Edexcel GCSE Physics

Your notes

Efficiency & Energy Resources

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Wasted Energy

Your notes

Wasted Energy

- Mechanical processes can become wasteful when they cause a rise in temperature
- These processes often involve **friction**
  - When friction acts, it has the effect of transferring energy from the kinetic store by heating to the objects and the **surroundings**
  - This energy cannot be used in a **useful** way, therefore it is called **wasted** energy
  - Energy that is transferred to the surrounding is said to be **dissipated** (spread out) to the surroundings

- Useful energy can be defined as:

  An energy transfer that serves an intended purpose

- Wasted energy can be defined as:

  An energy transfer that is not useful for the intended purpose and is dissipated to the surroundings

Example: A Bat Hitting a Ball

- The moving bat has energy in its **kinetic** store
- Some of that energy is transferred **usefully** to the **kinetic** store of the ball
- Some of that energy is transferred from the **kinetic** store of the bat to the **thermal** store of the ball **mechanically** due to the impact of the bat on the ball
- Some of that energy is **dissipated** by **heating** to the **thermal** store of the bat, the ball, and the surroundings

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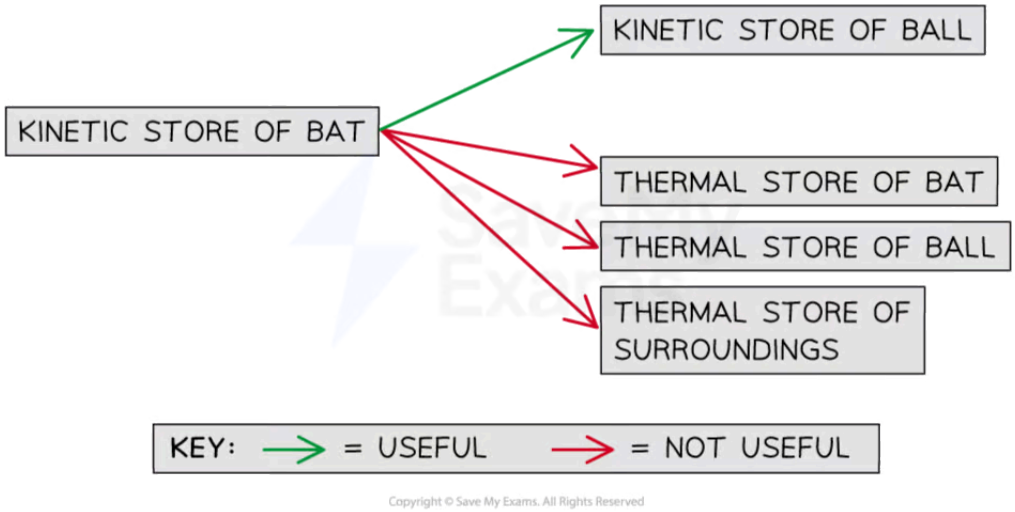

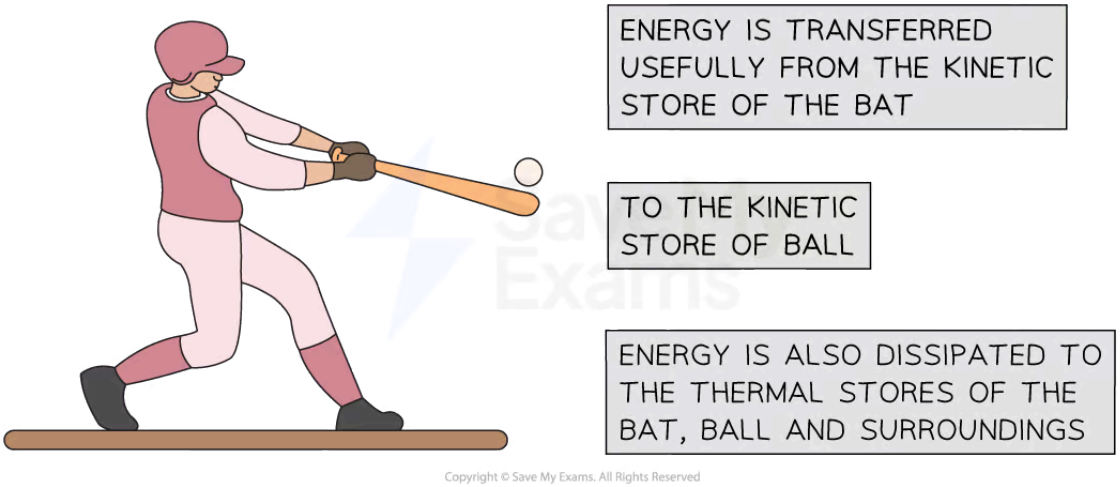

Energy transfers taking place when a bat hits a ball

Worked Example

A student uses an electric motor to lift a load.

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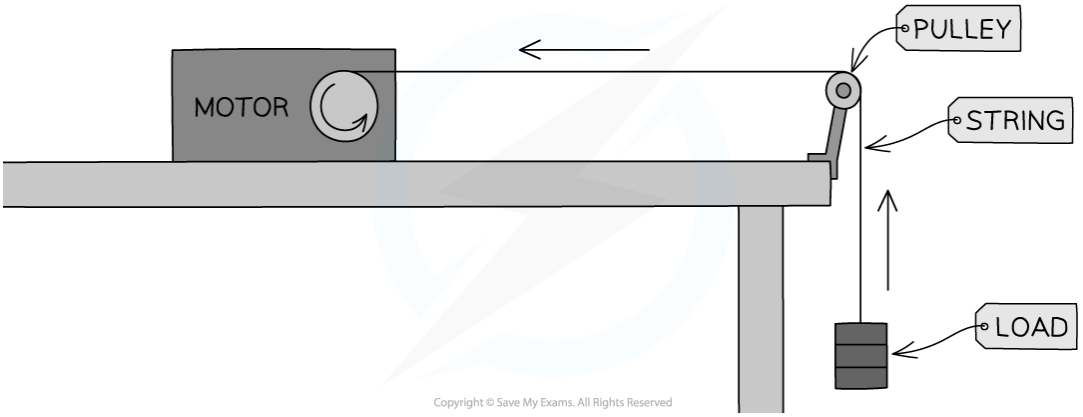


As the motor turns, energy is transferred to the load as the string and the pully lift it up.

a) State the useful energy transfer happening in this system.

b) State the main wasted energy transfer happening in this system.

Answer:

Part (a)

- The motor turns so it is **moving**, therefore energy is transferred **from** the **kinetic store** of the motor
- The load is **lifted** upwards (through a gravitational field) by the string and pulley, therefore energy is transferred **usefully to** the **gravitational potential store** of the load

Part (b)

- As the motor operates, **friction** between the components causes heating
- Therefore, energy is transferred **from** the **kinetic store** of the motor to the **thermal store** of the motor and **dissipated to the surroundings**

Examiner Tips and Tricks

Make sure you are able to identify "useful" and "wasted" energy transfers as this is commonly tested in exams!

Learn the term '**dissipated to the surroundings**', because if you say the energy is simply "lost", this will not gain you the mark as it implies that energy is not conserved.

Dissipation of Energy

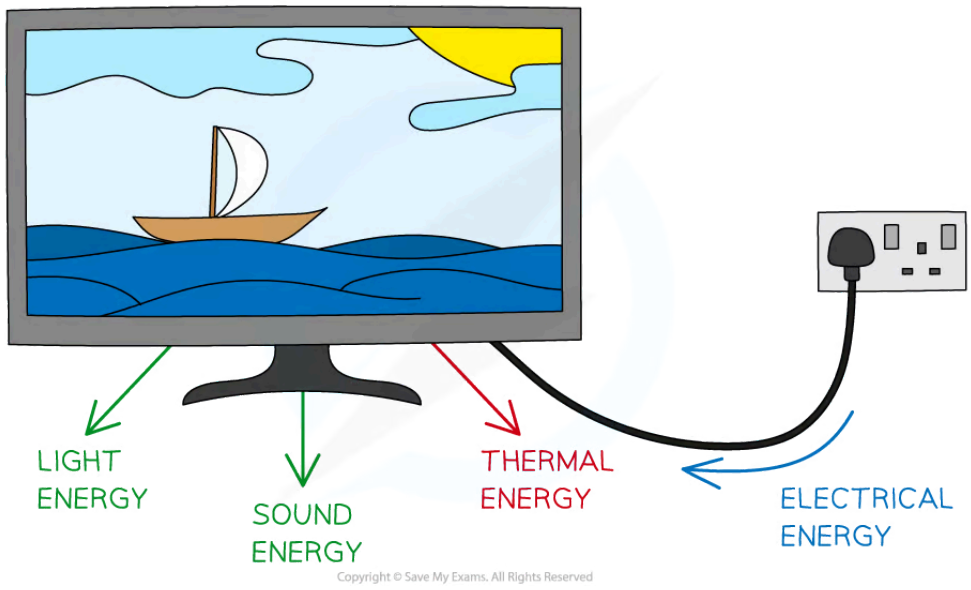
Your notes

- Energy transferred **by heating** and **by radiation** have a tendency to spread out to the surroundings
  - This is known as **dissipation** of energy
- Dissipated energy is very difficult to "gather" so that it can be used again
  - As a result, the energy becomes **less useful**
  - Because of this, whenever a process produces **unwanted** heating, light or sound, the energy is dissipated and essentially **wasted**

- **Not all dissipated** energy is **wasted** energy as the following examples show:

Example 1: A Television

- The **useful** energy transfers occurring in a television:
  - Energy is transferred electrically from the mains supply and is **dissipated** to the surroundings **by radiation** as visible light, and by **heating** as sound waves
- The **wasted** energy transfers occurring in a television:
  - Energy is transferred electrically from the mains supply to the **thermal store** of the television and is then **dissipated** to the surroundings **by heating**

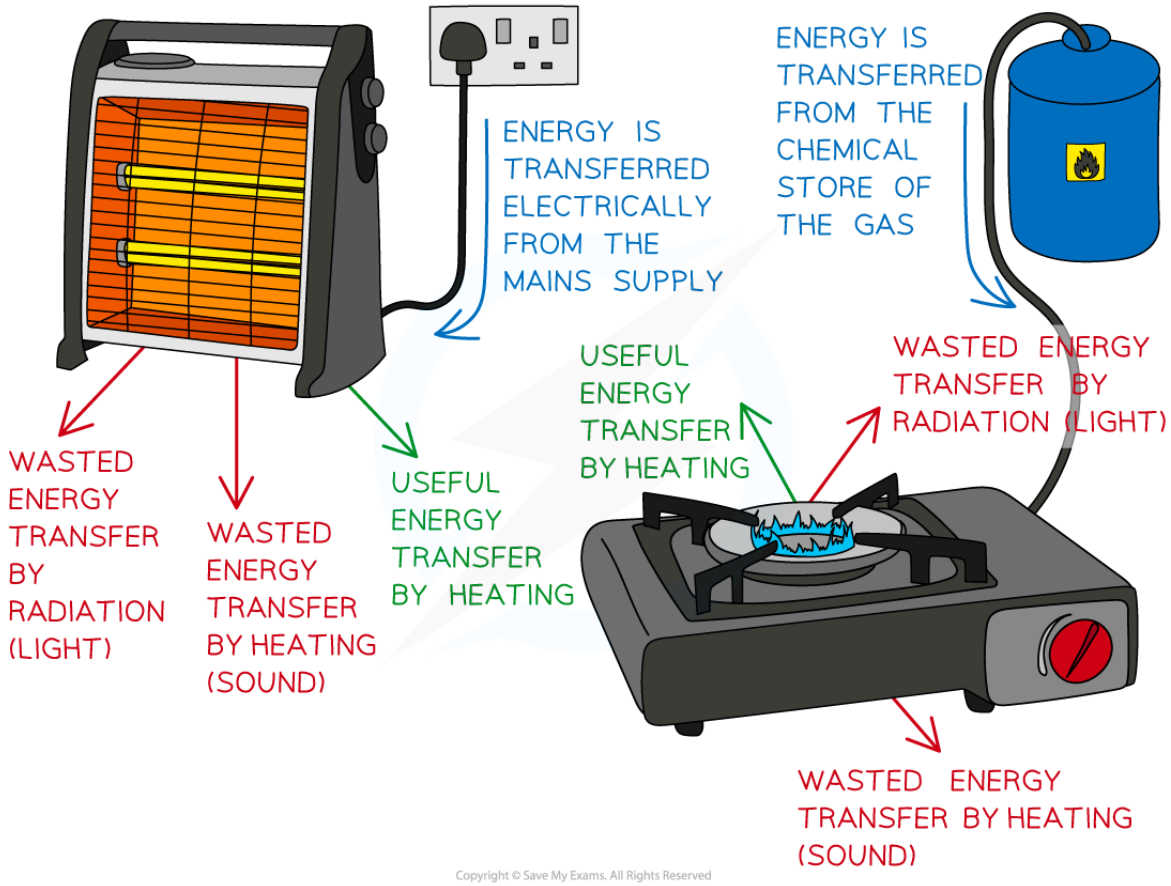


Useful and wasted energy transfers in a television

Example 2: Heaters

Your notes

- The **useful** energy transfers occurring in a heater:
  - Energy is transferred electrically from the mains supply to the **thermal store** of the heating element and is then **dissipated** to the surroundings by **heating**
- The **wasted** energy transfers occurring in a heater:
  - Energy is transferred electrically from the mains supply to the **thermal store** of the heating element and is then **dissipated** to the surroundings **by radiation** as visible light



Useful and wasted energy transfers in an electric heater

Reducing Energy Loss

- There are many situations where energy transfers are actually **unwanted**:
  - Keeping a house warm

- Keeping a hot drink hot or cold
- Friction of mechanical parts

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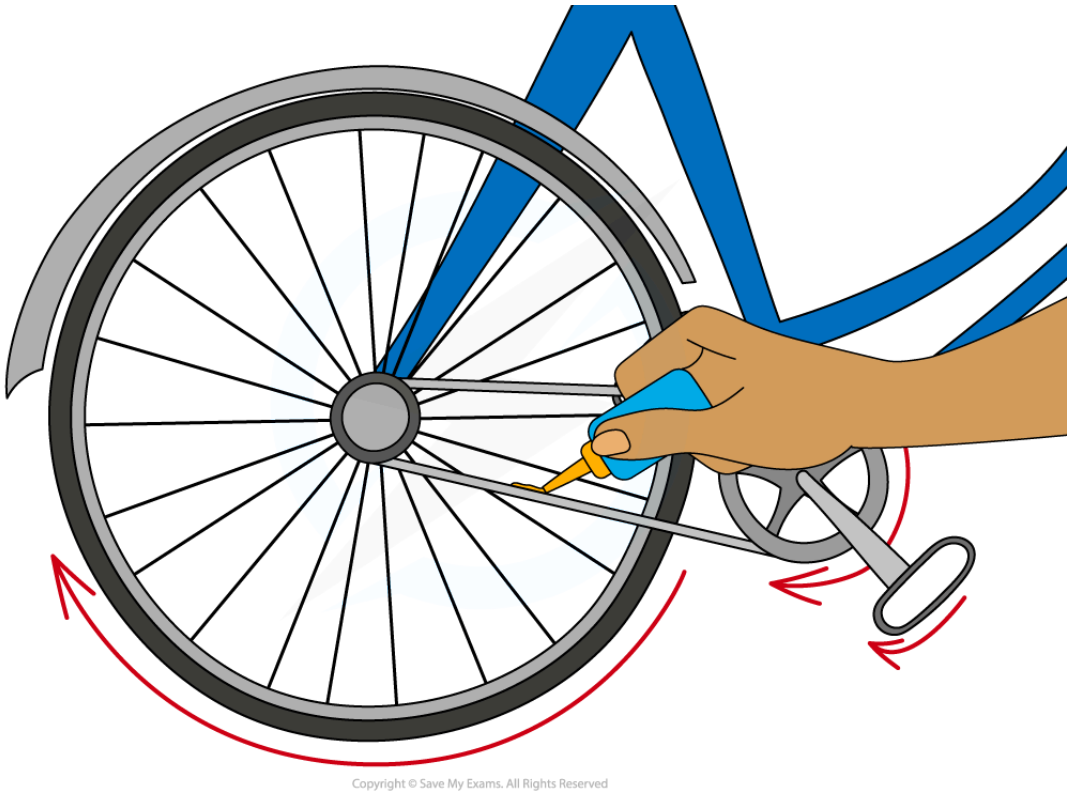
Insulated mugs are used to maintain the temperature of hot or cold drinks

- When an appliance is used for heating something (a kettle, a heater, a tumble drier, a central heating system etc.), the appliance requires a lot of energy
  - It can become expensive for a household to run such appliances
  - The production of electricity using fossil fuels produces greenhouse gases which contribute to global warming
  - The combustion of (methane) gas produces greenhouse gases which contribute to global warming
- Therefore, it is often useful to explore ways of **reducing** unwanted energy transfers
- Energy that is **dissipated to the surroundings** is often the main source of **wasted** energy transfers
- If these unwanted energy transfers can be prevented, or reduced, the **useful** energy transfers can be made more **efficient**

Lubrication

- Friction is a major cause of **wasted energy transfers** in machines
- For example, the gears on a bike can become hot if the rider has been cycling for a long time
  - Energy is transferred **wastefully** from the **kinetic energy store** of the bike to the **thermal energy store** of the gears and the chain
  - Since the energy is originally transferred from the **kinetic store** of the **rider** to the **kinetic store** of the **bike**, this means that the person has to do more **work** to make the bike move
- This wasted energy transfer can be reduced if the amount of friction can be **reduced**
  - This can be achieved by **lubricating** the parts that rub together



Lubrication helps reduce friction in the parts of a cycle

Insulation

- **Insulation** reduces energy transfers from **conduction**

- The effectiveness of an insulator is dependent upon:

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- The thermal **conductivity** of the material
  - The lower the conductivity, the less energy is transferred
- The **density** of the material
  - The more dense the insulator, the more conduction can occur
  - In a denser material, the particles are closer together so they can transfer energy to one another more easily
- The **thickness** of the material
  - The thicker the material, the better it will insulate


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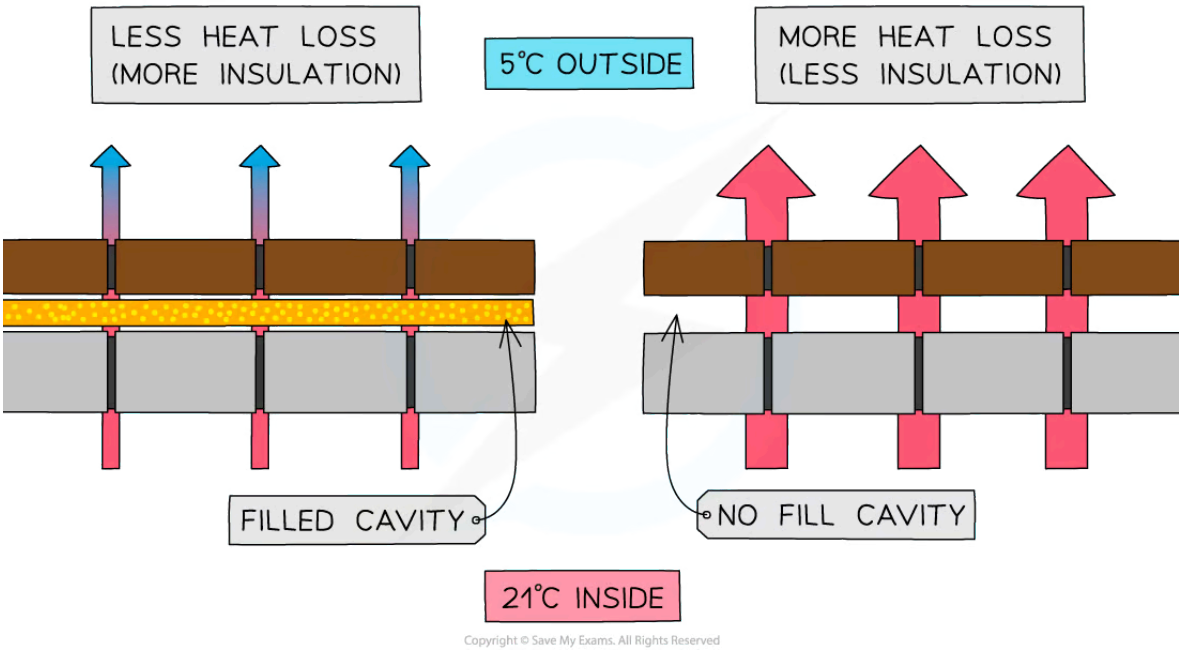
- Insulating the loft of a house lowers its rate of cooling, meaning less energy is transferred to the surroundings (outside)
- The insulation is often made from fibreglass (or glass fibre)
  - This is a reinforced plastic material composed of woven material with glass fibres laid across and held together
  - The air trapped between the fibres makes it a **good** insulator
- The gaps or cavities between external walls are often filled with insulation
  - This is called **cavity wall insulation**
  - This is often done by drilling a hole through the external wall to reach the cavity and filling it with a special type of foam which is made from blown mineral fibre filled with gas
  - This lowers the **conduction** of heat through the walls from the inside to the outside



Less energy is transferred by conduction if the cavity is insulated

Your notes

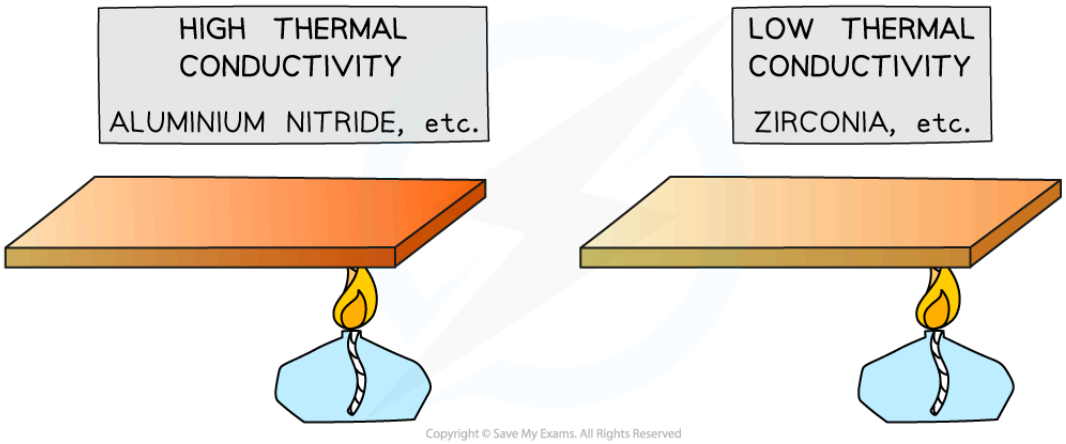
Conduction of Heat

Your notes

Factors Affecting Conduction

- **Thermal conduction** is the process where **energy** is **transferred** by vibrating particles in a substance
- The **vibrating** particles transfer energy from their **kinetic** store to the **kinetic** store of neighbouring particles
- The direction of energy transfer is always from **hot** to **cold**

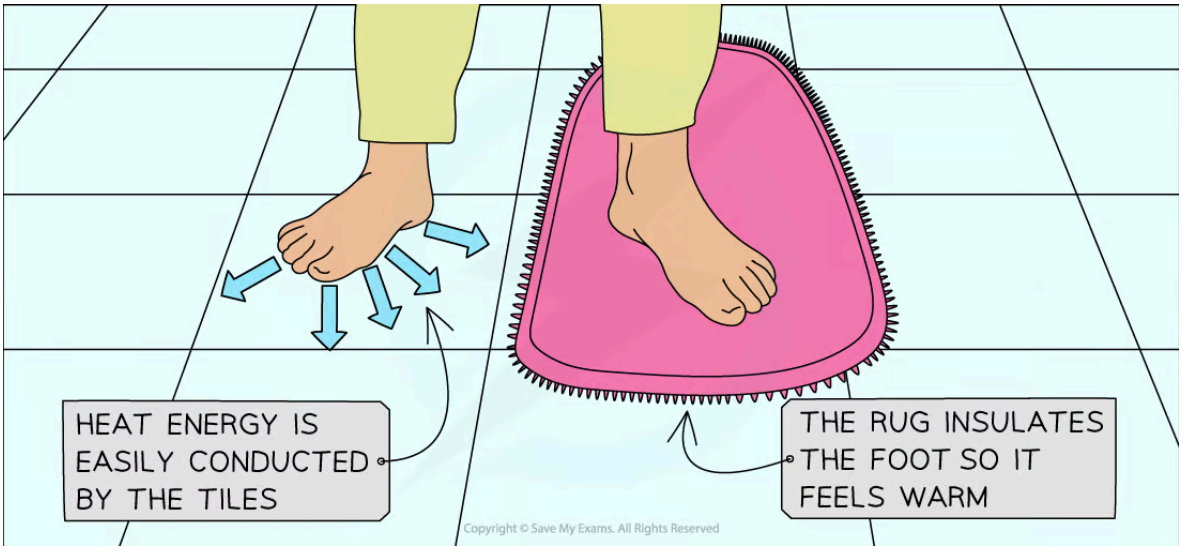
  The higher the thermal conductivity of a material, the higher the rate of energy transfer by conduction across the material
- Materials with **high** thermal conductivity **heat up faster** than materials with **low** thermal conductivity



Materials with high and low thermal conductivity

- Objects will **continue** to lose heat until they reach **thermal equilibrium** (equal temperature) with their surroundings
  - For example, a mug of hot coffee will cool down until it reaches room temperature
- Conduction is the main method of energy transfer by heating in solids
  - Metals are extremely good thermal **conductors**
- Non-metals are poor thermal conductors whilst liquids and gases are extremely poor

- Poor conductors are called **insulators**



Energy is transferred by heating from the hotter foot to the cooler tiles by conduction

- **Factors affecting** thermal conduction are:
  - The **thickness** of the material
  - The **thermal conductivity** of the material
  - The **temperature difference** between two areas of the material (for example the internal and external surfaces of a wall)

- The rate of energy transfer is **reduced** by:
  - **Increasing** the thickness of the material
  - **Decreasing** the thermal conductivity of the material
  - **Decreasing** the temperature difference

Your notes

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Efficiency

The **efficiency** of a system is a measure of the amount of **wasted energy** in an energy transfer

- Efficiency is defined as:

  The ratio of the useful energy output from a system to its total energy output

- If a system has **high** efficiency, this means most of the energy transferred is **useful**
- If a system has **low** efficiency, this means most of the energy transferred is **wasted**

- Efficiency can be represented as a **decimal** or as a **percentage**
- The equation for efficiency is:

$$\text{efficiency} = \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}}$$

Worked Example

The blades of a fan are turned by an electric motor. In one second, 300 J of energy is transferred electrically from the mains supply to the fan. 85 J is wasted due to friction and sound.

Calculate the percentage efficiency of the motor.

Answer:

Step 1: List the known quantities

- Total energy supplied to the device (input) = 300 J
- Total wasted energy = 85 J

Step 2: State the equation

$$\text{efficiency} = \frac{\text{useful energy transferred by the device (output)}}{\text{total energy supplied to the device (input)}} \times 100\%$$

Step 3: Determine total energy transferred by the device (output)

- Due to the conservation of energy:

$$\text{total energy transferred by the device (output)} = \text{total energy supplied to the device (input)}$$

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- Therefore, total energy transferred by the device (output) = 300 J

Step 4: Calculate the useful energy transferred by the device (output)

- Due to conservation of energy

$$\text{total energy transferred by the device} = \text{useful energy transferred by the device} + \text{wasted energy}$$

$$\text{useful energy transferred by the device} = \text{total energy transferred by the device} - \text{wasted energy}$$

$$\text{useful energy transferred by the device} = 300 - 85$$

$$\text{useful energy transferred by the device} = 215 \text{ J}$$

Step 5: Substitute these values into the efficiency equation

$$\text{efficiency} = \frac{\text{useful energy transferred by the device (output)}}{\text{total energy supplied to the device (input)}} \times 100\%$$

$$\text{efficiency} = \frac{215}{300} \times 100\%$$

$$\text{efficiency} = 72\%$$

Examiner Tips and Tricks

Efficiency can be in a ratio (between 0 and 1) or percentage format (between 0 and 100%)If the question asks for efficiency as a ratio, give your answer as a fraction or decimal.

If the answer is required as a percentage, remember to multiply the ratio by 100 to convert it:

- if the ratio = 0.25, percentage = 0.25 × 100 = 25 %

Remember that efficiency has **no units** (only %)

Your notes

Improving Efficiency

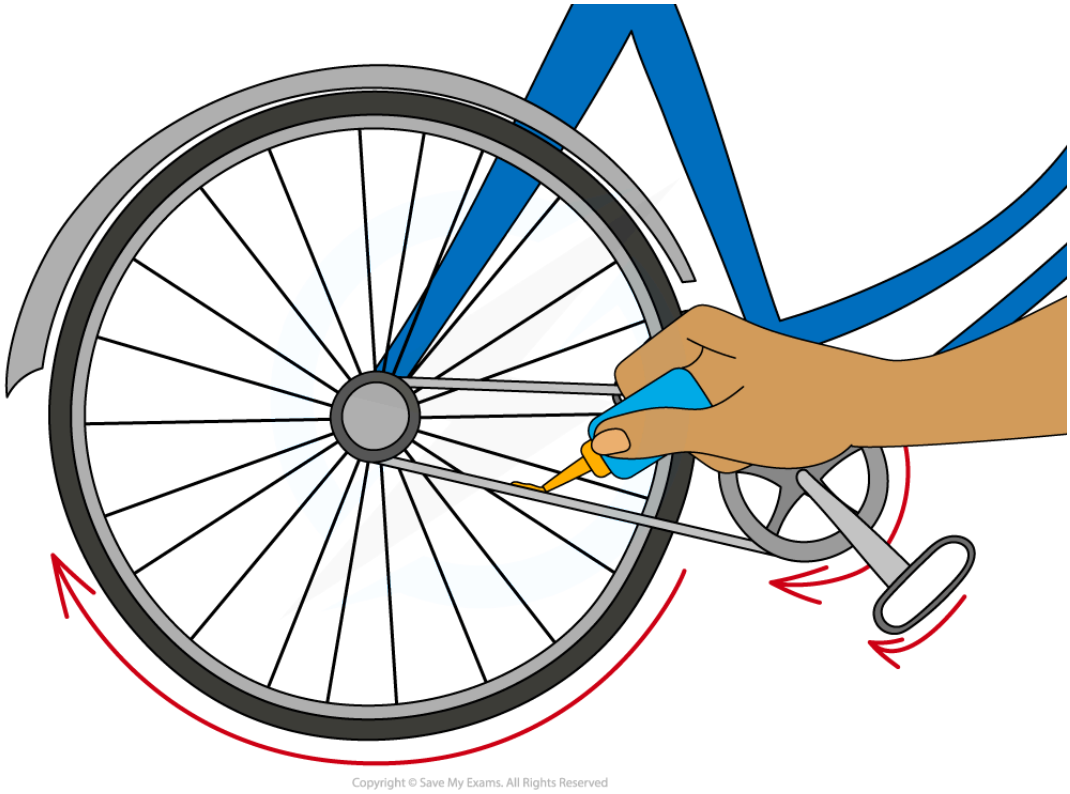
Higher Tier Only

- The efficiency of a device can be improved by **reducing** wasted energy transfers
- Machines waste energy due to:
  - Friction between their moving parts
  - Air resistance
  - Electrical resistance
  - Noise

Reducing Friction

- In a mechanical system, for example, there is often **friction** between the moving parts of the machinery
- This results in unwanted energy transfers **by heating** to the machinery and the surroundings
- **Friction** can be reduced by:
  - Adding bearings to prevent components from directly rubbing together
  - Lubricating parts

Your notes



Lubricating parts of a bicycle to reduce friction

Reducing Electrical Resistance

- In electric circuits there is **resistance** as current flows through the wires and components
- This results in unwanted energy transfers **by heating** to the wires, components and the surroundings
- **Resistance** can be reduced by:
  - Using components with lower resistance
  - Reducing the current

Reducing Air Resistance

- **Air resistance** causes a frictional force between the moving object and the air that opposes its motion
- This results in unwanted energy transfers **by heating** to the object and the surroundings
- **Air resistance** can be reduced by:
  - Streamlining the shapes of moving objects

- For example, a racing cyclist adopts a more **streamlined** posture to reduce the effects of air resistance
  - Also, the bicycle, clothing and helmet are designed to allow them to go as fast as possible

Many factors such as posture, clothes and bicycle shape must be considered when trying to reduce air resistance

Reducing Noise

- Sound is often created by moving parts of machinery
- This results in unwanted energy transfers **by heating** to the surroundings as sound waves cause the particles in the air and nearby objects to vibrate
- **Sound** can be reduced by:
  - Tightening loose parts to reduce vibration
  - Lubricating parts

Examiner Tips and Tricks

Your notes

When answering questions about improving efficiency, it is helpful to identify the useful energy transfers and the wasted energy transfers. Remember, the efficiency of a device is improved by **increasing** the **useful** energy transfers and **reducing** the **wasted** energy transfers.


Your notes

Energy Resources

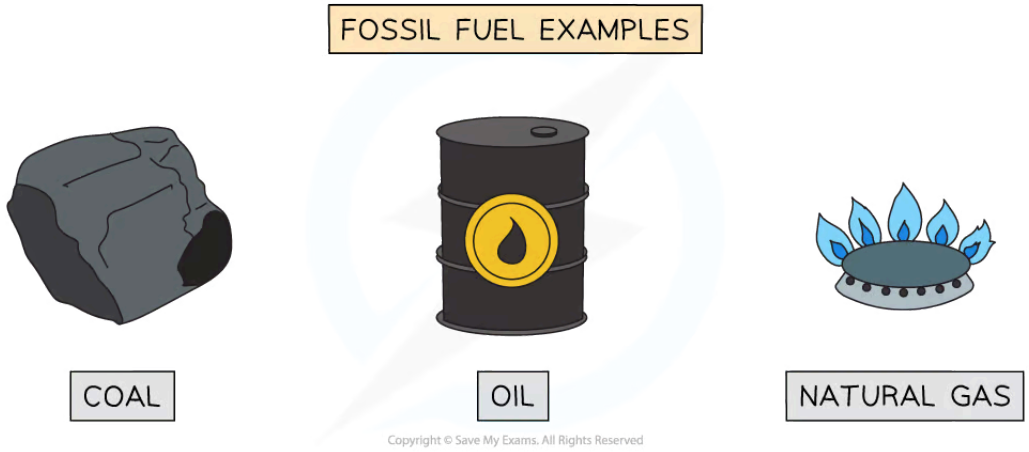
Your notes

Energy Resources

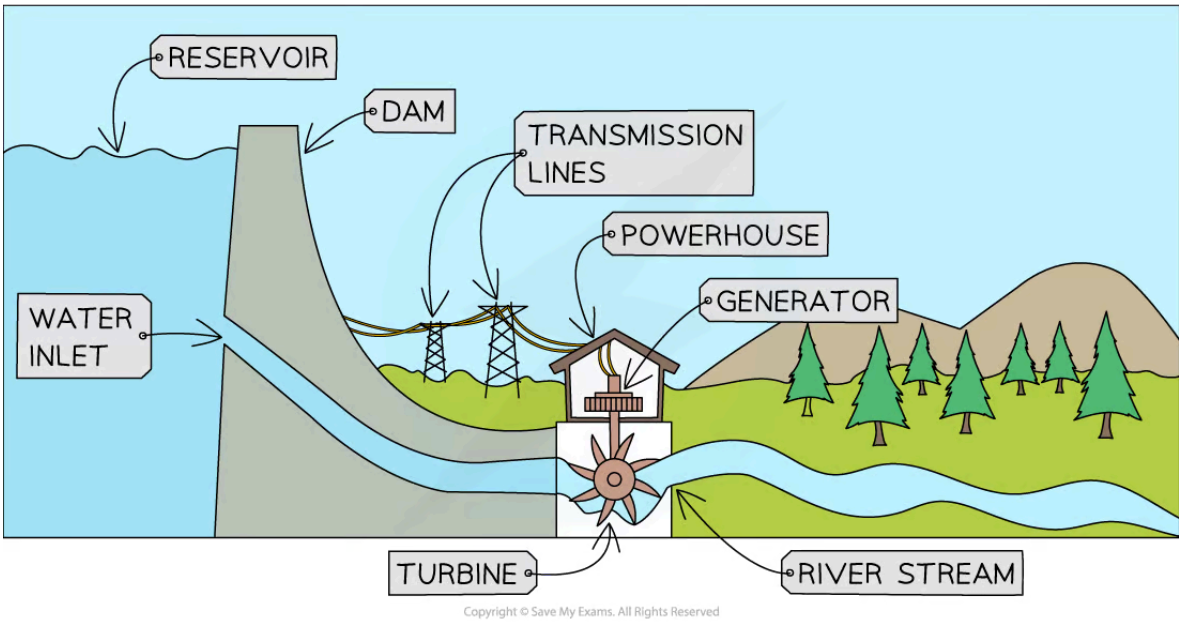
- **Energy resources** are large stores of energy that can be used to **generate electricity** and heat homes and businesses
- Some electricity drawn from the **National Grid** is generated from **non-renewable** resources, and some is generated from **renewable** resources
- A **renewable** energy resource is defined as

  An energy source that is replenished at a faster rate than the rate at which it is being used
- As a result of this, a renewable energy resource is one that will not run out
- Renewable resources include:
  - Solar energy
  - Wind
  - Bio-fuel
  - Hydroelectricity
  - Geothermal
  - Tidal
- **Non-renewable** energy resources include:
  - Fossil Fuels (coal, oil and natural gas)
  - Nuclear fuel

Your notes



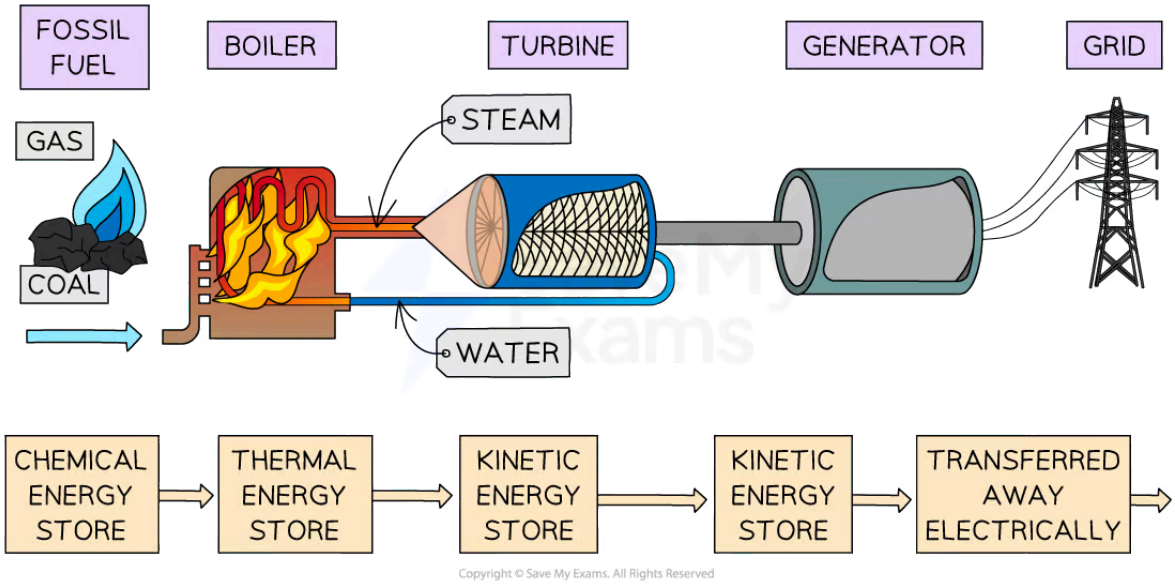
- Electricity is generated in very similar ways, no matter what energy resource is used
- A **turbine** is turned, which turns a **generator**, which generates electricity
- The element that differs is **how** the turbine is made to turn
- **Water** can be used to turn turbines in the case of hydroelectric dams, tidal barrages and tidal turbines
- Energy in the **kinetic store** of the flowing water is transferred to the **kinetic store** of the turbine and then to the **kinetic store** of the generator and transferred **electrically** to the National Grid



A hydroelectric dam transfers energy from the gravitational potential energy store of the water to its kinetic energy store mechanically to turn a turbine

- **Fossil fuels** can be combusted to heat water, and the **steam** produced can be used to turn turbines
- Energy from the **chemical store** of the fuel is transferred to the **thermal store** of the water, which is then transferred to the **kinetic store** of the turbine, and then transferred to the **kinetic store** of the generator and then transferred **electrically** to the National Grid

Your notes

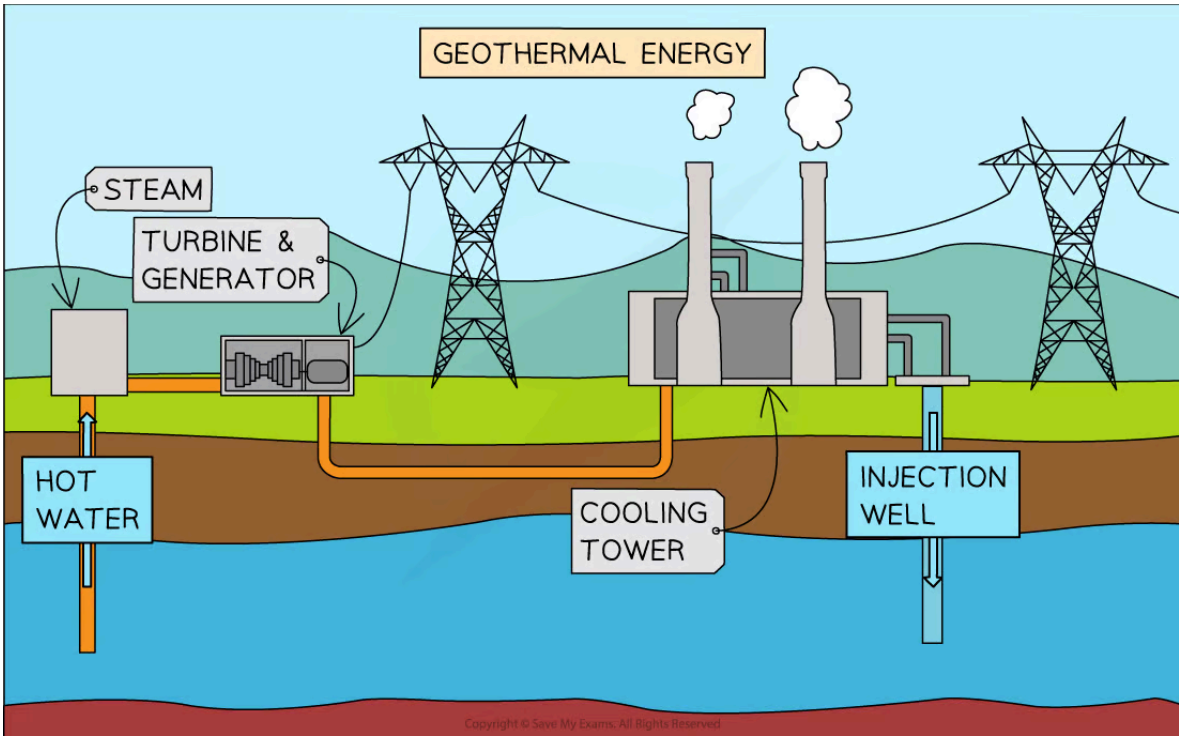


The energy transfers involved in the production of electricity from fossil fuels

- **Nuclear fuel** can also be used to heat water to produce **steam** to turn turbines
- The energy transfers involved in electricity generation from a nuclear power plant are:

  Nuclear store of fuel → thermal store of water → kinetic store of turbine → kinetic store of generator
- **Geothermal** energy is another way to produce the **steam** that turns the turbines
- Water is pumped down to the hot rocks and returns through a fissure as steam

Your notes



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

- Generating energy reliably requires the use of a range of different energy resources, as listed in the table below:

Energy Resources Table

Your notes

Energy Resources	Description
Fossil fuels	Fossil fuels are combusted to heat water to produce steam to turn turbines to generate electricity
Nuclear	Nuclear fuels are reacted to heat water to produce steam to turn turbines to generate electricity
Bio-fuels	Plant matter, ethanol or methane can be produced and used as a fuel in place of fossil fuels
Wind	Wind turns turbines directly to generate electricity
Hydroelectric	Water is stored at a height, and when released, rushing water turns turbines directly to generate electricity
Tidal	The movement of water due to tides turn turbines directly to generate electricity
Geothermal	Hot rocks underground are used to heat water to produce steam to turn turbines which generate electricity
Solar	Solar cells use light to generate electricity, solar panels use thermal radiation to heat water to produce warm water for household use
Water waves	Moving water due to waves turn turbines directly to generate electricity

Your notes

Worked Example

Electricity can be generated by wind power. Describe the energy transfers which occur when a wind turbine is used to generate electricity for the National Grid.

Answer:

Step 1: Determine where the energy is transferred from

Energy is transferred from the kinetic store of the moving wind...

Step 2: Determine the energy transfer involved as energy is transferred from the wind to the turbine

...to the kinetic store of the turbine as the wind makes it turn.

Step 3: Name the other energy transfers that occur in the process of generating electricity

Energy is transferred from the kinetic store of the turbine to the kinetic store of the generator and is transferred electrically to the National Grid.


Your notes

Comparing Energy Resources

- Each energy resource has various advantages and disadvantages associated with it
- A **renewable** energy resource is one that is replenished at a faster rate than the rate at which it is being used
  - As a result of this, renewable energy resources will not run out
- A **reliable** energy resource is one that can produce energy at any time
- **Non-reliable** resources can only produce energy some of the time (e.g. when it's windy)
- The table below shows a comparison of the advantages and disadvantages of the different energy resources:

Comparison of Different Energy Resources Table

Your notes

Energy Resource	Renewable?	Advantages	Disadvantages
Fossil fuels	No	Reliable. Can produce large amounts of energy at fairly short notice.	Produces significant greenhouse gases and pollution
Nuclear	No	Reliable. Produces no greenhouse gases or pollution. A large amount of energy is produced from a small amount of fuel.	Produces dangerous radioactive waste that can take thousands of years to decay
Bio-fuels	Yes	The CO_2 produced while burning the fuel is balanced by the CO_2 absorbed whilst producing it.	Can take up a lot of land and consume resources that are needed for food production
Wind	Yes	Produces no greenhouse gases or pollution. Land can still be used for farming.	Not reliable. Turbines can be noisy and ugly. Not everywhere is suitable
Hydroelectric	Yes	Reliable and can produce large amount of energy at short notice. Produces no pollution of greenhouse gases.	Can involve flooding large area, destroying important wildlife habitats
Tidal	Yes	The tides are very predictable, and a large amount of energy can be produced at regular intervals.	Very few suitable locations. Can cause environmental harm to estuaries and disrupt shipping
Geothermal	Yes	Reliable. Geothermal stations are usually small.	Can result in the release of harmful gases from underground. Not many places are suitable
Solar	Yes	Produces no greenhouse gases or pollution. Good for producing energy in remote places.	Not reliable (only works when sunny). Solar farms can use up lots of farmland.

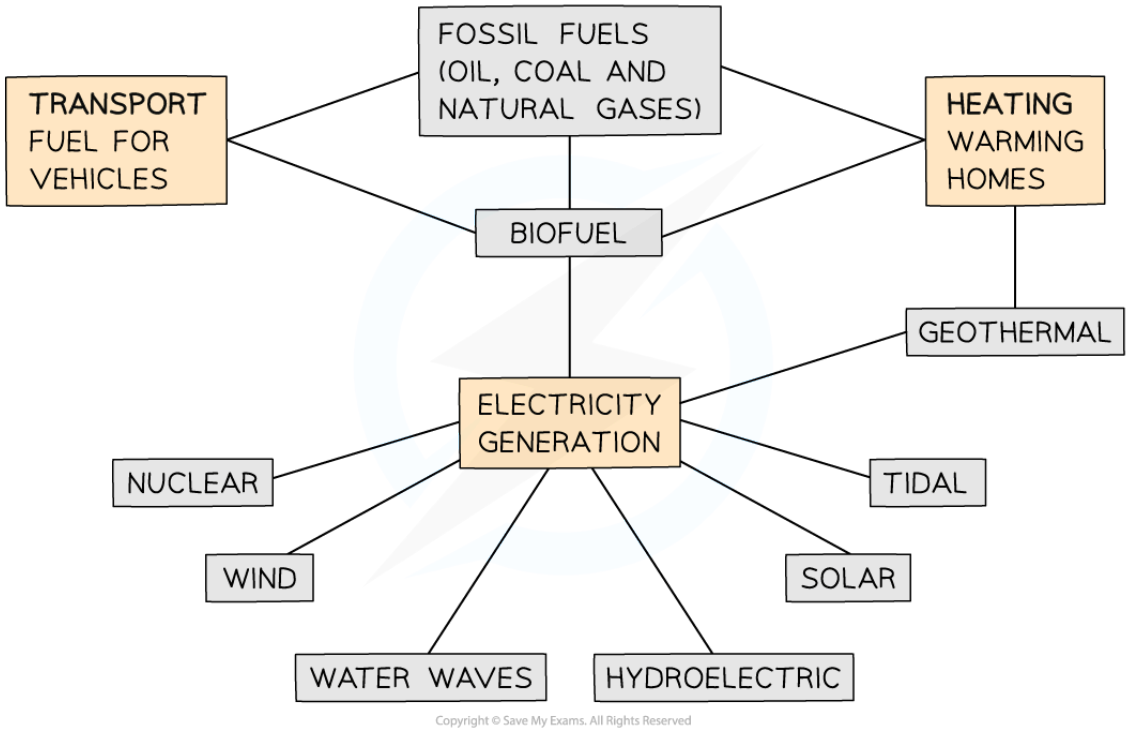
Your notes

Examiner Tips and Tricks

Make sure you're familiar with the advantages and disadvantages of large scale electricity production from renewable and non-renewable energy sources, as this is a common exam question!

The Use of Energy Resources

- The three main uses of energy resources include:
  - Transport
  - Electricity generation
  - Heating



Types of energy resources

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
- Vehicles can also be powered by **biofuel**
  - The advantage of biofuel is that it is a **renewable** resource
  - However, the claim that biofuels are carbon-neutral is largely **controversial**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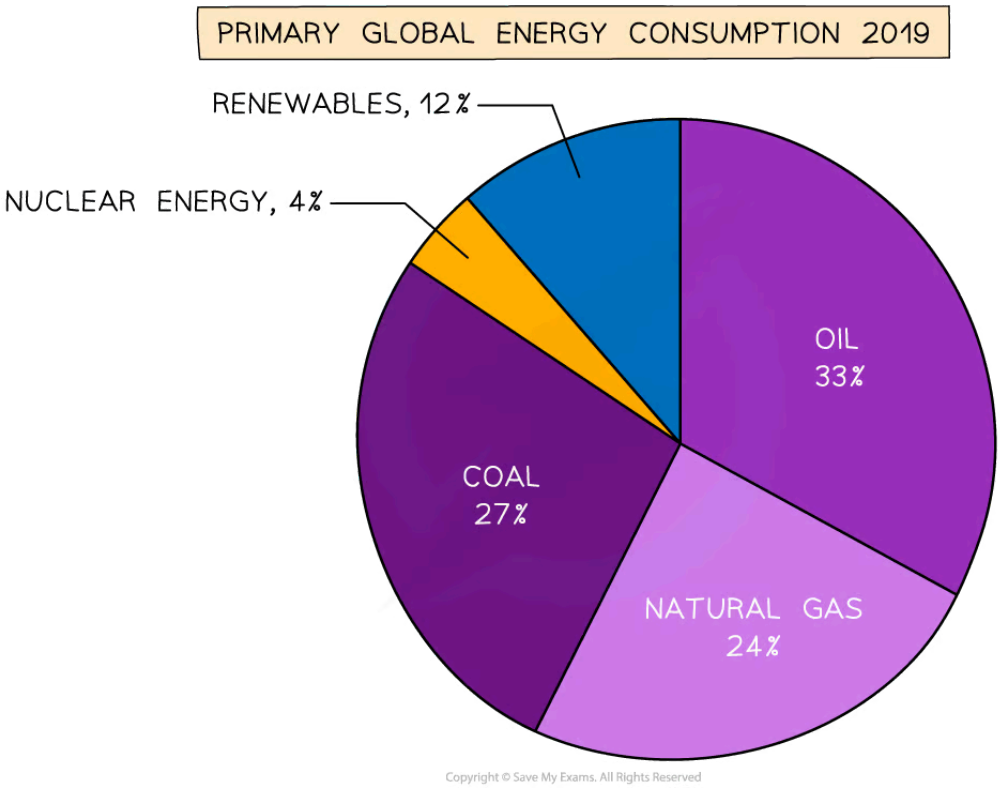
Electricity Generation

- 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
- On the downside, the majority (84%) of the world's energy is still produced by non-renewable, carbon-emitting sources
  - This has an enormous **negative** impact on the environment
  - Currently, scientists are working hard to develop more and more efficient ways to produce electricity using more carbon-neutral energy resources



Pie chart of global energy consumption

Heating

- Most homes in cold countries are fitted with **central heating systems**
- These utilise **natural gas** in order to heat up water which can be pumped around radiators throughout the home
  - Unfortunately, gas is a non-renewable energy resource
- In geologically active countries, such as Iceland, they are fortunate to be able to heat their homes using **geothermal** energy

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