Energy and Energy Resources:

Changes in energy stores:

- magnetic
- internal (thermal)
- chemical
- kinetic
- electrostatic
- elastic potential
- gravitational potential
- nuclear

- Energy can be transferred from one store to another
- Energy can be transferred by heating, waves, an electric current, or when a force moves an object

Energy store	Description	Examples
Magnetic	The energy stored when repelling poles have been pushed closer together or when attracting poles have been pulled further apart.	Fridge magnets, compasses, maglev trains which use magnetic levitation.
Internal (thermal)	The total kinetic and potential energy of the particles in an object, in most cases this is the vibrations - also known as the kinetic energy - of particles. In hotter objects, the particles have more internal energy and vibrate faster.	Human bodies, hot coffees, stoves or hobs. Ice particles vibrate slower, but still have energy.
Chemical	The energy stored in chemical bonds, such as those between molecules.	Foods, muscles, electrical cells.
Kinetic	The energy of a moving object.	Runners, buses, comets.
Electrostatic	The energy stored when repelling charges have been moved closer together or when attracting charges have been pulled further apart.	Thunderclouds, Van De Graaff generators.
Elastic potential	The energy stored when an object is stretched or squashed.	Drawn catapults, compressed springs, inflated balloons.
Gravitational potential	The energy of an object at height.	Aeroplanes, kites, mugs on a table.
Nuclear	The energy stored in the nucleus of an atom.	Uranium nuclear power, nuclear reactors.

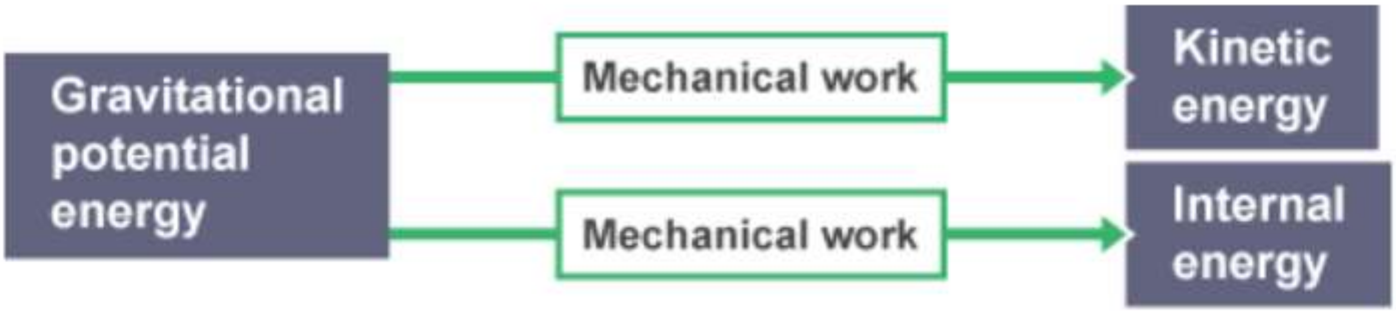
The conservation of energy

- **Energy** can be transferred usefully, stored or **dissipated**, but it cannot be created or destroyed.
- In all cases, energy comes from one store and is transferred to another store. This means that all the energy in the universe was present at the **Big Bang** and will still be around at the very end of time.

Examples of conservation of energy

The skydiver

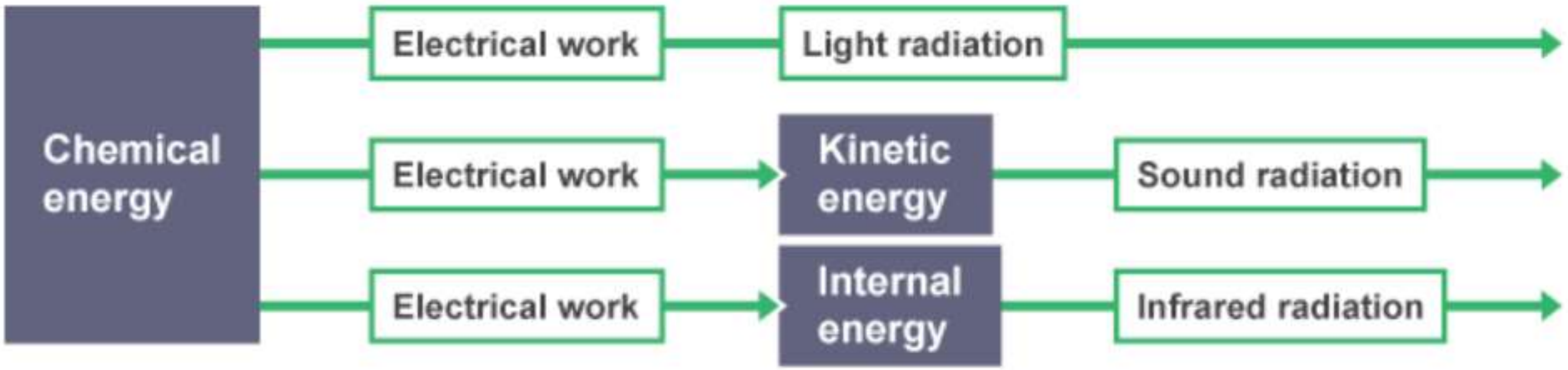
- When a skydiver jumps out of a plane, he begins to lose energy from the **gravitational potential energy store** as his height decreases, and his kinetic energy store increases as his speed increases.
- However, not all of the energy lost from the gravitational potential energy store is transferred into the **kinetic energy store**. As some work is done pushing against the air particles, some of the gravitational potential energy is transferred to the air particles and is stored as **internal energy**.



Gravitational potential energy
Mechanical work
Kinetic energy
Mechanical work
Internal energy

Smart phones

- All smart phones contain a battery that stores chemical energy. When a smart phone is in use, the battery's chemical energy store decreases. The energy is transferred via the electrical work pathway to light the screen and produce sound.
- The light that comes from a smart phone is emitted via the light radiation pathway, and the sound waves are produced by a speaker that vibrates back and forth and are emitted via the sound radiation pathway. Eventually both the light and the sound pathways lead to (very small) increases in the internal energy store (temperature) of the surroundings.
- In addition to this, many smart phones also heat up when used, so energy from the **chemical store** is also transferred to the internal energy store. This causes an increase in the temperature of the phone and causes it to emit more energy via the infrared radiation pathway.


Chemical energy
Electrical work
Light radiation
Electrical work
Kinetic energy
Sound radiation
Electrical work
Internal energy
Infrared radiation

Calculating energy changes

The amount of **gravitational potential energy** stored by an object at height can be calculated using the equation:

$$\Delta GPE = m \times g \times \Delta h$$

This is when:

- change in gravitational potential energy (ΔGPE) is measured in joules (J)
- mass (m) is measured in kilograms (kg)
- gravitational field strength (g) is measured in newtons per kilogram (N/kg)
- change in vertical height (Δh) is measured in metres (m)

Calculating kinetic energy

- The amount of **kinetic energy** of a moving object can be calculated using the equation:

$$kinetic\ energy = \frac{1}{2} \times mass \times velocity^2$$

$$KE = \frac{1}{2} \times m \times v^2$$

This is when:

- kinetic energy (*KE*) is measured in joules (J)
- mass (*m*) is measured in kilograms (kg)
- speed (*v*) is measured in metres per second (m/s)

Calculating elastic potential energy

- The amount of **elastic potential energy** stored in a stretched spring can be calculated using the equation:

$$E_e = \frac{1}{2} k e^2$$

$$\text{elastic potential energy} = \frac{1}{2} \times \text{spring constant} \times \text{extension}^2$$

This is when:

- elastic potential energy (E_e) is measured in joules (J)
- spring constant (k) is measured in newtons per metre (N/m)
- extension (e) is measured in metres (m)

Energy and work

- When a **force** causes a body to move, work is being done on the object by the force. Work is the measure of energy transfer when a force (F) moves an object through a distance (d).
- So when work is done, **energy** has been transferred from one energy store to another, and so:
- energy transferred = work done
- Energy transferred and work done are both measured in joules (J).

Calculating work done

- The amount of work done when a force acts on a body depends on two things:
- the **size of the force** acting on the object
- the **distance** through which the force causes the body to move in the direction of the force
- The equation used to calculate the work done is:

$$W = F \times d$$

- This is when:
- work done (*W*) is measured in joules (J)
- force (*F*) is measured in newtons (N)
- distance (*d*) is in the same direction as the force and is measured in metres (m)

Energy and power

- When work is done on an object, energy is transferred.
- The **rate** at which this energy is transferred is called **power**.
- So the more powerful a device is, the more energy it will transfer each second.

Calculating power

- The equation used to calculate power is:

$$power = \frac{W}{t}$$

This is when:

- power (P) is measured in watts (W)
- work done (W) is measured in joules (J)
- time (t) is measured in seconds (s)

- One watt is equal to one joule per second (J/s). This means that for every extra joule that is transferred per second, the power increases by one watt.

Efficiency

- Devices are designed to waste as little energy as possible. This means that as much of the input energy as possible should be transferred into useful energy stores.
- How good a device is at transferring energy input to useful energy output is called **efficiency**.
- A very efficient device will waste very little of its input energy.
- A very inefficient device will waste most of its input energy.

Calculating Efficiency

$$efficiency = \frac{useful\ energy\ transferred}{total\ energy\ supplied}$$

$$percentage\ efficiency = efficiency \times 100$$

$$(percentage\ efficiency = \frac{useful\ energy\ transferred}{total\ energy\ supplied} \times 100)$$

Efficiency and power

- As power is equal to useful energy transferred per second, another way to calculate efficiency is to use the formula:

$$efficiency = \frac{useful\ power\ transferred}{total\ power\ supplied}$$

$$percentage\ efficiency = efficiency \times 100$$

- This is when both useful power transferred and total power supplied are measured in watts (W).
- It is not possible to have an efficiency of greater than 1 or efficiency percentage of 100%. This would mean that more energy is being transferred than is being supplied, which would mean that energy is being created. This would break the law of **conservation of energy**

Wasted energy

- Devices waste energy for various reasons including friction between their moving parts, electrical resistance, and unwanted sound energy.
- Devices can be made more efficient by reducing the energy that they waste or **dissipate** to the surroundings. One example is lubrication being used to reduce the friction between moving parts of a machine.

Electrical appliances

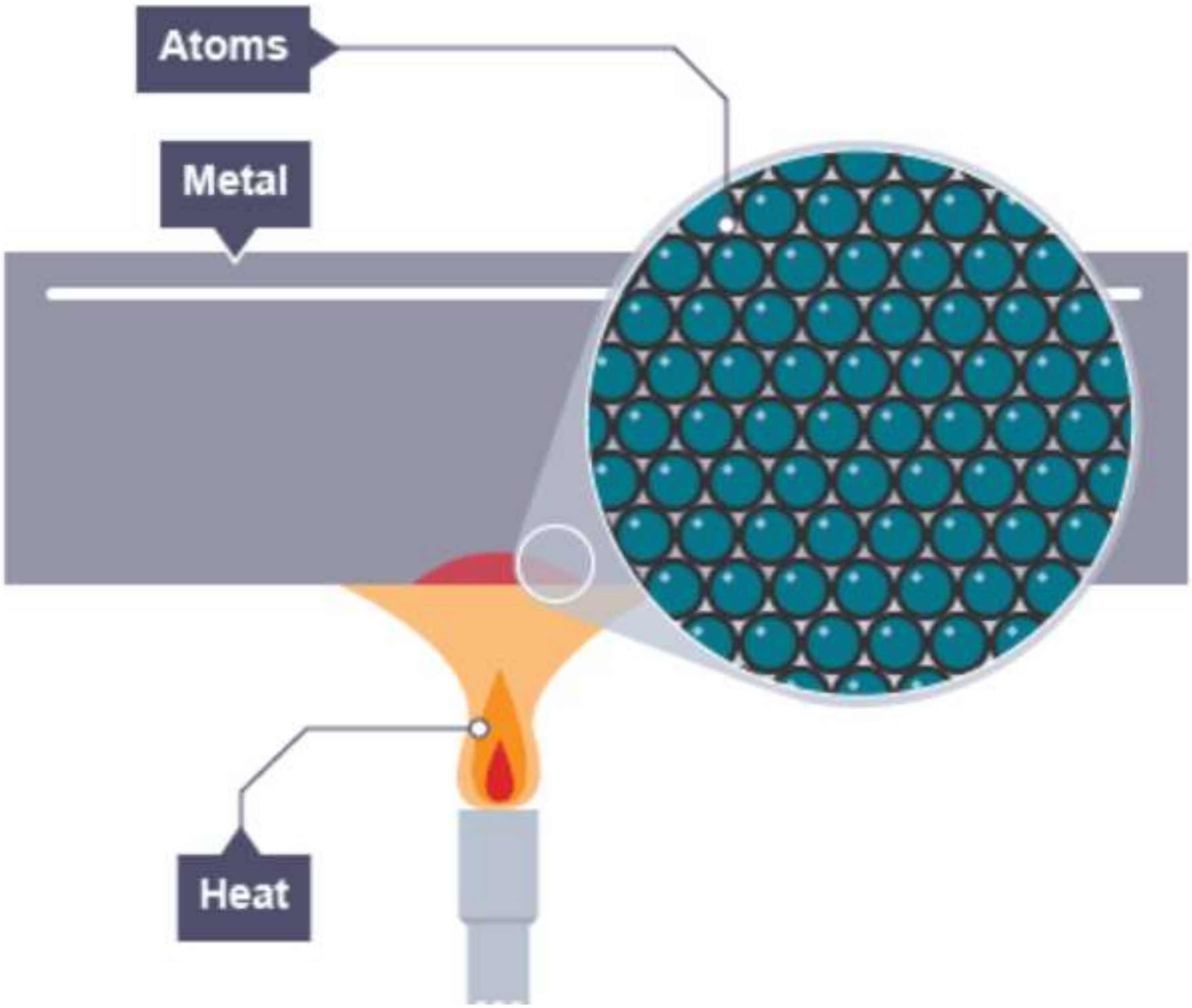
Appliance	Useful energy	Wasted energy
Electric kettle	Energy that heats the water.	Internal (thermal) energy heating the kettle. Infrared radiation lost to the surroundings.
Hair dryer	Internal (thermal) energy heating the air. Kinetic energy of the fan that blows the air.	Sound radiation. Internal (thermal) energy heating the hairdryer. Infrared radiation lost to the surroundings.
Light bulb	Light radiation given out by the hot filament.	Infrared radiation lost to the surroundings.
TV	Light radiation that allows the image to be seen. Sound radiation that allows the audio to be heard.	Internal (thermal) energy heating the TV set. Infrared radiation lost to the surroundings.

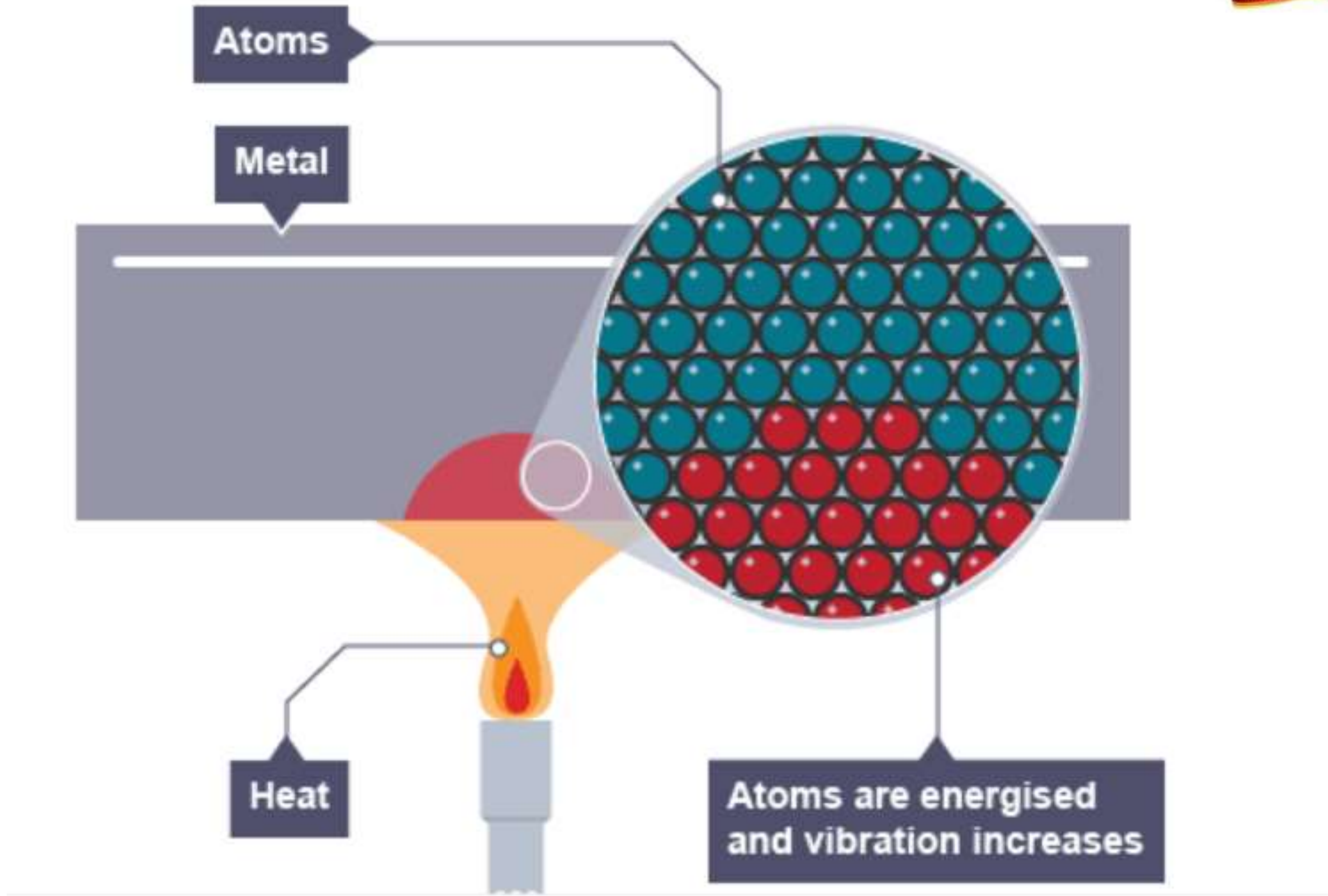
Energy and heating

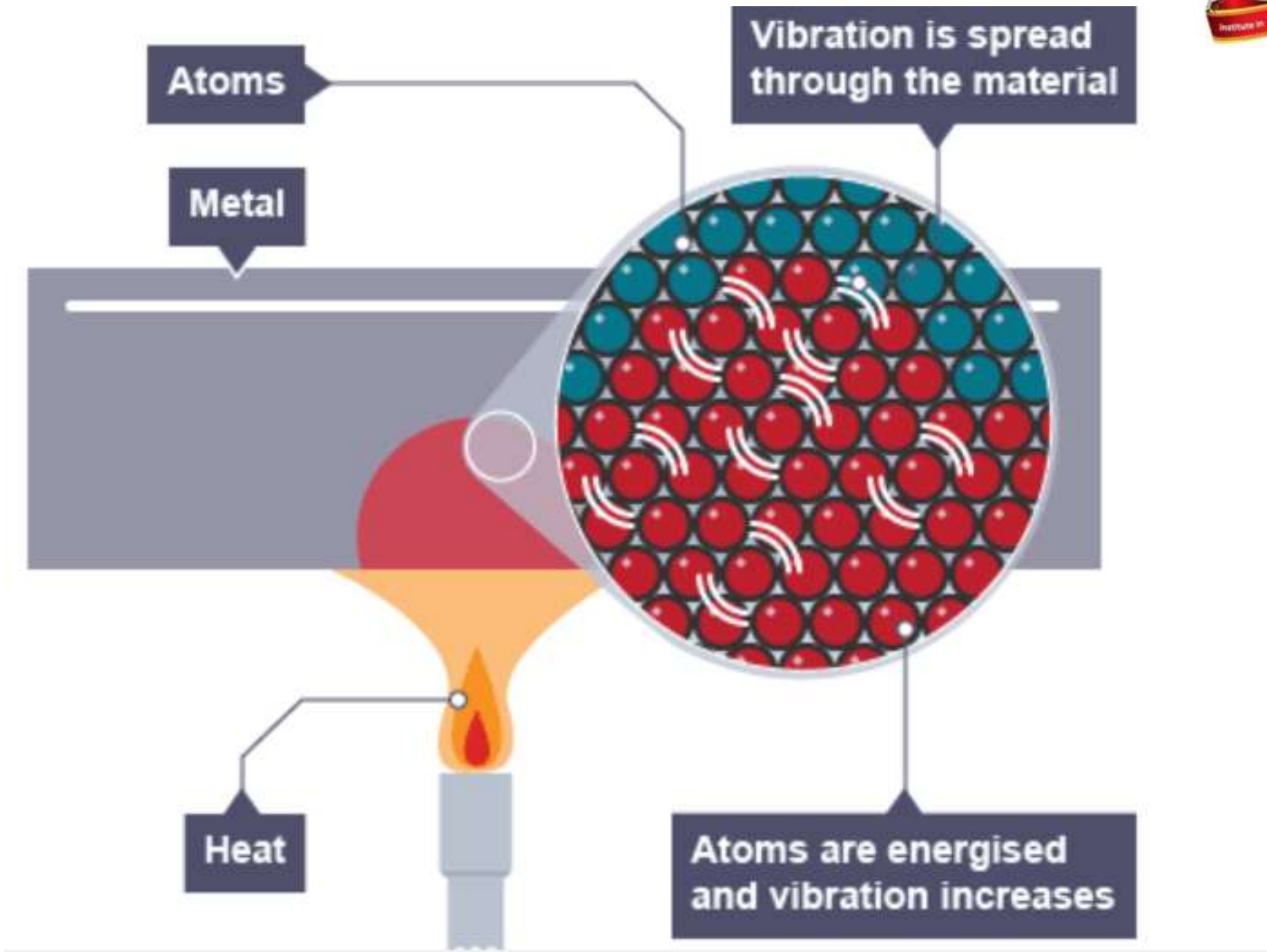
- As well as transferring **energy** from one store to another, energy is transferred or transmitted from place to place. As it moves through a substance, energy is transmitted by conduction, convection or radiation.

Conduction

- A conductor is a material that allows internal (thermal) energy to be transmitted through it easily.
- The aluminium base of a pan, the copper in the wires from a plug and the steel of a bell are all **conductors**.
- All metals are good conductors. When one end of a metal rod is put into a fire, the energy from the flame makes the **ions** in the rod vibrate faster. Since the ions in the solid metal are close together, this increased **vibration** means that they collide with neighbouring ions more frequently. Energy is passed on through the metal by these collisions, transmitting the energy. More frequent collisions increase the **rate** of transfer.


Atoms
Metal
Heat


Atoms
Metal
Heat
Atoms are energised and vibration increases


Atoms
Vibration is spread through the material
Metal
Heat
Atoms are energised and vibration increases

Insulation

- An insulator is a material that will not allow the easy flow of energy.
- The cushion on a chair is an **insulator**. A metal seat at a railway station will feel cold as it conducts energy away from the passenger's body, whereas a cushion on the chair would not allow energy to flow so easily.

Specific heat capacity

- When materials are heated the molecules gain **kinetic energy** and start moving faster. The result is that the material gets hotter.
- Different materials require different amounts of energy to change temperature. The amount of energy needed depends on:
- the mass of the material
- the substance of the material (**specific heat capacity**)
- the desired temperature change
- It takes less energy to raise the temperature of a block of aluminium by 1°C than it does to raise the same amount of water by 1°C. The amount of energy required to change the temperature of a material depends on the specific heat capacity of the material.

Heat capacity

- The specific heat capacity of water is 4,200 Joules per kilogram per degree Celsius (J/kg°C). This means that it takes 4,200 J to raise the temperature of 1 kg of water by 1°C.

Calculating thermal energy changes

- The amount of **thermal energy** stored or released as the temperature of a system changes can be calculated using the equation: $\Delta E_t = m \times c \times \Delta\Theta$
- This is when:
- change in thermal energy (ΔE_t) is measured in joules (J)
- mass (m) is measured in kilograms (kg)
- specific heat capacity (c) is measured in joules per kilogram per degree Celsius (J/kg°C)
- temperature change ($\Delta\theta$) is measured in degrees Celsius (°C)

Energy needs

- Nearly everything requires **energy** and a way to use energy is by transferring it from one **energy store** to another.
- Systems that can store large amounts of energy are called **energy resources**. The major energy resources available to produce electricity are **fossil fuels**, **nuclear fuel**, bio-fuel, wind, **hydroelectricity**, **geothermal**, tidal, water waves and the Sun. Ultimately, all the energy on Earth originally comes from the Sun but has been stored as different energy resources.

Energy Needs

Energy is needed in:

- homes - for cooking, heating and running appliances
- public services, eg schools and hospitals - running machinery and warming rooms
- factories and farms - operating heavy-duty machines and production chains
- transport - buses, trains, cars and boats all need a fuel source and some trains and trams connect to an electricity supply

Reducing heat transfers – houses

- Heat energy is lost from buildings through their roofs, windows, walls, floors and through gaps around windows and doors. However, there are ways that these losses can be reduced.

Take a look at this **thermogram** of a house. The roof and windows are the hottest, showing that most heat is lost from the house through those parts.

Reducing heat transfers - houses

- Heat energy is transferred from homes by **conduction** through the walls, floor, roof and windows.
- It is also transferred from homes by **convection**. For example, cold air can enter the house through gaps in doors and windows, and convection currents can transfer heat energy in the loft to the roof tiles.
- Heat energy also leaves the house by **radiation** - through the walls, roof and windows.

Ways to reduce heat loss

- Simple ways to reduce heat loss include fitting **carpets, curtains and draught excluders**. It is even possible to fit reflective foil in the walls or on them.
- Heat loss through windows can be reduced by using **double glazing**. These special windows have air or a vacuum between two panes of glass. If the double glazing has a vacuum there will be no conduction or convection. If the double glazing is made with air between the glass then convection is minimised because there is little room for the air to move. Air is a poor conductor so there will be very little heat loss by conduction.
- Heat loss through walls can be reduced using **cavity wall insulation**. This involves blowing **insulating** material into the gap between the brick and the inside wall. Insulating materials are bad conductors and so this reduces the heat loss by conduction. The material also prevents air circulating inside the cavity, therefore reducing heat loss by convection.
- Heat loss through the roof can be reduced by laying **loft insulation**. This works in a similar way to cavity wall insulation

Where does energy come from?

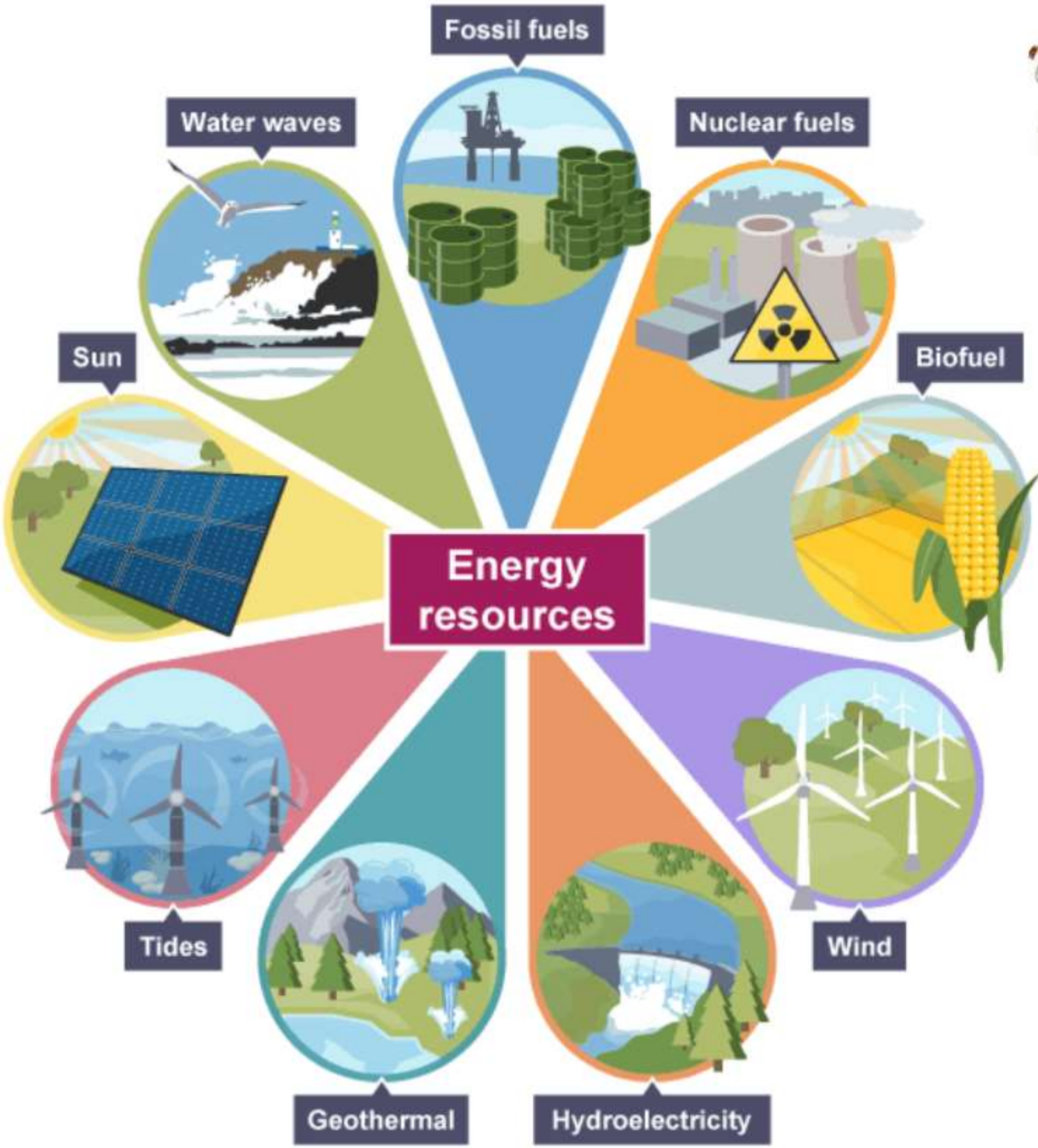
- There are different **energy resources** in the world and the amount of **energy** stored by them varies greatly.
- For example, the nuclear energy within 1 kg of uranium contains a very large amount of energy, but the **gravitational potential energy** stored by many thousands of tonnes of water held back by a dam contains less.

Resources

Renewable resources are replenished either by:

- human action, eg trees cut down for bio-fuel are replaced by planting new trees
- natural processes, eg water let through a dam for **hydroelectricity** is replaced through the **water cycle**

A non-renewable energy resource is one with a **finite** amount. It will eventually run out when all reserves have been used up.



Fossil fuels
Water waves
Nuclear fuels
Sun
Biofuel
Energy resources
Tides
Wind
Geothermal
Hydroelectricity

Energy resource	Energy store	Renewable?	Uses	Power output	Environmental impact
Fossil fuels (oil, coal and natural gases)	Chemical	Non-renewable	Transport, heating, electricity generation	High	Releases CO_2 (causes global warming)
Nuclear fuels	Nuclear	Non-renewable	Electricity generation	Very high	Radioactive waste (needs to be disposed of safely)
Bio-fuel	Chemical	Renewable	Transport, heating, electricity generation	Medium	'Carbon neutral', so low impact
Wind	Kinetic	Renewable	Electricity generation	Very low	Takes up large areas that could be used for farming, some people say windmills spoil the view
Hydroelectricity	Gravitational potential	Renewable	Electricity generation	Medium	Local habitats are affected by the large areas that need to be flooded to build dams

Geothermal	Internal (thermal)	Renewable	Electricity generation, heating	Medium	Very low
Tides	Kinetic	Renewable	Electricity generation	Potentially very high, but hard to harness	Tidal barrages can block sewage which needs to go out to sea
Sun	Nuclear	Renewable	Electricity generation, heating	Dependent on the weather and only available during daylight	Very little
Water waves	Kinetic	Renewable	Electricity generation	Low	Very low