



DP IB Environmental Systems & Societies (ESS): SL



Energy Choices & Security

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- * What are Fossil Fuels?
- * Renewable & Alternative Energy Sources
- * Energy Security Strategy



Your notes

What are Fossil Fuels?

Fossil Fuels

What are Fossil Fuels?

- Fossil fuels include:
 - **Coal**
 - **Natural gas** (mostly methane) which is used in domestic boilers and cookers
 - **Crude oil** which is refined into petrol, diesel, and other fuels
- 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 chemical energy stores within plants through photosynthesis (plants use energy from sunlight to make food)
 - Animals ate the plants and the energy was then transferred to their chemical store

FOSSIL FUEL EXAMPLES



COAL



OIL



NATURAL GAS

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Fossil fuels include coal, oil and natural gas

Advantages of Fossil Fuels

- The current systems of transport and electricity generation used by human societies rely heavily on fossil fuels, which are generally **readily available** on a daily basis

- In the past fossil fuels have been **reliable** for **large scale energy production** (although this is changing as supplies deplete and prices rise)
- **Efficient** - fossil fuels typically have a high **energy density** (they produce a large amount of energy per kilogram)



Your notes

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
- 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
- **Oil spills** can occur during transport of fossil fuels, which damage the environment and wildlife over very large areas
- Prices fluctuate rapidly
- Supplies can be affected by conflict and political disagreements (e.g. the war in Ukraine)

Uses of Fossil Fuels

- Fossil fuels are mainly 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

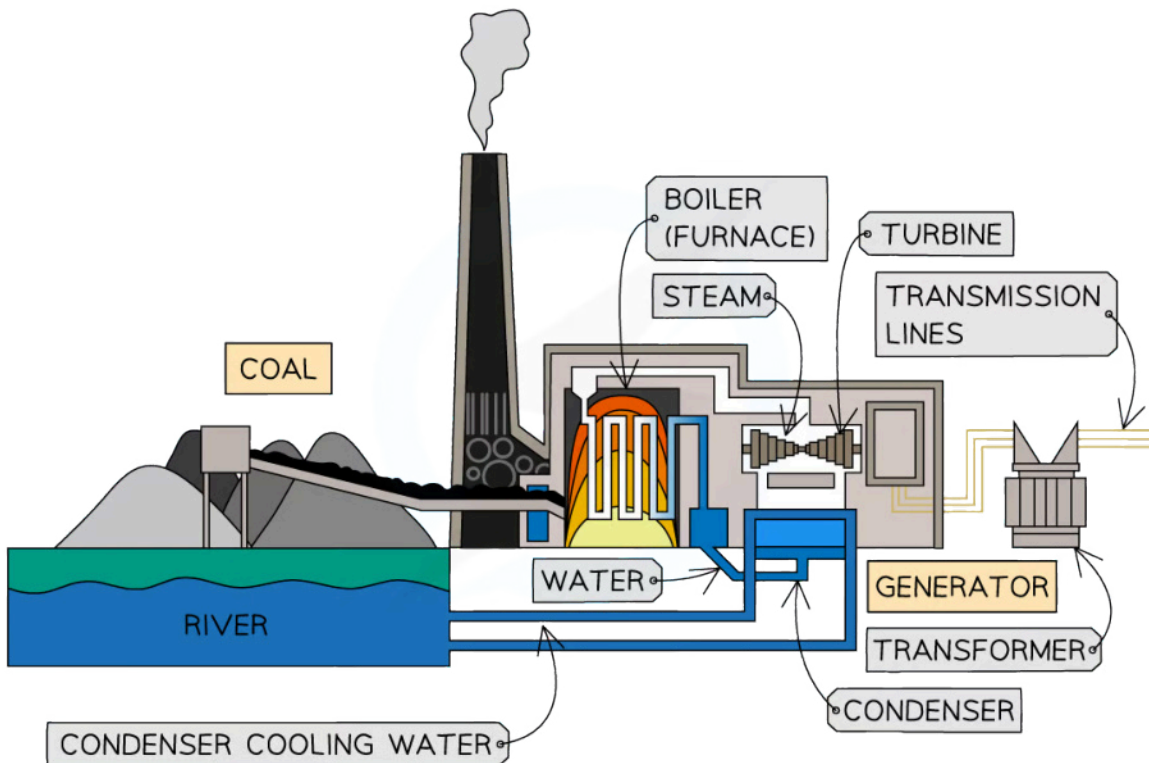
- The disadvantage is that when the vehicle is being charged, it is connected to the National Grid, which currently uses a combination of renewable and non-renewable energy sources

Electricity Generation

- Fossil fuels, such as coal and oil, are used to produce energy on-demand when energy is needed
 - This is done by **burning** the materials when the energy is required
 - When coal is burned, it produces **thermal energy**
- This is used to boil water creating **steam**
- Steam is forced around the system and this turns a **turbine**
- The turbine turns coils in a magnetic field in the **generator**
 - This generates electricity
- The electricity is transferred through a step-up transformer and is carried out of the system by electrical lines
- The steam within the turbine will cool and condense and then be pumped back into the boiler to repeat the process



Your notes



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Electricity generation of coal through a power station

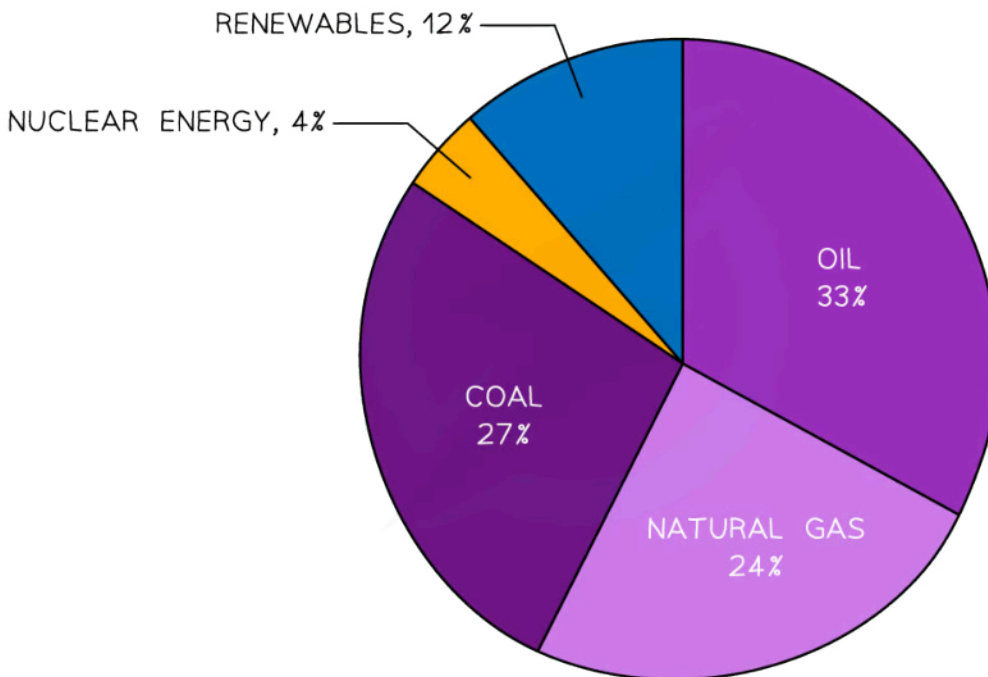


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Heating

- Heating systems in cold countries vary depending on the region and availability of resources
- In some countries, **central heating systems** are commonly used and often rely on fossil fuels such as natural gas, fuel oil, coal, or coke for heating purposes
 - These systems typically heat up water, which can then be pumped around radiators throughout the home
- However, it's important to note that not all countries rely on central heating systems or use gas as the principal fuel for heating
 - In regions where natural gas is less common or unavailable, alternative heating methods may be used, such as **electrical heating** or district heating systems
 - Electrical heating is common in some countries like Japan, where it is often powered by nuclear energy rather than fossil fuels
 - In certain areas, renewable energy sources such as geothermal heating or solar heating systems may also be employed as sustainable alternatives

PRIMARY GLOBAL ENERGY CONSUMPTION 2019



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Pie chart of global energy sources used in 2019



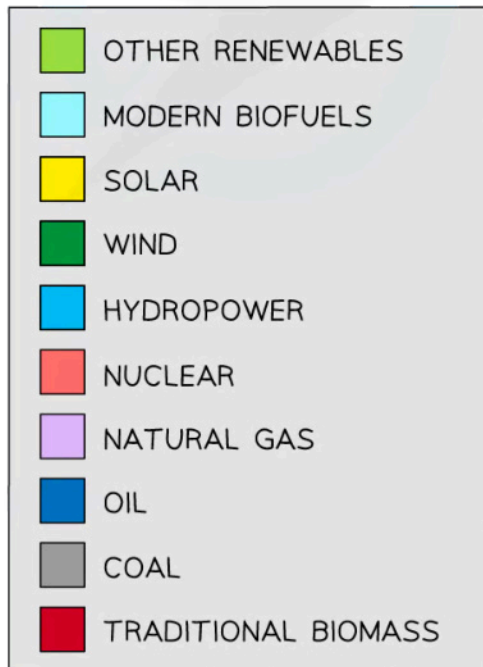
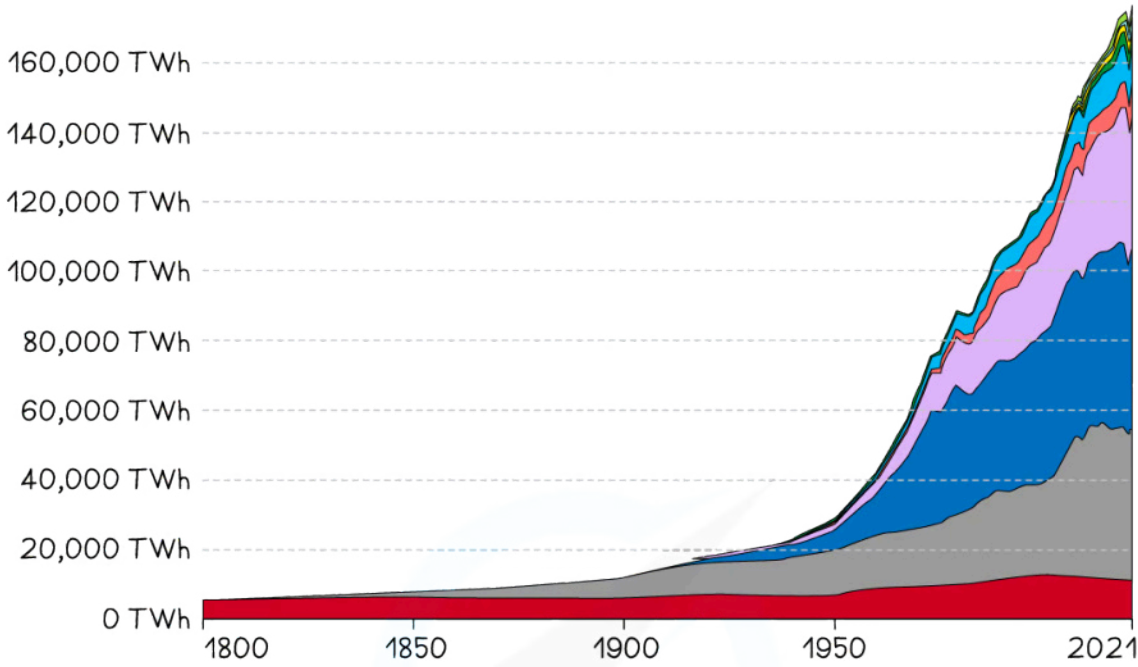
Your notes

Energy Demand

- The demand for energy across the globe is rising
- Population growth and development are the two main causes of the increase in energy demand:
 - The **higher demand for food** leads to more intensive farming, which requires more energy for machines, light and heat
 - Increasing **industry** requires energy for heating, lighting and machinery
 - There is more **transport** all of which requires energy in the form of petrol, diesel or electricity
 - **Urbanisation** increases with the development increasing domestic appliances, heating, lighting
 - **Increased wealth** means people buy more appliances and technology which require energy



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World energy demand



Your notes

Renewable & Alternative Energy Sources

Renewable & Alternative Energy Sources

What are Renewable Energy Sources?

- Sources of energy with lower carbon dioxide emissions than fossil fuels include **renewable energy sources**
- Renewable energy are energy sources that will not run out and include:
 - Solar
 - Biomass
 - Hydropower
 - Wind
 - Wave and tidal
 - Geothermal
- Once in place, these renewable energy sources do not produce any greenhouse gas emissions (with the exception of **biomass**)
 - However, it is important to note that greenhouse gases may be emitted in the production, construction and transport of the equipment required for the above renewable energy sources

Renewable Energy Sources Examples:

Solar

- The energy from the Sun that falls on the Earth is transferred by radiation
 - Mostly visible light and infrared radiation
- The amount of energy transferred from the Sun to the Earth each hour is roughly 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 is **expensive** (due to the equipment required) and **inefficient**

Solar PV panels

- Solar photovoltaic (PV) panels transfer energy from sunlight electrically producing a current, and therefore generating electrical power
 - Solar cells, sometimes called photovoltaic cells, are made of semiconducting materials
 - A number of photovoltaic cells or panels connected together can supply electricity to homes, small-scale businesses, communication devices and satellites
 - Energy generated can be stored in batteries for later use

Advantages

- 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 farms produce no greenhouse gases or pollution
- Solar energy can be generated in remote places where they don't have electricity (e.g. to power solar street signs in rural areas)
- Can be small or large scale
- Can be incorporated into building design
- Technology is improving and reducing the cost

Disadvantages

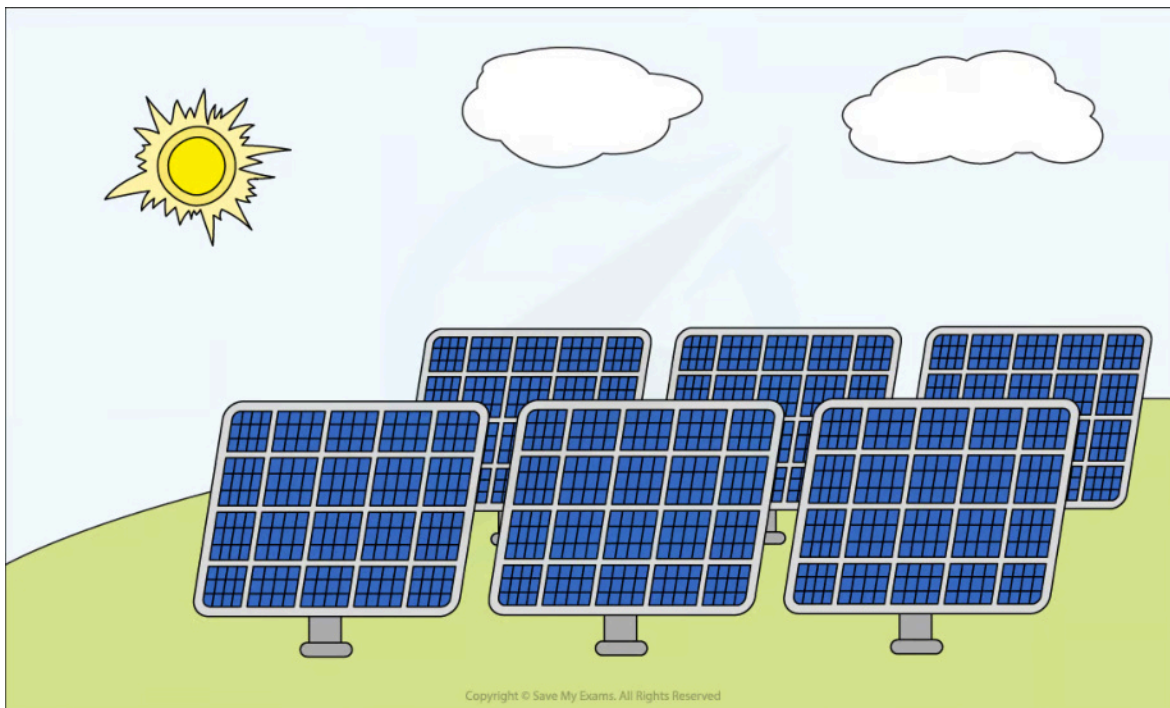
- Solar farms need to be large scale to produce large amounts of electricity, which is expensive to set up
- Uses large areas of land
- People often don't like the appearance of large solar farms, this is known as visual pollution
- In many places on Earth sunlight is not a reliable energy resource (there are not enough sunshine-hours to justify the set-up costs)



Your notes



Your notes



Solar PV panels use energy from sunlight to produce electricity

Solar thermal panels

- Solar thermal 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 solar panels


Advantages

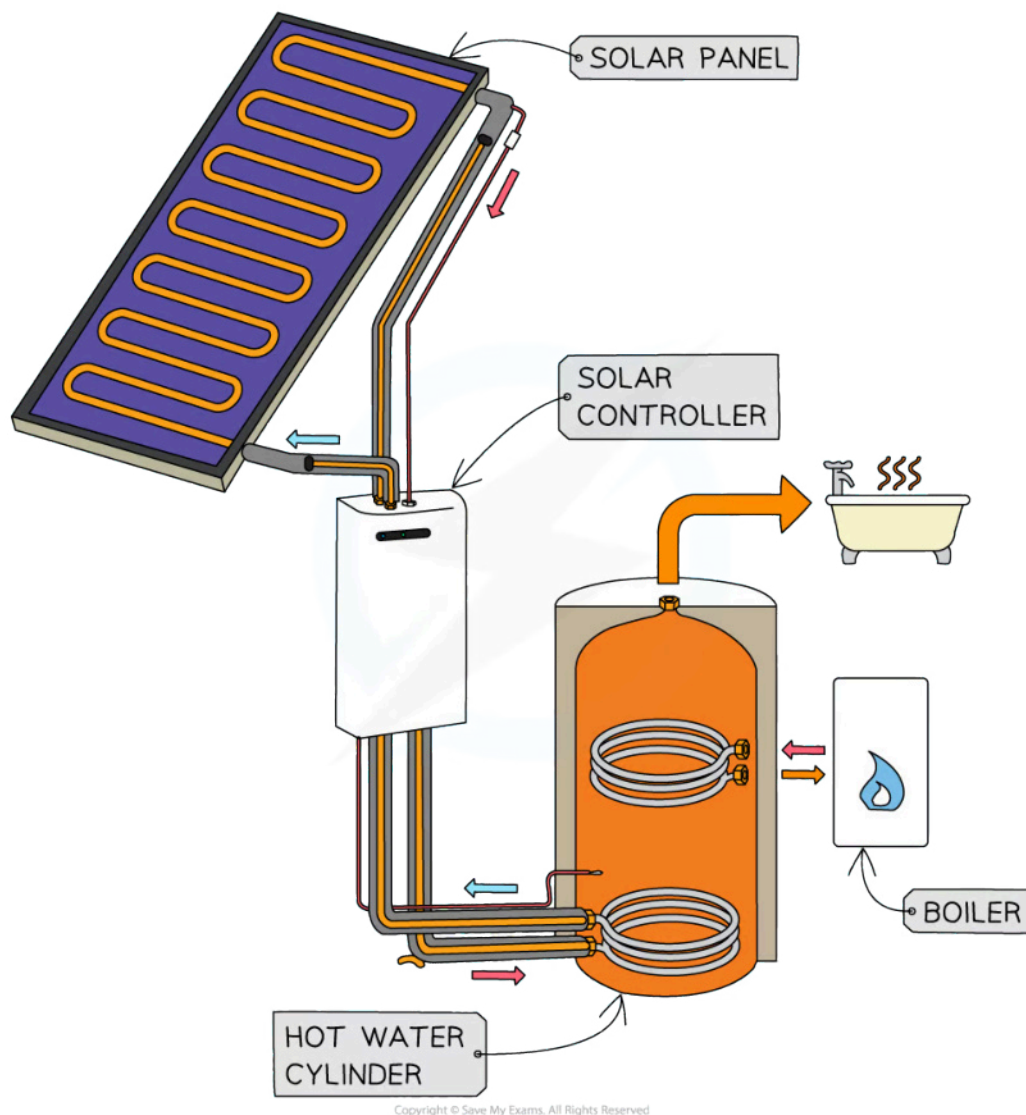
- Solar energy is a renewable resource
- In many places on Earth sunlight is a reliable energy resource (this means that the sun shines most of the time)
- Solar thermal panels produce no greenhouse gases or pollution once they are operating
- Solar thermal panels can cut the cost of energy bills for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

Disadvantages

- Additional energy (e.g. from fossil fuels) 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



Solar thermal panels use energy from sunlight to heat water directly

Biomass

- Biofuels (also known as biomass fuels) are renewable fuels derived from **organic materials**, such as plants and animal waste, that can be used as an alternative to fossil fuels.
 - However, they have only half the energy density of fossil fuels

- The three main biofuels are:
 - **Biodiesel** - made by refining renewable fats and oils (e.g. vegetable oils, animal fats, or recycled cooking oil)
 - **Bioethanol** - made by fermentation (of crops rich in sugars or starches, such as corn or sugarcane)
 - **Biogas** - released when organic waste products decompose

Advantages

- Biofuel is a renewable resource - uses waste or bioproducts that can be regrown
- Some vehicles can be powered by biofuel rather than using fossil fuels
- Biofuel is considered to be carbon neutral
- No sulfur dioxide is produced

Disadvantages

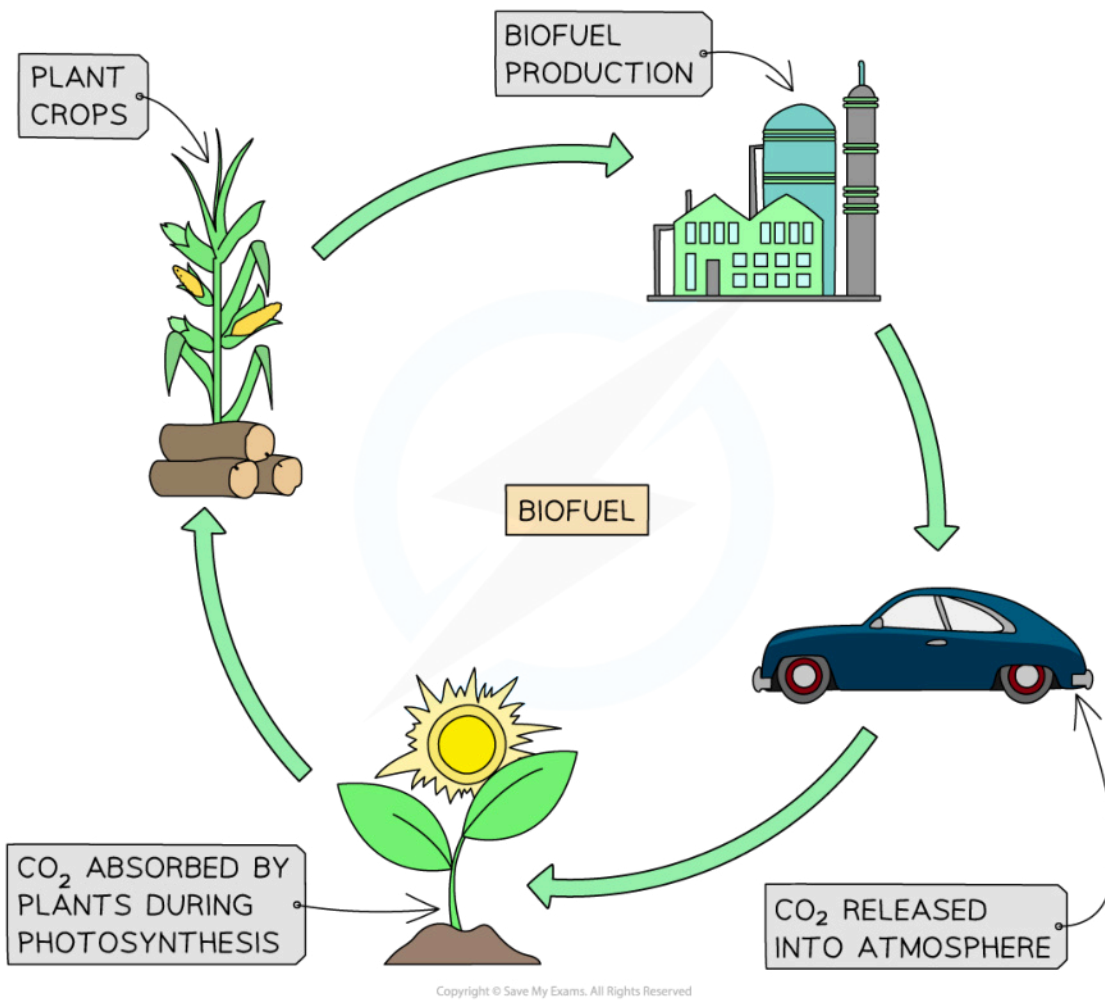
- Crops of biofuel producing plants must be grown which takes time
- Growing the crops takes a lot of land, and takes resources needed for food production
- Burning biofuels releases carbon dioxide into the atmosphere (however, it is considered carbon neutral because plants take in carbon dioxide when they photosynthesise)



Your notes



Your notes



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

Hydropower

- When water is stored above ground level it has **gravitational potential energy**
- 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

Advantages

- Can respond to demand quickly so is reliable and available



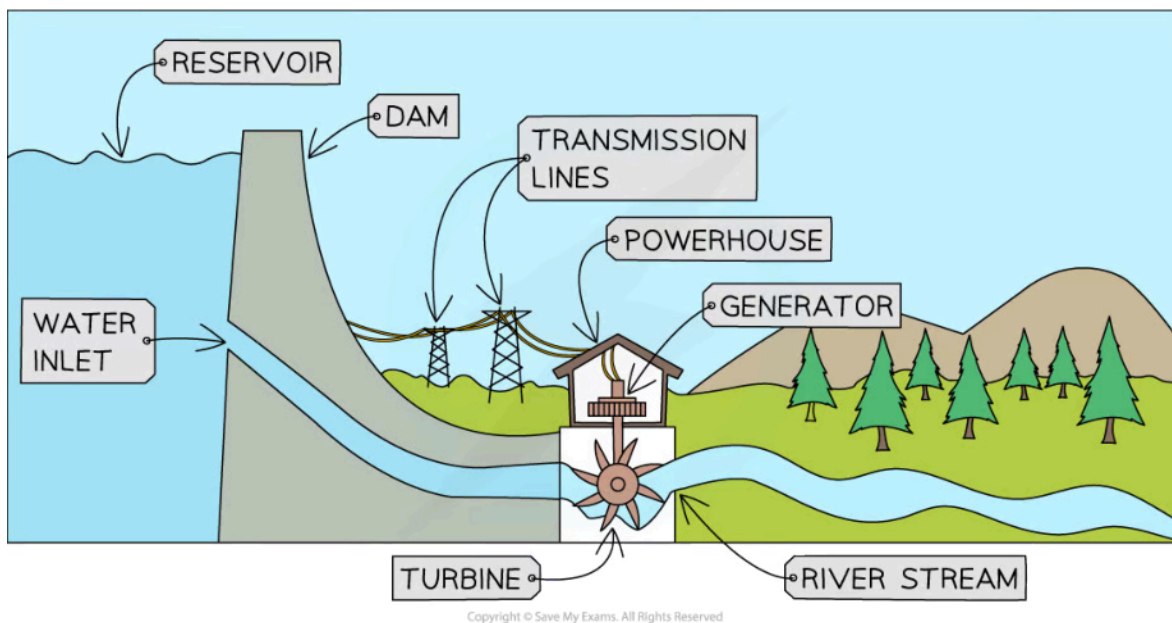
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- Can generate large scale amounts of electricity in a short period of time

- Often in sparsely populated areas

Disadvantages

- Expensive to build and maintain
- Creating reservoirs sometimes results in the need to flood valleys, which destroys habitats, towns and villages
- The pumping systems (used if water needs to be pumped up to the reservoir) often rely on fossil fuels, releasing large amounts of greenhouse gases
- Dam traps sediment which can affect ecosystems downstream
- Visual pollution
- Can prevent fish movement and migration upstream



A hydroelectric dam transfers the gravitational potential energy of the water to kinetic energy in order to generate electricity

Wind

- Wind energy is a renewable form of energy that harnesses the power of the wind to generate electricity
- It involves the use of wind turbines, which have large blades that spin when the wind blows

- The rotating blades transfer **kinetic energy** to a **generator**, which converts it into electrical energy

Advantages

- Wind is an abundant resource that will never run out, making wind energy a sustainable and renewable source of power
- Wind energy produces no greenhouse gas emissions or air pollutants during operation, helping to reduce the negative impact on climate change and air quality
- Wind energy reduces dependence on fossil fuels and foreign energy sources, promoting energy independence and security
- The wind energy industry creates jobs in manufacturing, installation, operation, and maintenance of wind turbines
- Can be small or large scale
- Can be on land or offshore
- Cheap to run

Disadvantages

- Wind is not constant, and the availability of wind energy fluctuates
- Electricity generation from wind turbines depends on wind speed and consistency
- Wind turbines can be visually intrusive, especially when installed in large numbers
- Some people may find the noise generated by wind turbines to be disruptive
- Wind farms require large areas of land, which can have an impact on agricultural or natural landscapes
- Birds and bats may occasionally collide with wind turbines, causing some impact on local wildlife populations



Your notes



Your notes



Photo by [Zbynek Burival](#) on [Unsplash](#)

A wind farm in Austria – some people think wind turbines are an eye-sore, especially when installed in large numbers

Wave and tidal

- The rise and fall of waves or the tide can be used to turn a turbine and generate electricity

Advantages

- No pollution
- Reliable and can produce a large amount of electricity at short notice
- Renewable energy resource
- Small systems are being developed to provide electricity for small islands

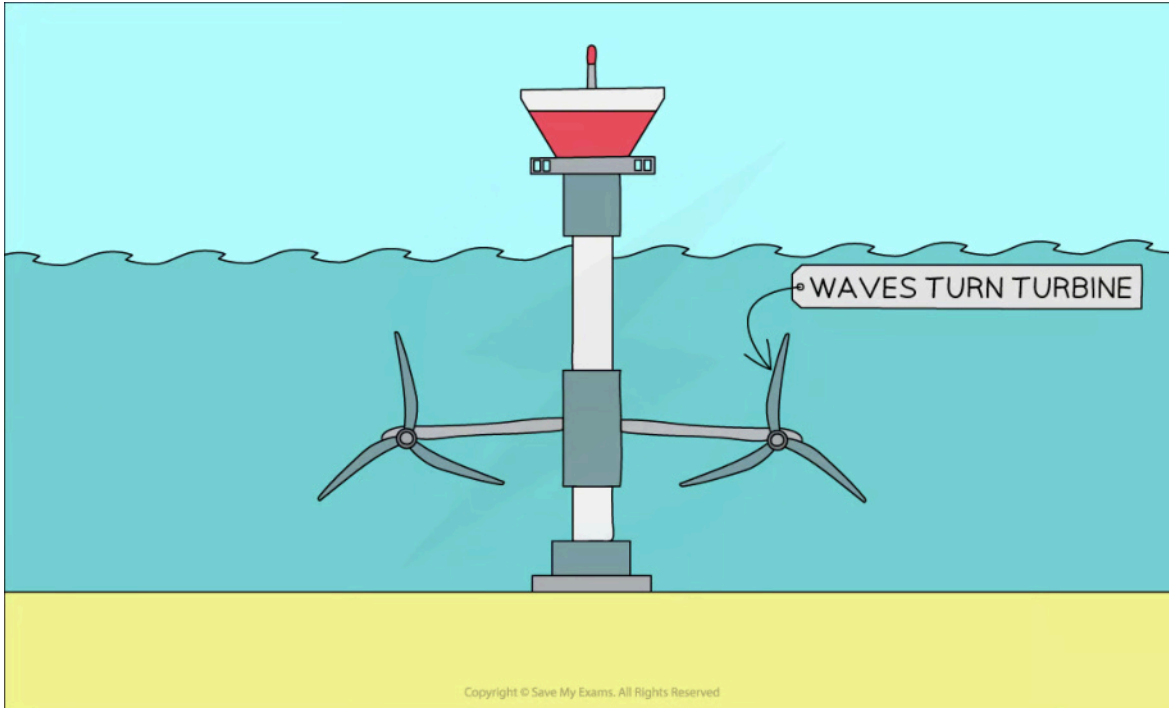
Disadvantages

- Expensive to build and maintain

- Damages fragile habitats
- Very few suitable locations
- The technology is not advanced enough for large scale electricity production



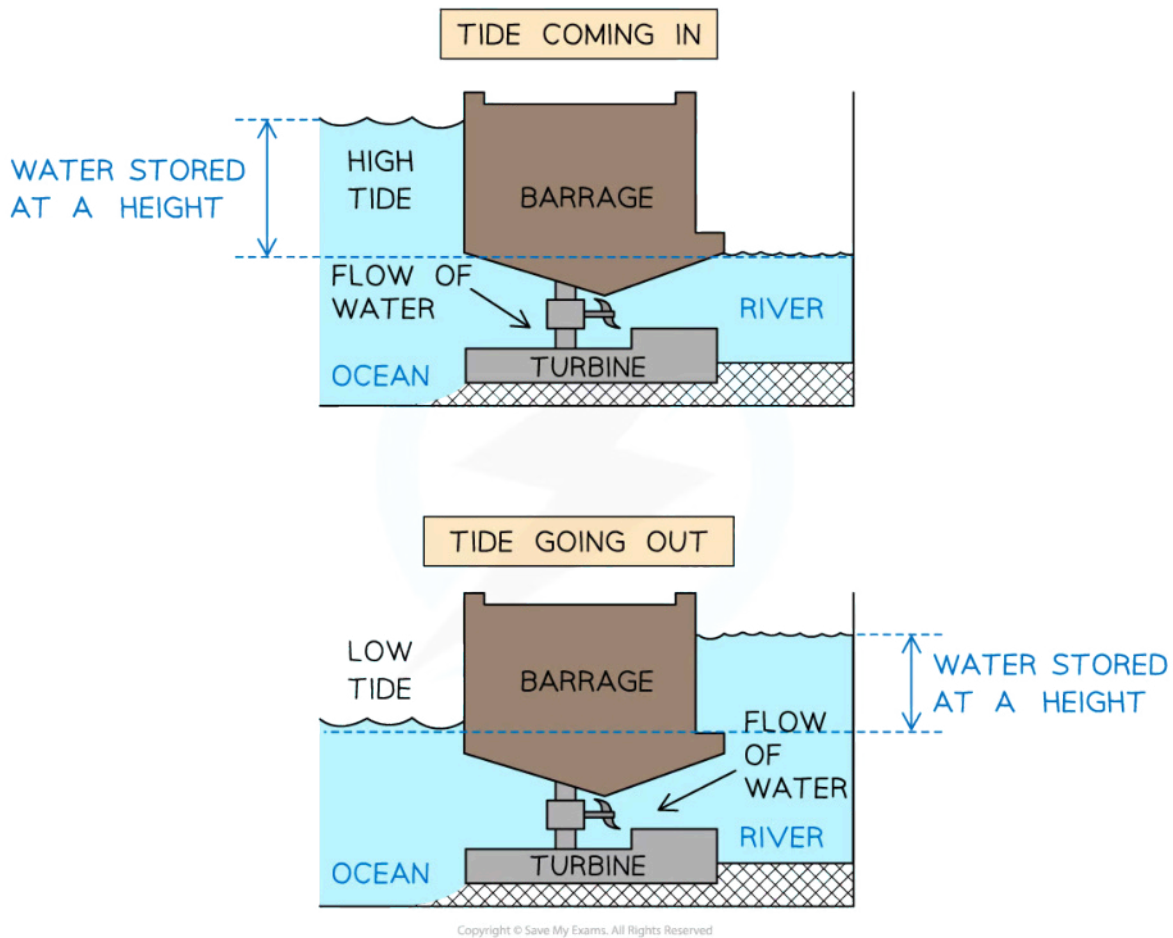
Your notes



Underwater turbines generate electricity from the movement of waves



Your notes



Tidal barrages can generate electricity from the movement of water, both as the tide comes in and as it goes out again

Geothermal

- Geothermal energy is caused by the heat that is generated from within the Earth
 - The Earth's interior is extremely hot, partly due to radioactive elements deep in the Earth that release energy as they decay
- This geothermal energy heats up rocks in the Earth's crust, sometimes to an extremely high temperature
 - Water can be poured into shafts below the Earth's surface
 - The water is heated and returned via another shaft as **steam** or **hot water**



Your notes

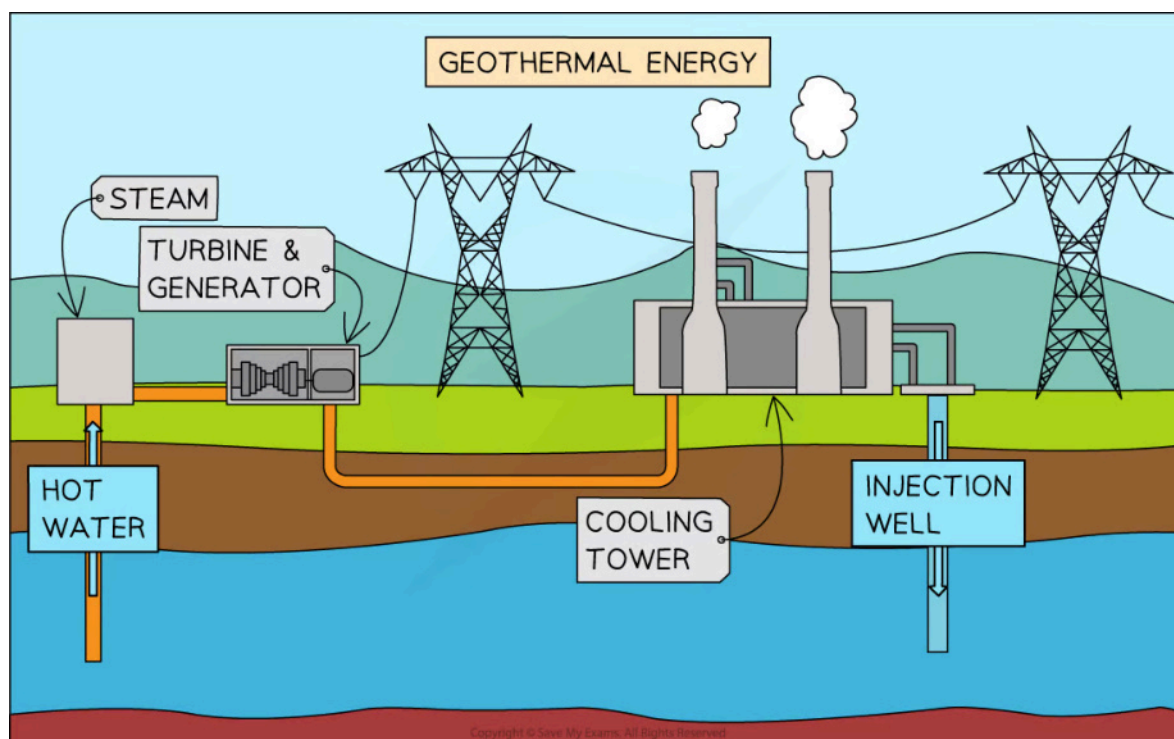
- Steam can be used to turn a **turbine** and generate electricity, and the hot water can also be used to **heat homes**

Advantages

- Renewable resource
- Reliable source of energy
- Geothermal power stations are usually small compared to nuclear or fossil fuel power stations

Disadvantages

- Few suitable locations on Earth, so only viable for small scale electricity production in many countries
- Can result in the release of greenhouse gases from underground
- Expensive to build and maintain



Cold water is heated by natural geothermal energy underground, and then returned as hot water or steam, which can be used to generate electricity

Nuclear

- Energy stored in the nucleus of atoms can be released when the nucleus is broken in two

- This is known as **nuclear fission**
- Nuclear power stations use fission reactions to create **steam**, to turn **turbines** to generate electricity
- Nuclear power is a low carbon low-emission non-renewable resource but is controversial due to the radioactive waste it produces and the potential scale of any accident

Advantages

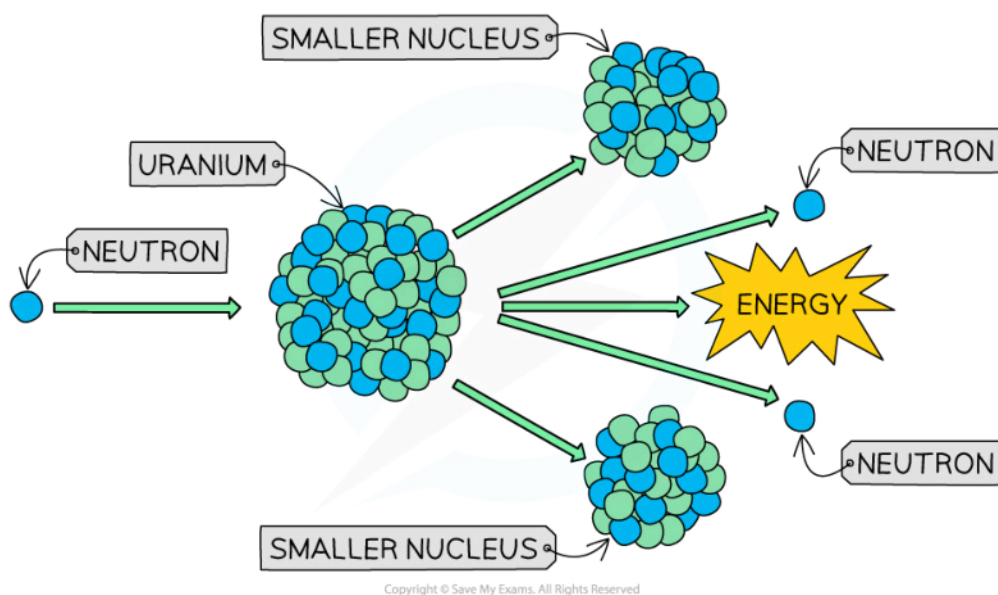
- No pollution released into atmosphere
- Nuclear reactors are perfectly safe as long as they are functioning properly (rigorous safety checks must be routinely carried out and rigorous safety procedures followed)
- Nuclear power stations can generate electricity reliably on a large scale to be available as needed
- Small amounts of uranium are needed, and large reserves are available
- Reduces reliance on fossil fuels
- Increases energy security

Disadvantages

- Uranium ore found in the ground is used for fission reactions and since there is a finite supply, nuclear power is a non-renewable resource
- Nuclear fuels produce radioactive waste, which needs to be stored for thousands of years
- Safe ways of storing radioactive waste are very expensive
- If an accident occurs at a nuclear reactor, radioactive waste can leak out and spread over large areas
- Cost of decommissioning (shutting down) nuclear power plants is very high



Your notes



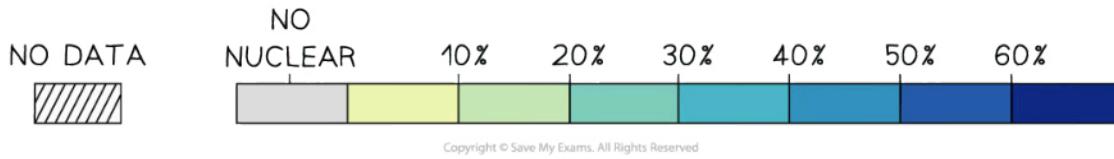
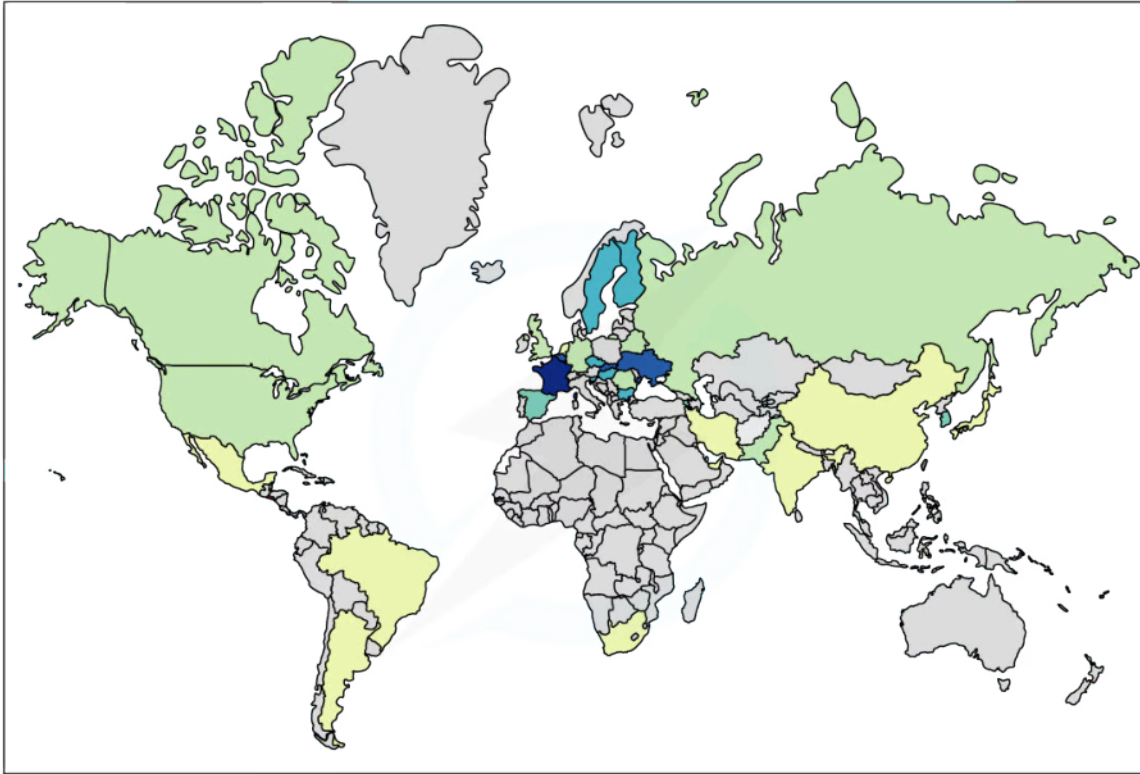
Nuclear fission occurs when a large nucleus is broken into two smaller nuclei, releasing large amounts of energy

- Nuclear energy is often used in countries who do not have their own supplies of fossil fuels, such as France
- In 2019 approximately 4% of the global primary energy supply was from nuclear power
- There are 439 active nuclear reactors across the world. Most of these are in just five countries:
 - USA (92)
 - France (56)
 - China (54)
 - Russia (37)
 - Japan (33)



Your notes

SHARE OF ELECTRICITY PRODUCTION FROM NUCLEAR, 2021



Share of electricity production from nuclear power plants

Energy Security Strategy



Your notes

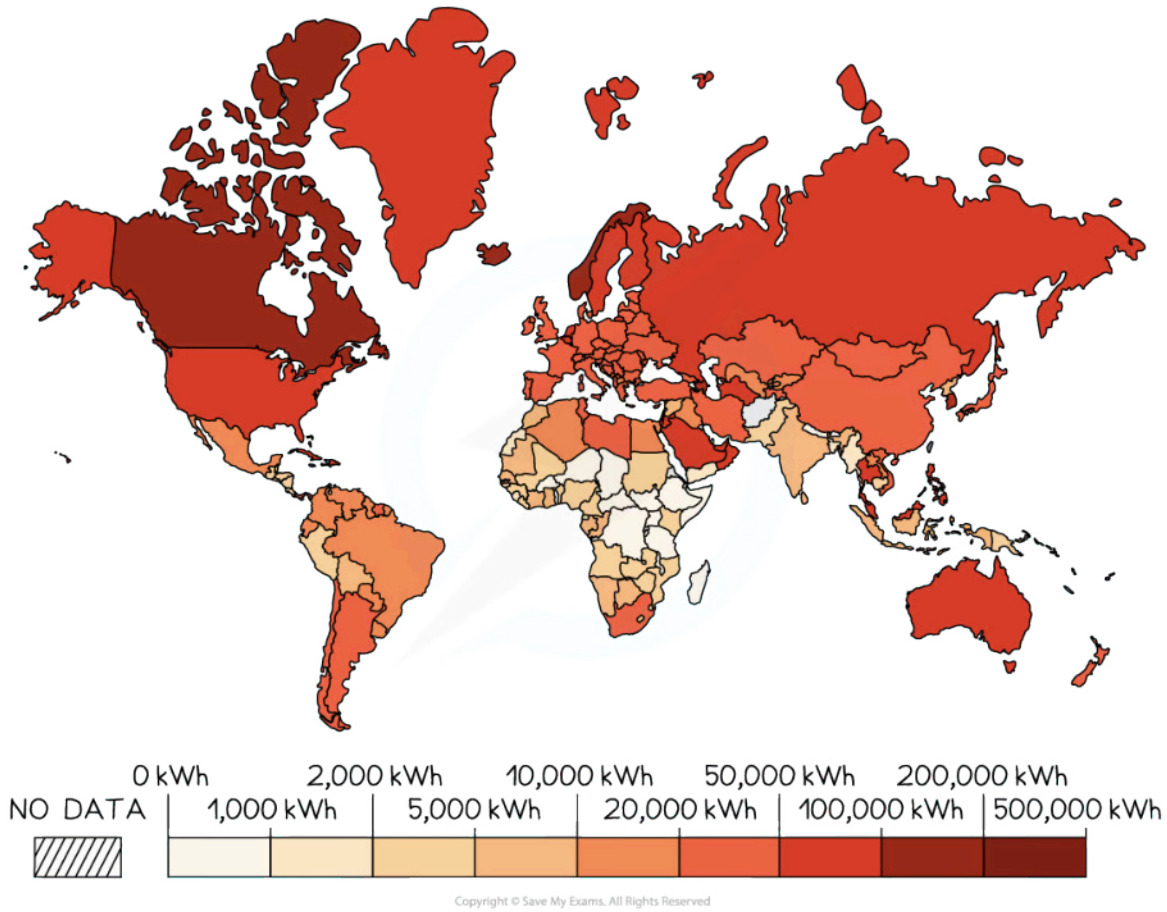
Energy Security

Energy Use

- MEDCs typically use more energy than LEDCs
- Countries with the highest energy consumption per person tend to be MEDCs and include countries such as Canada, Norway and Saudi Arabia
- Countries with the lowest energy consumption per person tend to be LEDCs and include countries such as Niger, Chad and Tanzania
- The greatest growth in energy use is occurring in LEDCs and newly emerging super-economies, such as those of China and India
- Development means more use of energy in:
 - Businesses and factories
 - In homes as people buy more appliances and technology
 - Transport



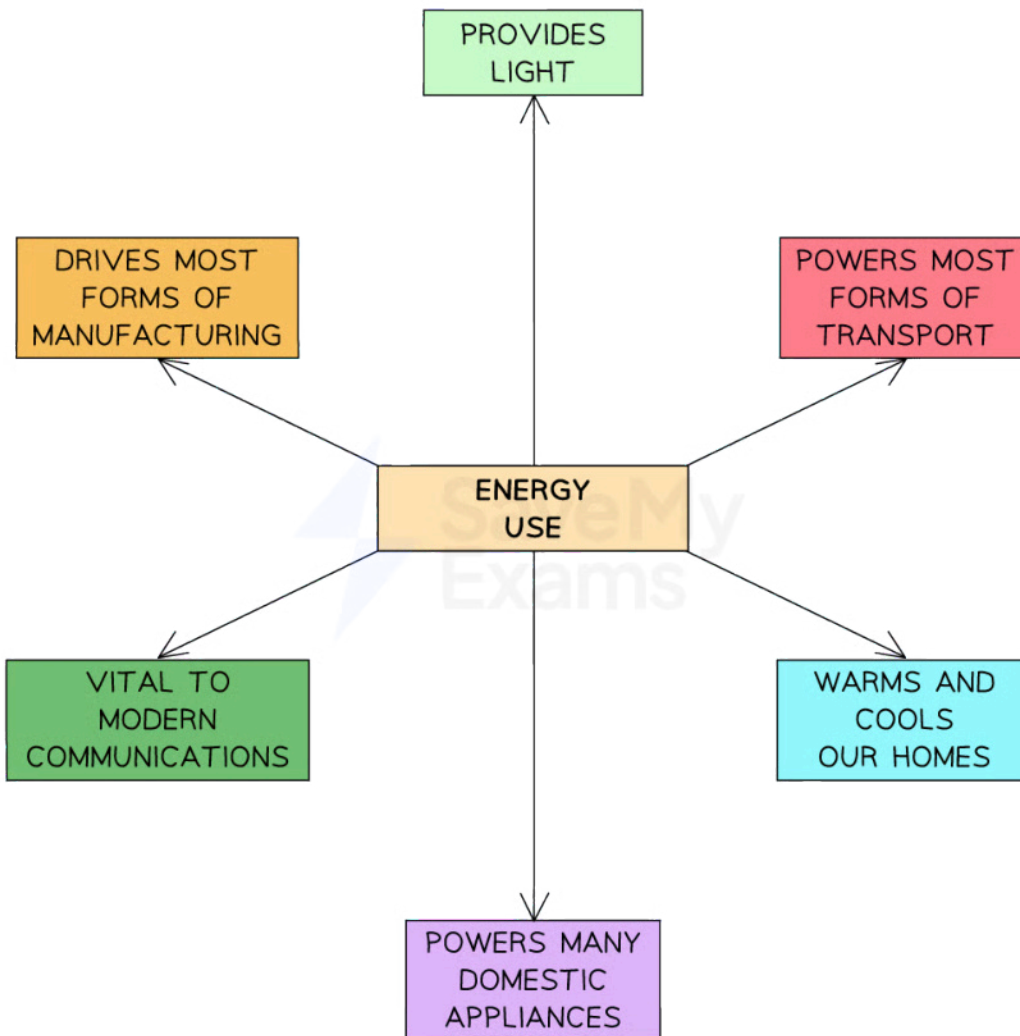
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Energy use per person in kilowatt hours (kWh)



Your notes



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Modern energy use

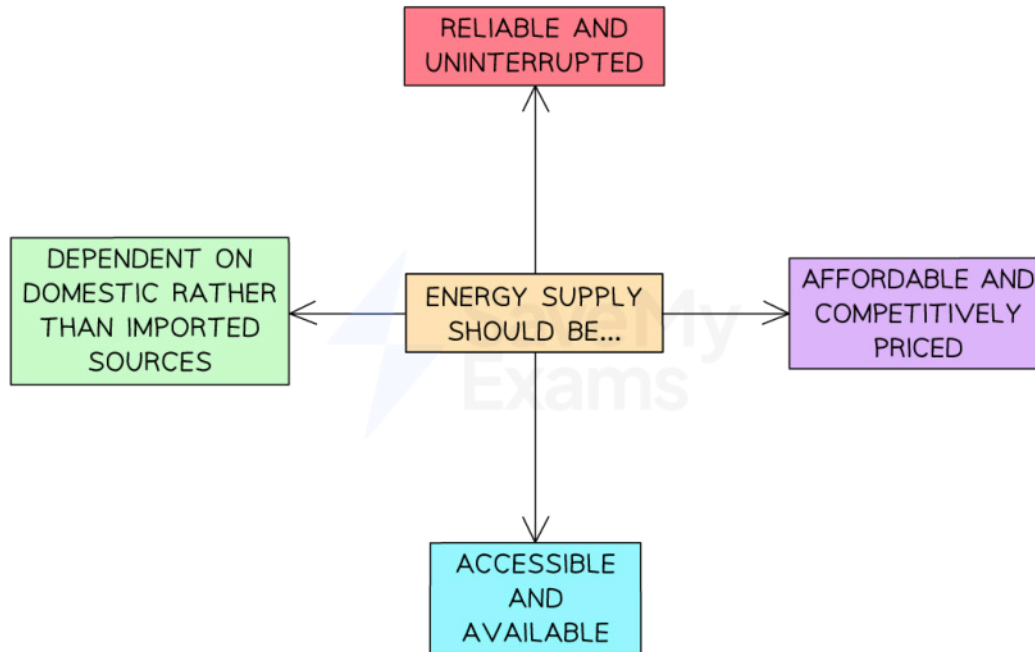
Energy Security

- Energy security refers to the **availability**, **reliability**, and **affordability** of energy sources to meet a country's needs
 - Adequate supply of energy ensures that there is enough energy available to meet the demands of individuals, industries, and the overall economy
 - Reliable supply of energy means that the energy sources can be **consistently accessed** and delivered **without disruptions** or **shortages**

- Affordable energy supply ensures that energy is **priced reasonably**, allowing individuals and businesses to access and afford the energy they need



Your notes



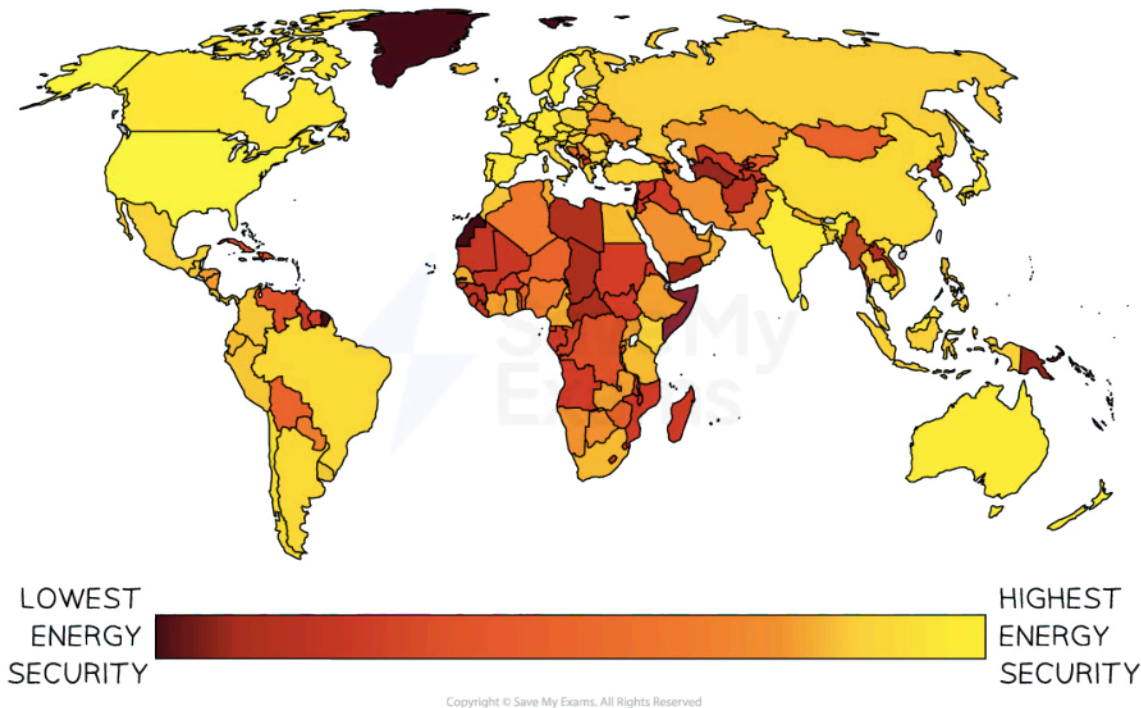
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Aspects of energy supply in achieving energy security

- **Energy independence** is an important aspect of energy security, referring to a country's ability to produce or procure **its own energy resources** without relying heavily on **imports** from other nations
 - Diversification of energy sources and supply routes can enhance energy security by reducing dependence on a **single source** or **supplier**
 - Developing domestic energy resources, such as renewable energy or domestic fossil fuel reserves, can contribute to energy security by reducing reliance on external sources
 - International cooperation and collaboration in energy markets and policies can contribute to energy security by promoting **stable** and **transparent** energy trade relationships
- Energy efficiency and energy conservation play a crucial role in enhancing energy security by reducing overall energy demand and dependence on energy imports



Your notes



Global energy security index

Energy Conflicts

- The unequal distribution of energy resources among different regions or countries occurs when certain areas have abundant energy resources while others face **energy scarcity** or lack access to **modern energy services**
 - This disparity in energy availability can create a power imbalance, where energy-rich countries or regions have a strategic advantage over those with limited energy resources
- Unequal access to energy sources can exacerbate **existing socio-economic inequalities**, as energy is essential for various aspects of **development**, including healthcare, education, and economic growth
 - Limited access to reliable and affordable energy can hinder social progress and perpetuate poverty cycles, leading to social unrest and potential conflicts
 - Energy-related conflicts may arise due to competition for scarce resources, territorial disputes over energy-rich areas, or disagreements on energy pricing and supply routes
- Geopolitical **tensions** can escalate when countries rely heavily on imported energy and are **vulnerable** to disruptions or geopolitical influences in energy markets

- Inadequate governance, corruption, and lack of transparent energy policies can further exacerbate tensions and increase the likelihood of conflict
- Addressing energy inequities and promoting fair distribution of energy resources can contribute to stability, peace, and sustainable development



Your notes

Energy Choices

- Energy choices adopted by different societies are influenced by a huge number of factors that shape their decision-making processes
- The availability of different energy sources, considerations of sustainability, scientific and technological advancements, cultural attitudes, and political, economic, and environmental factors all play significant roles in determining the energy mix used by a society
- Understanding how these influences interact is crucial for comprehending why certain energy sources are preferred over others and how societal preferences may shift over time

Availability

- The availability of different energy sources plays a significant role in influencing energy choices
- Regions or countries with abundant natural resources such as oil, gas, coal, or renewable energy sources like wind, solar, or hydropower may opt for the energy sources that are most readily available to them

Sustainability

- The growing concern for environmental sustainability has a profound impact on energy choices
- Societies are increasingly considering the long-term impact of energy sources on the environment, including carbon emissions, air pollution, and resource depletion
- This drives the adoption of renewable energy sources and cleaner technologies that have smaller environmental footprints

Scientific and Technological Developments

- Advances in science and technology can shape energy choices
- Breakthroughs in renewable energy technologies, energy storage systems, and energy efficiency solutions make these options more viable and attractive
- Scientific research also provides valuable insights into the environmental impacts and feasibility of different energy sources, influencing decision-making

Cultural Attitudes

- Cultural attitudes and beliefs can influence energy choices

- Societal values, traditions, and perceptions of certain energy sources may shape preferences and acceptance
- For example, societies with a strong cultural connection to nature may prioritise renewable energy sources due to their harmony with the environment

Political, Economic, and Environmental Factors

- Political factors such as government policies, regulations, and incentives have a significant impact on energy choices
- Economic considerations, including the cost and affordability of energy sources, can influence decision-making
- Environmental concerns, such as the desire to reduce greenhouse gas emissions or mitigate climate change, can drive the adoption of cleaner energy alternatives

Energy Security

- The need for energy security, which ensures a reliable and uninterrupted supply of energy, can also influence energy choices
- Societies may prioritise energy sources that provide independence from external factors, reduce vulnerability to price fluctuations or geopolitical tensions, and enhance energy self-sufficiency

Case Study: Nepal

- Nepal is a developing country located between China and India
- The landscape is mountainous and includes much of the Himalayas
- The population is rural with only 16% of the population living in towns and cities
- Energy demand is very low but growing as the country develops



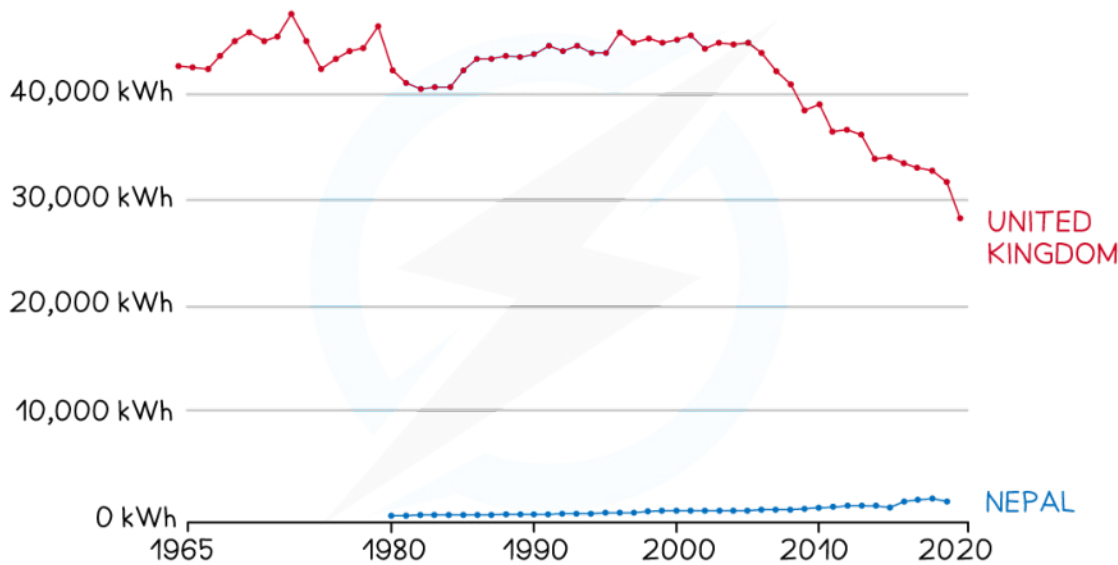
Your notes



Your notes

ENERGY USE PER PERSON

ENERGY USE NOT ONLY INCLUDES ELECTRICITY, BUT ALSO OTHER AREAS OF CONSUMPTION INCLUDING TRANSPORT, HEATING AND COOKING



SOURCE: OUR WORLD IN DATA BASED ON BP & SHIFT DATA PORTAL
 NOTE: ENERGY REFERS TO PRIMARY ENERGY – THE ENERGY INPUT BEFORE THE TRANSFORMATION TO FORMS OF ENERGY FOR END-USE (SUCH AS ELECTRICITY OR PETROL FOR TRANSPORT).

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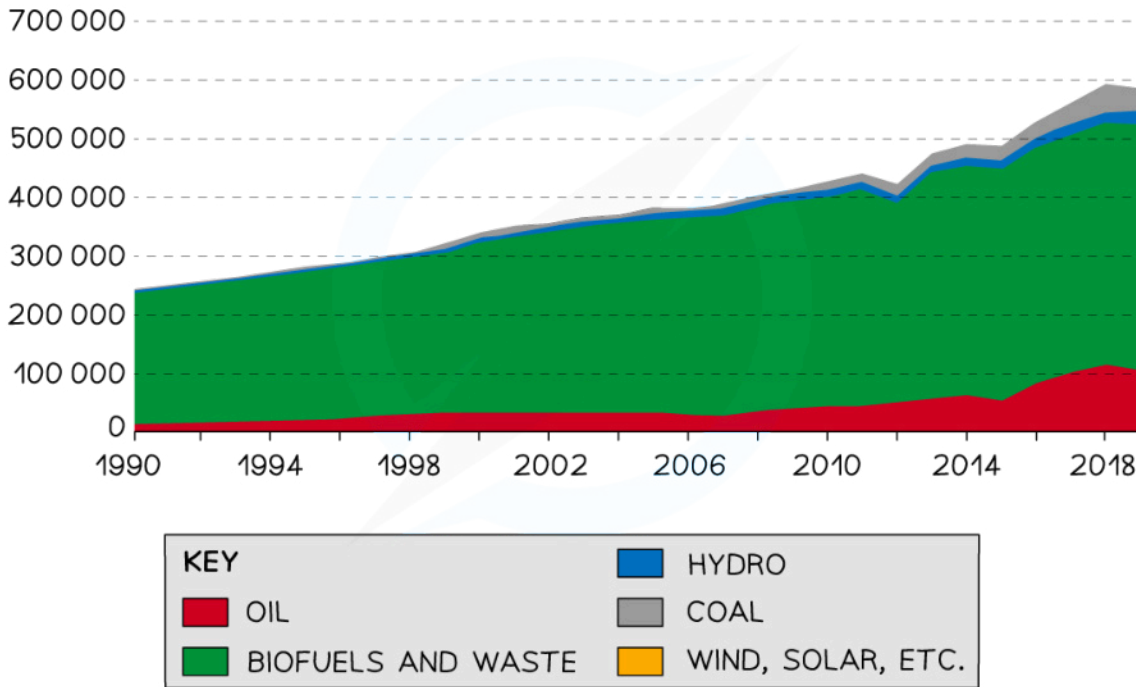
Energy use per person in Nepal and UK

Energy mix

- The main source of energy for 82% of the rural population is fuelwood
 - In urban areas, the use of fuelwood is 36%
- Nepal has no suitable coal, oil or gas reserves so these have to be imported
- Access to electricity has increased rapidly over the past 15 years
 - 88% of the population now have access to electricity
- Support from the World Bank has led to more investment in hydropower

- There are now over 3000 micro-hydro plants in Nepal

TOTAL ENERGY SUPPLY (TES) BY SOURCE, NEPAL 1990–2019



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Energy mix in Nepal

Case Study: Norway

- Norway is a developed country in northern Europe
- The demand for energy is one of the highest in the world
- The population is mainly urban with 83% of people living in towns and cities



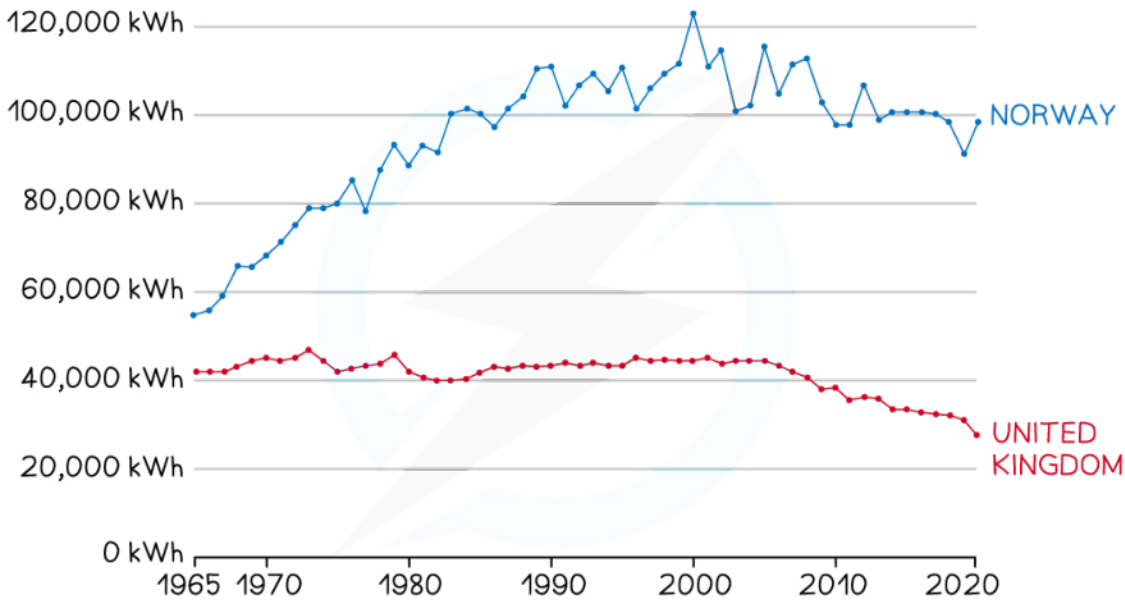
Your notes



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ENERGY USE PER PERSON

ENERGY USE NOT ONLY INCLUDES ELECTRICITY, BUT ALSO OTHER AREAS OF CONSUMPTION INCLUDING TRANSPORT, HEATING AND COOKING



SOURCE: OUR WORLD IN DATA BASED ON BP & SHIFT DATA PORTAL
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Energy use per person in Norway and UK

Energy mix

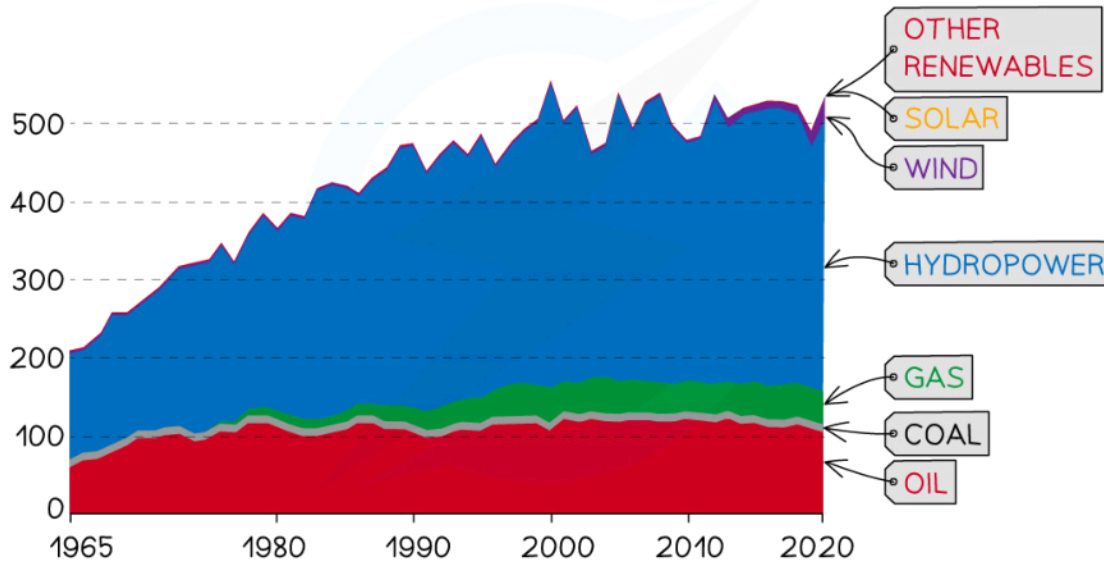
- Norway has significant energy resources including:
 - 1% of the world gas reserves (17th in the world)
 - 0.3% of the world oil reserves (22nd in the world)
 - There are also some coal reserves
- Norway is one of the world's largest energy exporters
- Hydropower generates 90% of Norway's electricity and accounts for 65% of energy use



Your notes

ENERGY CONSUMPTION BY SOURCE, NORWAY

PRIMARY ENERGY CONSUMPTION IS MEASURED IN TERAWATT-HOURS (TWh). HERE AN INEFFICIENCY FACTOR (THE 'SUBSTITUTION' METHOD) HAS BEEN APPLIED FOR FOSSIL FUELS, MEANING THE SHARES BY EACH ENERGY SOURCE GIVE A BETTER APPROXIMATION OF FINAL ENERGY CONSUMPTION.



SOURCE: BP STATISTICAL REVIEW OF WORLD ENERGY
NOTE: 'OTHER RENEWABLES' INCLUDES GEOTHERMAL, BIOMASS AND WASTE ENERGY.

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Energy mix in Norway

Sustainable future

- There are over 1500 hydropower plants in Norway
- Due to the issue of reliance on hydropower during the dry season and the environmental impact of large hydropower plants
- Norway is expanding other renewable energy sources
- Demand continues to increase
- Norway is expanding the number of wind farms:
 - There are currently 53 wind farms

- 36 additional onshore and offshore are planned and due to be started or completed by 2030
 - Includes the world's first floating wind farm
- Norway is also investing in solar energy:
 - Homeowners in Oslo get a 30% subsidy for installing solar panels
- To reduce the consumption of oil Norway is encouraging the population to move to electric cars:
 - In 2021, 66% of all new car sales in Norway were electric



Your notes