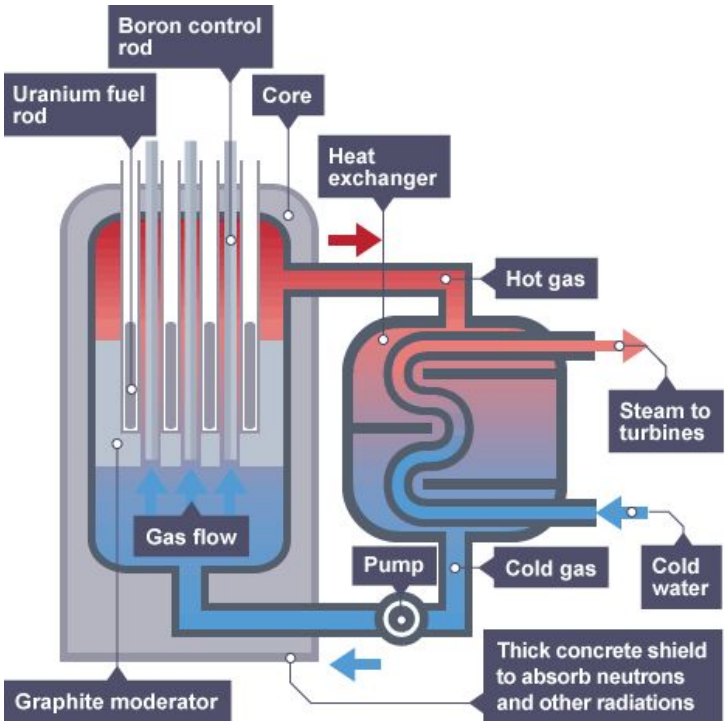


Diagram showing the components of a nuclear reactor system (bbc.co.uk)

Advantages

- Nuclear energy sources are **very efficient**.
- They produce **lots of energy** from just a small amount of material.
- **No harmful gases** are released.

Disadvantages

- **Nuclear waste** is produced that remains **radioactive and harmful** for a long time. This material could be catastrophic if released into the environment through a nuclear reactor accident.

Renewable Sources

These energy sources are **replaced** at a much faster rate or are **infinitely available**. They are much more **sustainable** but can be **difficult to harness** to the extent required and often only facilitate energy production at a much slower rate.

Wind

Currents in the Earth's atmosphere can be used to turn **wind turbines** that directly turn an **electrical generator.** Without wind no electricity can be generated, and often many turbines are required to generate the electricity required.

Advantages

- **No fuel cost** (wind is free).
- **No harmful gases** are produced.

Disadvantages

- Eyesore.
- Can be noisy.
- Amount of electricity generated is dependent on the **wind intensity and direction** i.e. the electricity source is inconsistent and not entirely dependable. If there is negligible wind, no electricity will be generated.

Solar Power

Light and Heat energy released as a result of **nuclear fission** in the sun can be harnessed to generate electricity. Solar cells (**photovoltaic** cells) transfer **light energy** into electrical energy, whereas solar panels use **heat energy** to **heat water** that can then be used in a domestic setting. They are good for **small scale** energy generation but require direct sunlight to work well.

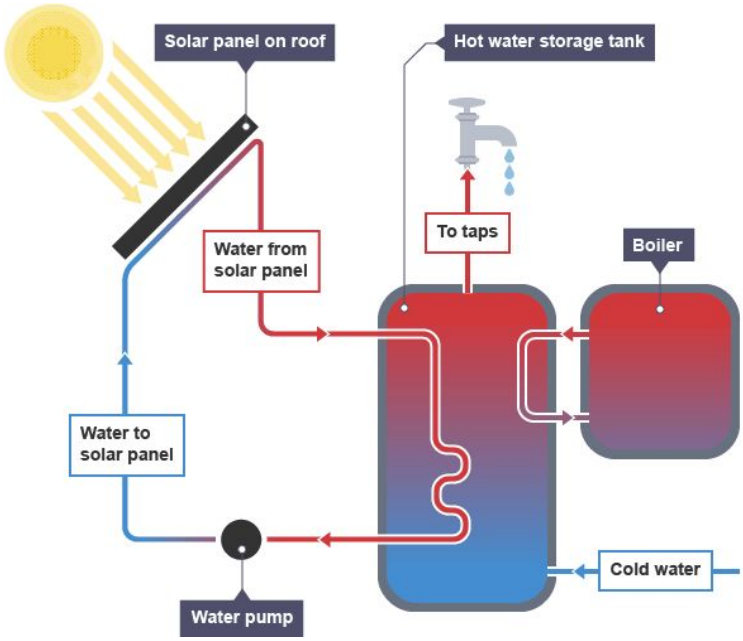


Diagram showing how solar panels can be used to heat water (bbc.co.uk)

Advantages

- **No fuel costs** (sunlight is free).
- **No harmful gases** are produced.

Disadvantages

- **Expensive and inefficient**.
- Does not work at night.

Tidal, Wave and Hydroelectric Power

Tidal barrages are built in river estuaries. These force water through **turbines** as the tide rises and falls, generating electricity. Kinetic energy from moving waves can also be harnessed in a similar fashion. **Hydroelectric power** (HEP) is generated when water with gravitational potential energy is dropped from an elevated store through a dam. The **potential energy** is transferred to **kinetic energy** again driving turbines and generating electricity (**electrical energy**).

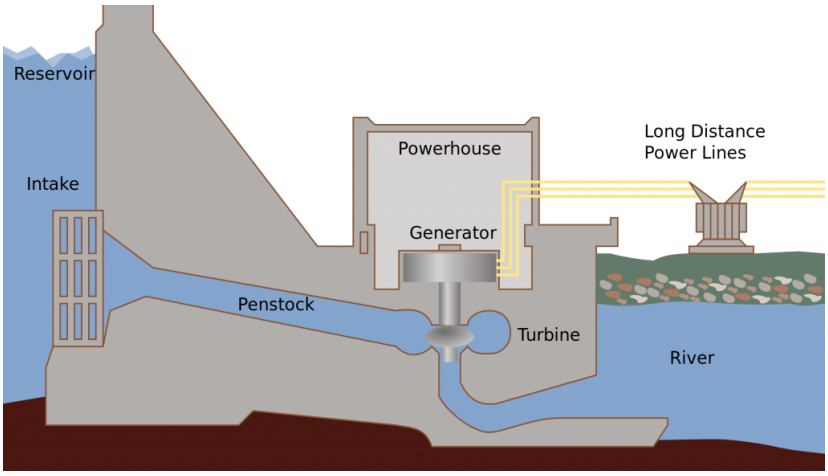


Diagram showing a hydroelectric dam system (studyrocket.co.uk)

Advantages

- **No fuel costs** (the movement of the tides and waves, and the water cycle are natural processes).
- **No harmful gases** are produced.
- **Reliable** source of energy (tides are particularly predictable).

Disadvantages

- Has been difficult to up-scale wave machines preventing it from becoming a more significant energy source.
- Building dams and tidal barrages can **destroy the habitat** of river and estuary species, **disrupting entire ecosystems**.
- Building dams and barrages can flood farmland **removing people from their homes** and forcing relocation upon them.
- Rotting underwater vegetation as a consequence of flooding **releases methane**: a greenhouse gas, into the atmosphere.

Biomass

Some energy sources are considered to be both **renewable and non-renewable**, such as **biomass**. Biomass energy is derived from **burning organic material**. Like fossil fuels it can be used to **produce electricity** in a power station or as a **direct heat source**. Biomass power stations operate in a similar manner to fossil fuel power stations i.e. heat from burning is used to boil water, producing steam which drives turbines generating electricity. Trees are grown and felled to produce material for burning.

Advantages

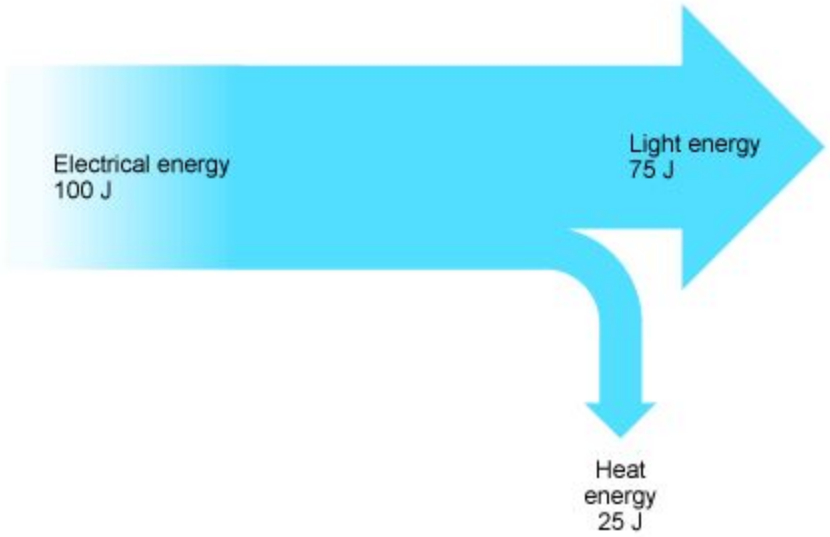
- **Carbon neutral**. Carbon released into the atmosphere was originally removed from the atmosphere during the growth of the tree.
- **Can be produced/grown locally** reducing inefficiencies/costs/emissions associated with transport.

Disadvantages

- **Doesn't burn as efficiently** as fossil fuels.
- Still **releases some harmful gases** into the atmosphere.
- Requires vast amounts of wood-farming space to be done on a large scale.

Sankey Diagrams

These are used to show the different **energy transfers** that take place during a process, and can also be used to **estimate efficiency**. Sankey diagrams are drawn **'to scale'** meaning a bigger line represents a greater value than a smaller line.



Example sankey diagram showing energy transfers (pintrest.com)

In the example above, the input electrical energy is mainly transferred to light energy and a small amount to heat energy. This is typical of a light bulb where the heat energy is **wasted energy**. Sankey diagrams make it clear to see the proportion of energy that transfers to useful or wasted energy, allowing **efficiency** to be calculated.

Modern LED bulbs produce more light energy compared to heat energy as they are **more efficient** than older filament bulbs that produce more wasted heat energy than light.

Efficiency

The efficiency of a device is measured as the proportion of the energy supplied that is transferred into **useful** energy. It can be calculated as a percentage of the input energy:

$$\%\ efficiency = \frac{useful\ energy\ (power)}{total\ input\ energy\ (power)} \times 100$$

The **greater** the percentage, the **more efficient** the device and therefore the more useful energy produced.

The National Grid

The National Grid is a system of **power lines** and **transformers** linking **power stations** to consumers across the UK. It allows electricity to be transferred for domestic use.

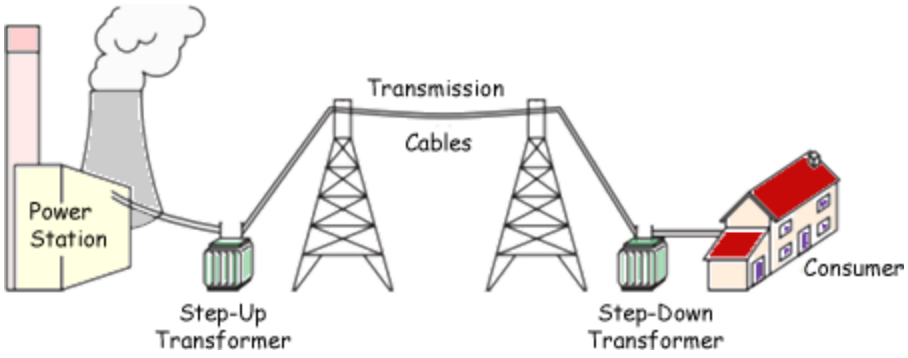


Diagram showing the components of The National Grid (cyberphysics.co.uk)

Transformers

Power stations produce electricity at **25,000 V**. This power station voltage needs to be transformed to a **higher** power line voltage to **reduce the current** ($P=IV$). Reducing the current will **reduce the amount of energy lost** through heat in the power lines. Step-up transformers can increase the voltage to up to **132,000 V**.

Step-down transformers then **reduce** the voltage back to a **safe level** ready for domestic use. Household electricity has a voltage around **230 V**.