



# Cambridge (CIE) IGCSE Physics



Your notes

## Energy Sources

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- \* Energy from the Sun
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- \* Energy from Water
- \* Geothermal Energy
- \* Nuclear Fusion



# The Sun

### Extended tier only

- The Sun transfers energy to Earth by **electromagnetic radiation**
- Most of our energy resources on Earth come indirectly from the **Sun**:
  - The Sun heats up the atmosphere, creating **wind** and producing **waves**
  - Water evaporated by the Sun falls as rain, filling up **reservoirs**
  - Plants grown using sunlight form the basis for fuels – both biofuels and fossil fuels
- Some energy resources, however, do not come from the Sun
- These include:
  - **Geothermal** – this comes from heat produced in the Earth's core
  - **Nuclear** – this comes from elements which make up a small proportion of the Earth's crust
  - **Tidal** – this comes (mainly) from the gravitational attraction of the Moon

## The Sun



*Energy from the Sun is the source of the energy stored in many of Earth's energy resources*

## Solar cells

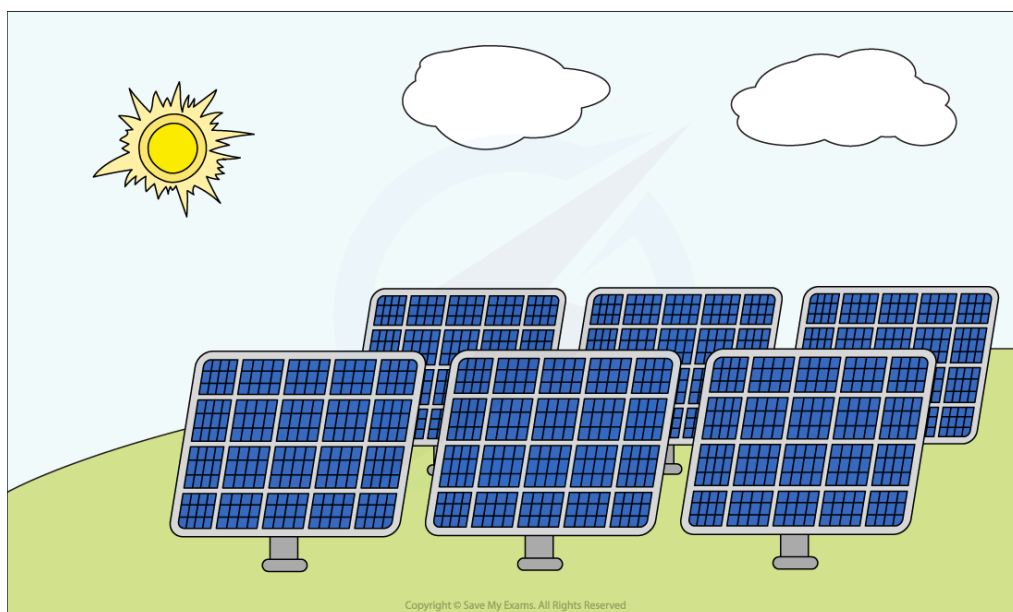
- The energy from the Sun that falls on the Earth is transferred by radiation
  - Mostly **visible light** and **infrared radiation**



Your notes

- The amount of energy transferred from the Sun to the Earth **each hour** is equal to the energy use of the world for **one year!**
- Therefore, scientists are working hard to find methods of harnessing this energy
  - Solar energy has a **low energy density**, which means large collecting devices are required
  - Collecting solar energy has been **expensive** (due to the equipment required) and **inefficient**
  - Although **improved technology** has improved efficiency, **greater demand** has lowered costs
- **Solar cells** transfer energy from sunlight and produce a current, therefore generating **electricity**
  - Solar cells, sometimes called photovoltaic cells, are made of semiconducting materials
  - A number of cells connected together can supply electricity to homes, small-scale businesses, communication devices and satellites
  - Energy generated from solar cells can be stored in batteries for later use

## Solar cells



*Solar cells use energy from sunlight to produce electricity*

## Advantages of solar cells

- Solar energy is a **renewable** resource
  - A **renewable** resource is one which can be **replenished at the same rate as it is used**



- In many places on Earth sunlight is a **reliable** energy resource (this means that the sun shines most of the time)
- Solar farms produce no **greenhouse gases** or **pollution**
- Solar energy can be generated in **remote places** where they don't have electricity
  - For example to power solar street signs in rural areas
- Solar cells are readily available
- Solar farms are relatively quick and cheap to build, and inexpensive to run compared to power stations
- Solar cells can be placed on top of buildings

## Disadvantages of solar cells

- Solar farms need to be **large scale** to produce large amounts of electricity
- In many places on Earth, sunlight is **not** a **reliable** energy resource (there are not enough sunshine-hours to justify the set-up costs)
- Solar cells remain fairly expensive for households to install and maintain (they must be kept clean to work at full capacity)
- Each solar cell only produces a small amount of electricity so solar farms are needed to produce large amounts of electricity
- Solar cells are relatively inefficient (around 20% - 40%)

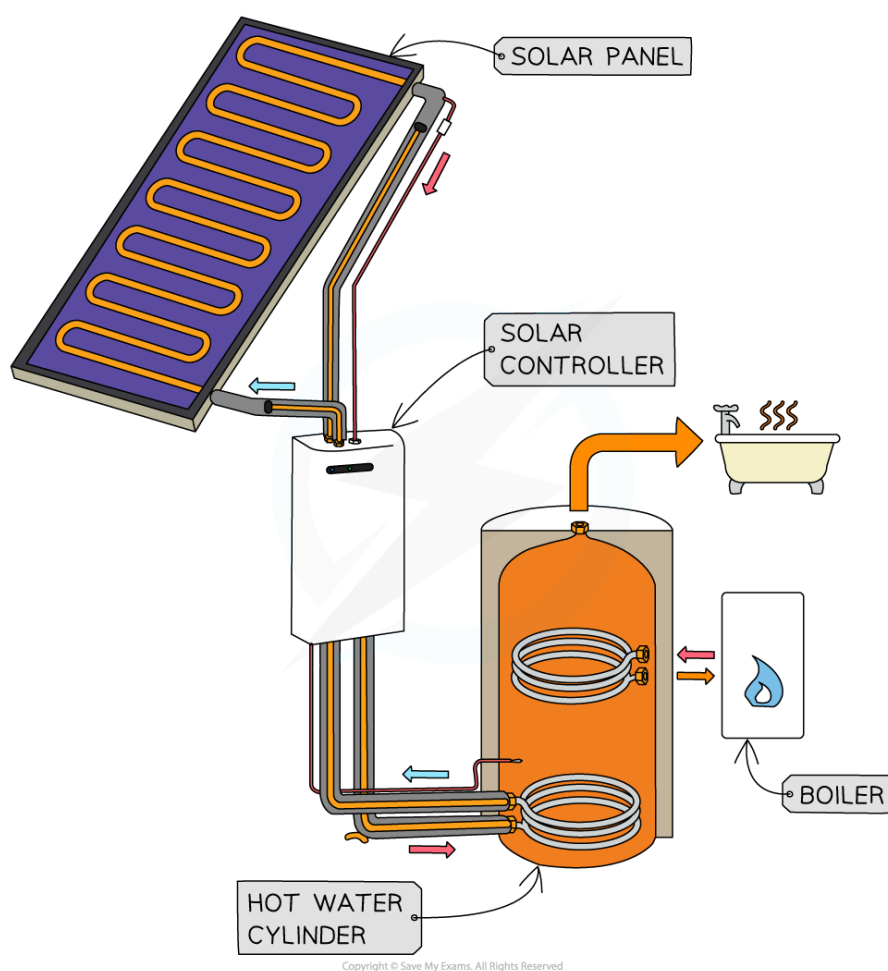
## Solar panels

- Useful energy may be obtained from infrared and other electromagnetic waves from the Sun using **solar panels**
- **Solar panels** transfer energy from sunlight to the thermal store of the solar panels which is used to **heat water** in the pipes
  - Solar panels can be used to warm domestic water supplies
    - This can reduce the cost of producing hot water since it is heated partially by the solar panels
  - **Solar furnaces** consist of large curved mirrors that focus the sun's rays on to a small area
    - These can be used to boil water, generating enough steam to turn turbines and generate electricity in a power station

## Solar panel



Your notes



### *Solar panels use energy from sunlight to heat water*

- Water is **stored** in a water **tank** and pumped through small **pipes** running through the solar panel
- **Infrared radiation** from the Sun heats the water in the pipes as it flows through them
- The water returns to the tank at a **higher temperature**
- Water may still need to be heated further to reach the desired temperature (eg. for a shower)

## Advantages of solar panels

- Solar energy is a **renewable** resource
- In many places on Earth, sunlight is a **reliable** energy resource (this means that the sun shines most of the time)
- Solar panels produce no **greenhouse gases** or **pollution** once they are operating
- Solar panels can cut the cost of energy bills for households
- Solar panels can be placed on the roofs of buildings

## Disadvantages of solar panels

- Solar furnaces need to be large scale to produce high temperatures
- Energy is still needed to heat water to a higher temperature in domestic households
- In many places on Earth, sunlight is **not** a **reliable** energy resource (the sun doesn't shine regularly enough to justify the set-up costs)



Your notes

## Wind energy

- Energy from the **wind** can be used to generate **electricity**
- The wind turns a **turbine**, which turns a **generator**, which generates electricity
- Energy from the kinetic store of the wind is transferred
  - mechanically to the kinetic store of the turbine
  - which is transferred mechanically to the kinetic store of the generator
  - which is transferred electrically to the National Grid

### Wind turbines



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## Advantages of wind power

- Wind is a **renewable** resource
- Wind turbines produce **no** greenhouse gases or pollution
- Wind farms are relatively **inexpensive** to build and cheap to run
- Wind turbines have a relatively high **efficiency** of 50%
- The land used for wind farms can still be used for **farming**
- **Off-shore** wind farms can be built in coastal areas
- Wind turbines do not use fuel, so there are no fuel costs

## Disadvantages of wind power

- Wind power is **not reliable** because the wind does not blow constantly
- Turbines are built facing a specific direction so they only work when the wind is blowing in that specific direction
- Some people consider wind farms to be **visual pollution**, so there can be local opposition to the construction of wind farms in some towns and cities
- Each turbine only produces a small amount of electricity, so wind farms are needed for large scale electricity generation
- High-voltage power lines are required to transmit the electricity to the National Grid



### Examiner Tips and Tricks

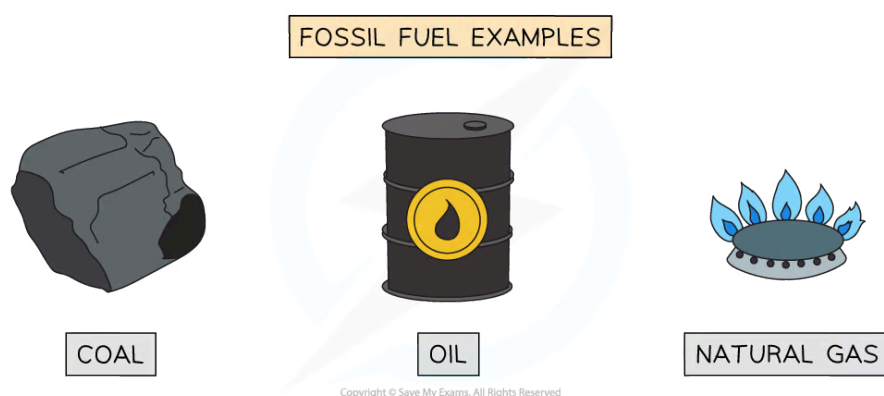
In your IGCSE exam, you may be required to discuss the advantages and disadvantages of energy resources. You may also need to apply your understanding of energy resources to unfamiliar scenarios, for example, by suggesting which type of energy resource would be best for a particular community. Make sure you can justify your choices.



# Fossil fuels

- Fossil fuels are:
  - **Coal**
  - **Natural gas** (mostly methane)
  - Crude **oil** which is refined into petrol, diesel, and other fuels

## Fossil fuels



### *Fossil fuels: coal, oil and natural gas*

- Fossil fuels are formed from the **remains of plants and animals**
- **Chemical energy** stored in fossil fuels originally came from **sunlight**
  - Energy from the sun was transferred to the chemical energy store of plants by photosynthesis (plants use energy from sunlight to make food)
  - Animals ate the plants and the energy was transferred to their chemical store

## Advantages of fossil fuels

- Fossil fuel power stations are **extremely reliable** and the infrastructure is well established in most countries
- Fossil fuel power stations are **extremely responsive** (they can be turned on and off easily), which means they can meet the changing demands of a nation
- Fossil fuels are relatively **safe** to store and use

## Disadvantages of fossil fuels

- It takes **millions of years** for fossil fuels to form
  - This is why they are considered to be a **non-renewable** energy resource





Your notes

- The increasing demand for a **decreasing supply** causes prices to increase
- Fossil fuels are predicted to **completely run out** within the next 200 years
- Burning fossil fuels pollutes the atmosphere with harmful gases such as:
  - **Carbon dioxide** which contributes to the **greenhouse effect**
  - **Sulphur dioxide** which produces **acid rain**
  - Both carbon and sulphur can be captured upon burning, preventing it from being released into the atmosphere but this is expensive to do
- Extraction of fossil fuels causes **damage** to the **environment**
- Fossil fuel power stations are **expensive** to build and decommission (close down)
- The **price** of fossil fuels is **volatile**, which means the price of the electricity produced can fluctuate based on global factors of supply and demand

## Uses of fossil fuels

- Fossil fuels are used for:
  - Transport
  - Generating electricity
  - Heating

## Transport

- The majority of vehicles in the world are powered by **petroleum** products such as petrol, diesel and kerosene
  - These resources all originate from crude oil, which is a **fossil fuel**
- A growing number of vehicles are now being powered by **electricity**
  - The advantage of this is that while the vehicle is being driven, it produces **zero carbon emissions**
  - The disadvantage is that when the vehicle is being charged, it is connected to the National Grid, which currently uses a **combination** of renewable and non-renewable energy sources

## Electricity generation

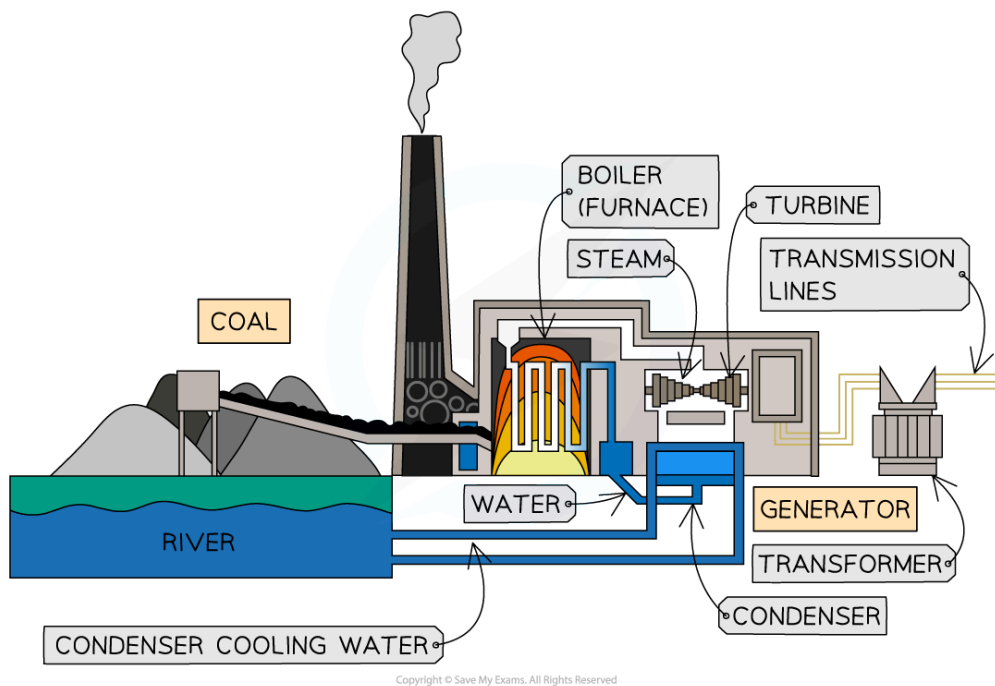
- Fossil fuels, such as **gas** and **coal**, are used to produce energy **on-demand** when energy is needed
  - The fossil fuel is burned (combusted) and used to heat water to produce **steam**
  - The steam turns a **turbine**
  - The turbine turns a **generator**, which generates electricity
  - The current produced is transmitted via the **National Grid**

- The steam is condensed into water to be used again



Your notes

## Electricity generation in a coal-fired power station

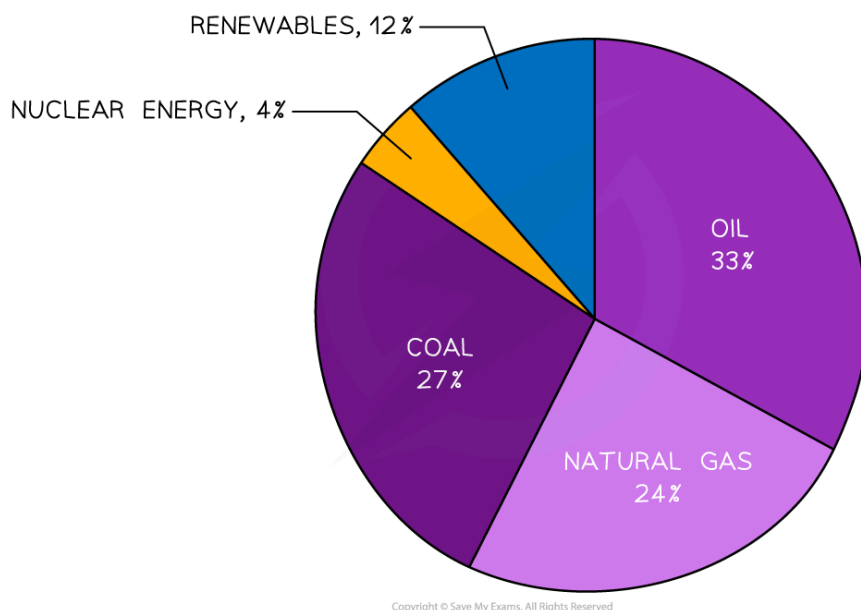


*Fossil fuels are burned to heat water to produce steam. The steam turns the turbine, which turns the generator, which produces electricity.*

- Electricity plays a bigger role in people's lives than ever before
  - With almost 8 billion people in the world, this means the **demand** for electricity is **extremely high**
  - To keep up with this demand, a combination of **all** the energy resources available is needed

## Global energy consumption

PRIMARY GLOBAL ENERGY CONSUMPTION 2019



Your notes

*Currently, more than three quarters of the global electricity production uses fossil fuels; this is increasing the levels of atmospheric carbon dioxide, which leads to global warming*

## Heating

- The majority of heating systems run on **fossil fuels**
  - **Gas** central heating systems are the most common, with a gas boiler that heats water through a system of pipes and radiators throughout the building
  - Boilers can also be powered by **oil** or biofuels
  - Open fireplaces burn wood or **coal**
- Electric heaters run on electricity
- Bottled gas can also be used in portable heaters
  - Bottled gas is either **propane** or **butane** which are also produced from fossil fuels

## Biofuels

- Biofuels are made from plant matter
  - Energy from sunlight is transferred to the **chemical store** of plants
- **Ethanol** or **methane** can be produced and used in place of fossil fuels
  - However, they have only half the **energy density** of fossil fuels

## Advantages of biofuel



- Biofuel is a **renewable resource**
- Some vehicles can be powered by **biofuel** rather than using fossil fuels
- Biofuel is considered to be **carbon neutral**
- No sulphur dioxide is produced
- Biofuel is added to petrol and diesel products in many country to **reduce** the volume of **pollutants** released in combustion

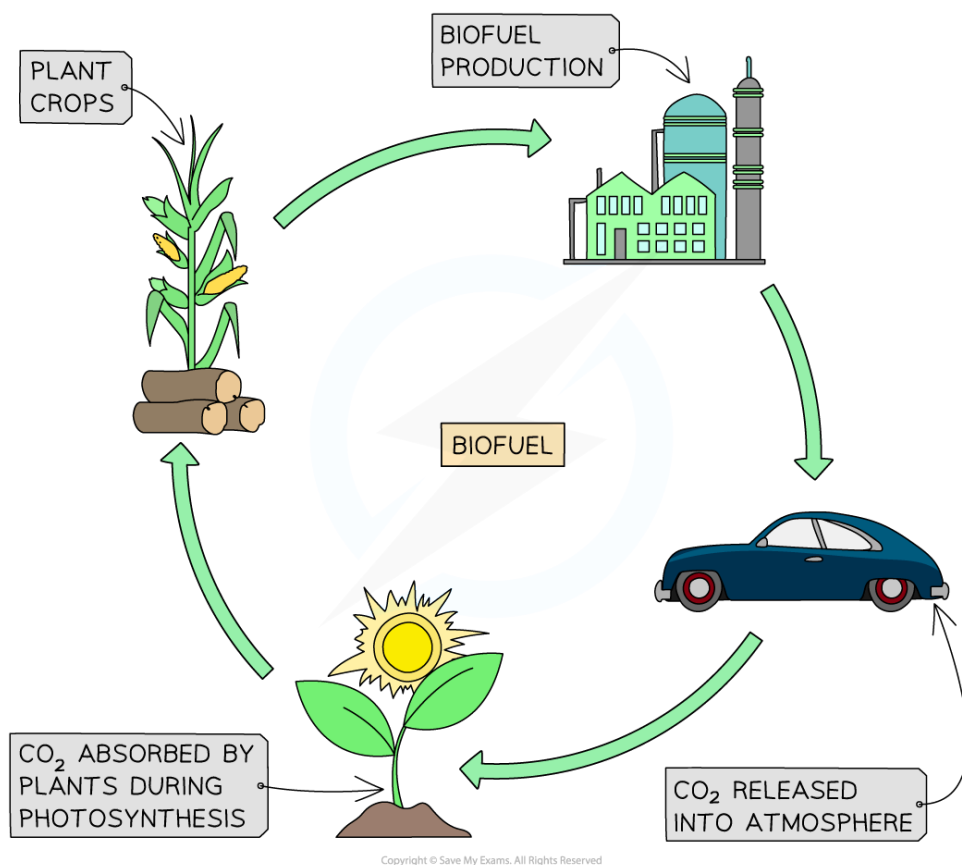
## Disadvantages of biofuel

- Crops of biofuel producing plants must be grown, which takes **time**
  - Growing the crops takes a lot of **land**, and takes **resources** needed for food production
- Burning biofuels releases **carbon dioxide** into the atmosphere
  - Biofuels are considered **carbon neutral** because plants take in carbon dioxide when they photosynthesise, however, this view is **controversial**
  - If the land had been used to grow crops for food, the same amount of carbon would have been taken out of the atmosphere, and much less carbon would have been returned
- Biofuels have only half the energy density of fossil fuels, which means twice as much fuel needs to be used to release the same amount of energy
- Not many vehicles can run on biofuel alone

## Cycle of biofuel production and use



Your notes

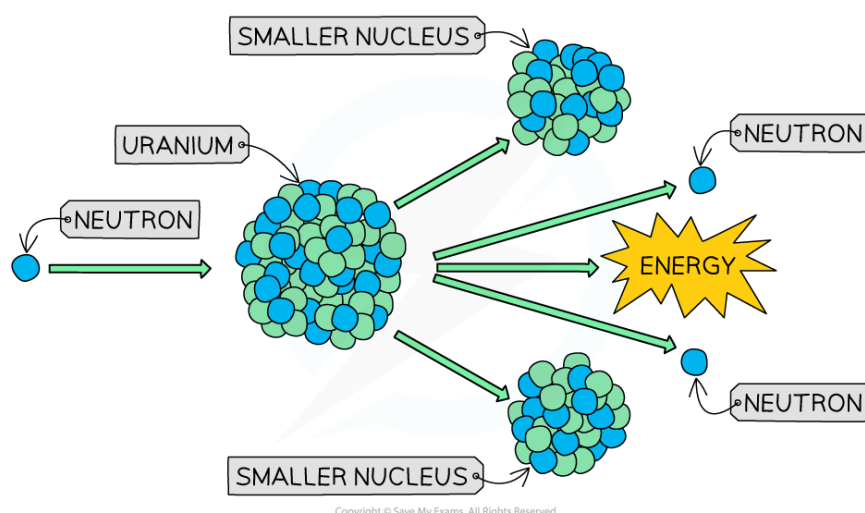


*Plants take in carbon dioxide during photosynthesis, but carbon dioxide is released back into the atmosphere when biofuels are burned*

## Nuclear fuel

- Energy stored in the **nucleus** of atoms can be released when the nucleus is broken in two
  - This is known as nuclear **fission**

### Nuclear fission



**Nuclear Fission: when a large nucleus is broken into two smaller nuclei, energy is released**

- Nuclear power stations use fission reactions to **heat water** to produce steam, to turn turbines that turn generators which **generate electricity**

## Advantages of nuclear power

- **No pollution** released into atmosphere
- Nuclear power stations are **extremely reliable** and **well established** in some countries
- Nuclear power stations are **responsive** as the output is easily controlled
- Nuclear power stations produce **massive amounts of power**
  - **Twice** the power output of a fossil fuel power station
- Nuclear fuel has a **high energy density**
  - A small amount of fuel releases massive amounts of energy

## Disadvantages of nuclear power

- Nuclear power is a **non-renewable** resource
  - Uranium ore mined from rocks so there is a **finite supply**
- Nuclear fuels produce **radioactive waste**
  - Radioactive waste is packaged and buried underground to be stored for **thousands** of years
  - Burial sites must remain undisturbed and uninhabited
- Nuclear power stations are **extremely expensive to build** and to decommission (close down)

- Nuclear power stations are **expensive** to run and **maintain** because rigorous safety protocols must be in place
- Nuclear power stations are **potentially** dangerous in the event of an **accident**



### Examiner Tips and Tricks

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Your notes



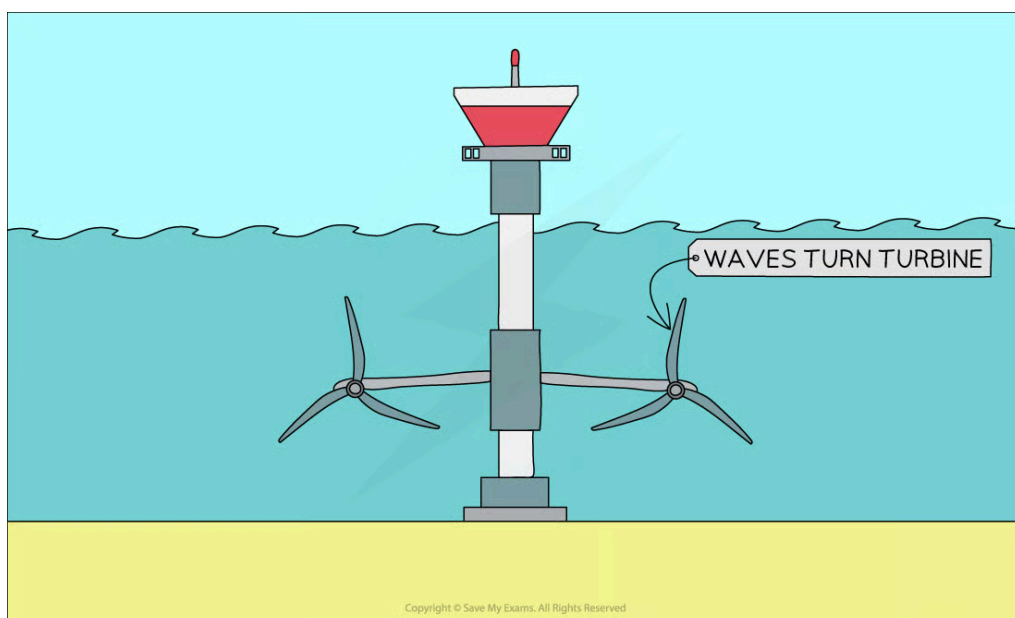
# Wave & tide power

- Energy can be obtained from the kinetic store of the waves and tides
- The motion of the water is used to turn a turbine, which turns a generator, which generates electricity

## Wave power

- Wave power uses underwater turbines
- The waves move the water which causes the turbines to turn

## Turbines using wave power



*Underwater turbines generate electricity*

## Tidal power

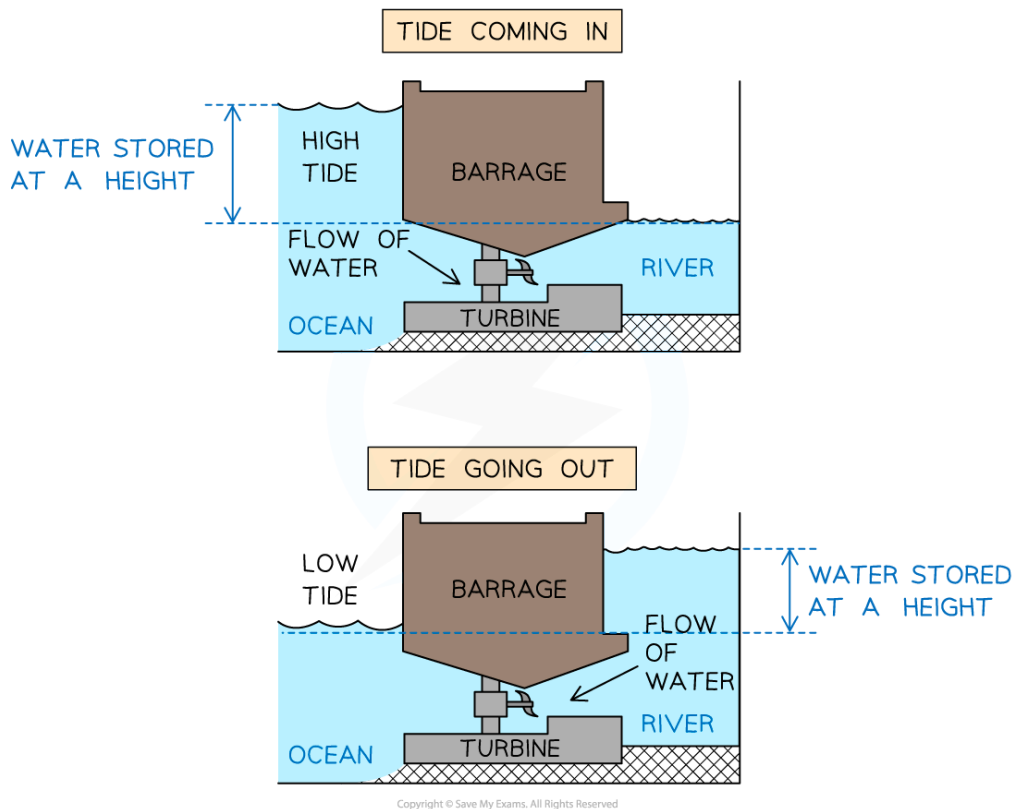
- Tidal power uses tidal barrages to store water at a height as the tide comes in and goes out
- When the barrage is opened, water flows through a channel over a turbine

## Tidal barrage





Your notes



*A tidal barrage stores water at a height and then opens a gate allowing water to flow over a turbine*

## Advantages of wave and tidal power

- Wave and tide power produce **no pollution** or greenhouse gases as no fuel is needed
- No fuel costs
- Tides are regular, so **tide power** is **reliable** and predictable
- **Large** amounts of electricity can be produced at **regular** intervals
- Wave and tidal power stations are **responsive**; they can be turned off and on quickly to meet demand
- Wave and tidal power are **renewable** energy resources
- Smaller power stations are useful for **small islands**
- Wave and tidal power stations are **inexpensive** to build and cheap to run
- Wave and tidal power stations are **very efficient** (around 80%)

## Disadvantages of wave and tidal power

- Tidal barrages are built in **estuaries** so there are not many suitable locations

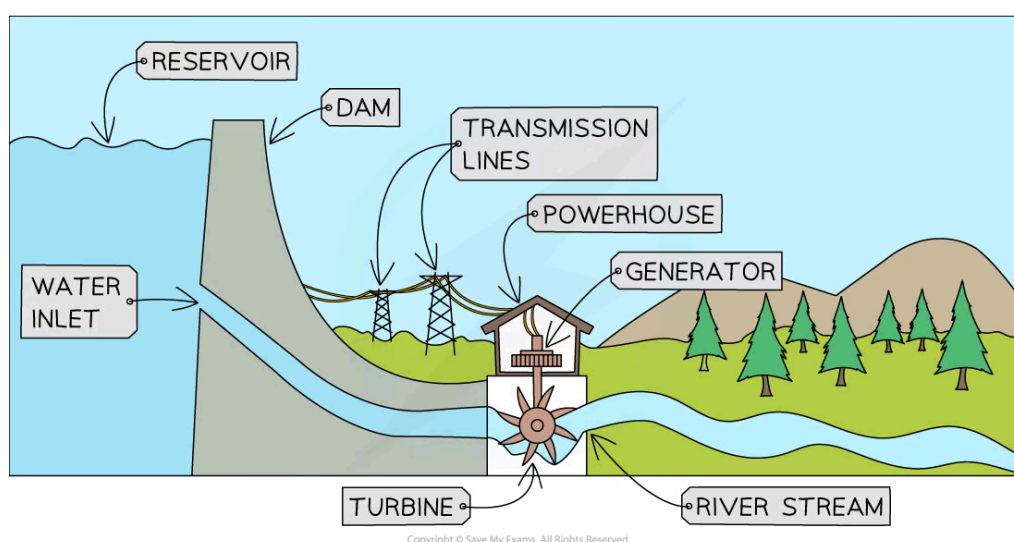


- The underwater turbines and tidal barrages can **interfere** with shipping routes and cause **damage** to habitats
- The technology for wave and tidal power is not currently advanced enough for large-scale electricity generation
- Wave and tidal power stations have a **long construction time** compared to some other power station types
- **Waves power** is **unreliable** as the waves are not always large enough to turn the turbines

## Hydroelectric dams

- When water is stored above ground level, it has energy in its **gravitational potential store**
- This energy can be transferred to **kinetic energy** if the water is allowed to flow down the slope
- Flowing water turns the turbine to **generate electricity**

### A hydroelectric dam



*A hydroelectric dam transfers energy mechanically from the gravitational potential energy store of the water to its kinetic energy store. The moving water turns the turbine*

### Advantages of hydroelectric power

- Hydroelectric dams are **reliable** and well established in most countries
- Hydroelectric power stations are **responsive** because they can be turned on and off easily to meet changing demand
- Hydroelectric power stations are cheap to run
- Hydroelectric power stations can produce **large** amounts of electricity
- Water is a **renewable** energy resource

## Disadvantages of hydroelectric power



Your notes

- Valleys are flooded to create the reservoir used to store the water, which **destroys habitats**, towns and villages
- **Pumping systems** are sometimes used to return the water to the reservoir
  - Pumping systems use **fossil fuels**, which release greenhouse gases and pollution into the atmosphere
- Hydroelectric power stations are **expensive to build** because the land and properties need to be acquired in order to build the reservoir
- High-voltage power lines are required to transmit electricity to the National Grid
- **Drought** can affect the supply of water



### Examiner Tips and Tricks

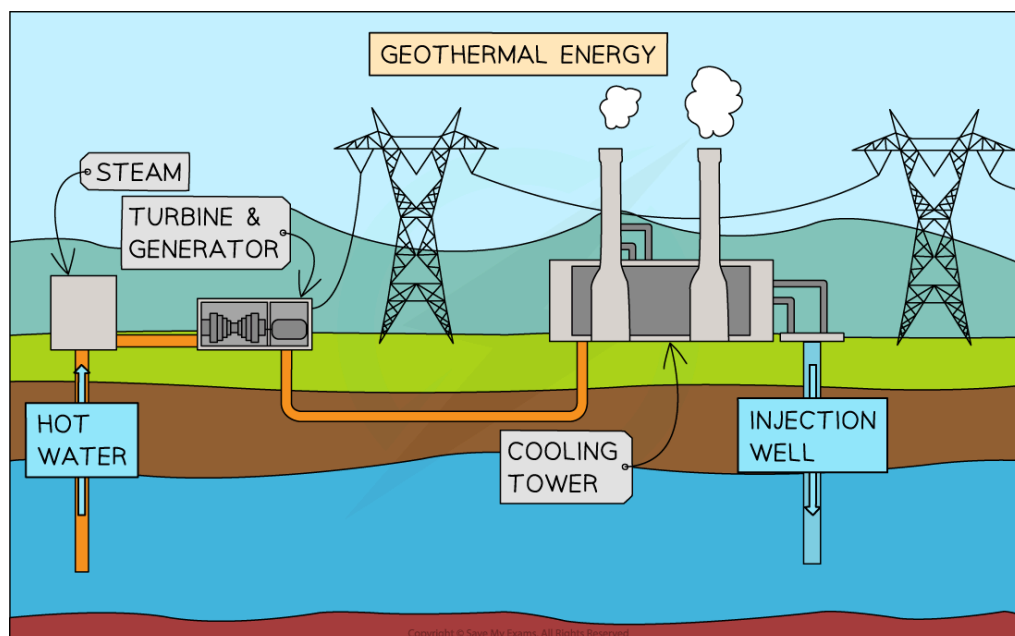
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# Geothermal energy

- **Tectonic activity** causes areas where the rocks below ground become **heated**
- Energy in the thermal store of the rocks can be obtained by:
  - Drilling **shafts** into the Earth's surface to expose the heated rocks
  - Injecting **water** into the shaft which is heated by the rocks
  - The water is returned via another shaft as **steam** or hot water
  - The steam can be used to turn a **turbine** and generate electricity
  - The hot water can be used to heat homes and provide a **hot water** supply to households

## Geothermal power station



*Cold water is heated by the rocks and returned as hot water or steam, which can be used to generate electricity*

## Advantages of geothermal energy

- Geothermal energy is **renewable**
- Geothermal power stations are **reliable** because the rocks remain hot for thousands of years so they can consistently produce electricity

## Disadvantages of geothermal energy



Your notes

- Geothermal energy depends on tectonic activity, so there are **few suitable locations** on Earth
- Methane (natural gas) is found in spaces between rocks and can be forced out when water is injected into the rocks (fracking)
  - Methane is a **greenhouse gas** which contributes to global warming (even without combustion)
- Geothermal power stations are **expensive** to build
- Geothermal power stations are **small** so they are not suitable for large-scale electricity production
- Geothermal power stations are **not very efficient** (around 12%)



### Examiner Tips and Tricks

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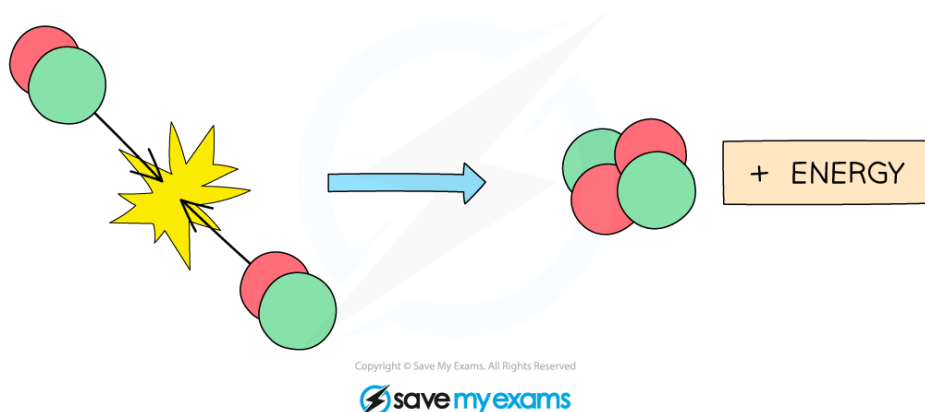


# Nuclear fusion

### Extended tier only

- The Sun releases energy by the process of nuclear **fusion** in its core
  - Nuclear fusion involves the **fusing** of hydrogen nuclei to form helium nuclei, releasing massive amounts energy in the process

## Nuclear fusion



***Fusion is the process in which small nuclei, such as hydrogen, are fused together to form larger nuclei, releasing energy in the process***

- It is **theoretically possible** to produce a **fusion reactor** that could be used to **generate electricity**
  - This technology could potentially solve the world's energy crisis
- Fusion requires extremely **high temperatures** and **high pressures**, like in the centre of a star
- Scientists are currently researching how to sustain a fusion reaction at lower temperatures
  - International research projects funded by some of the world's largest businesses are making progress with some promising results
- Currently, the fusion reactions require nearly as much energy as they release, but progress is being made toward net energy production
  - If they succeed, virtually limitless amounts of energy could be produced, with large-scale, carbon-free electricity generation