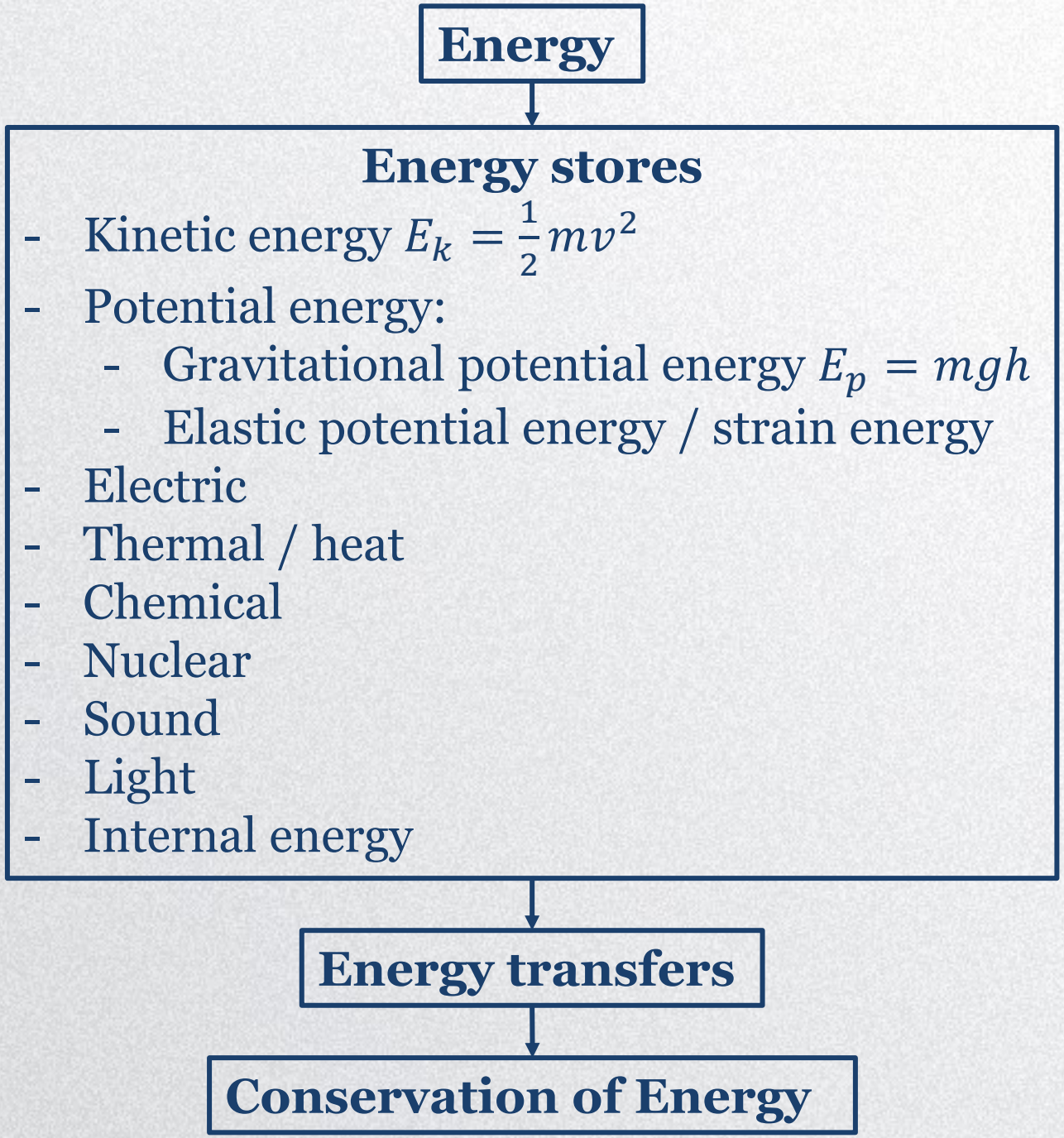
Cambridge IGCSE Physics
General Physics

By: Chaoyang Chu

Energy


Energy
Energy stores
- Kinetic energy $E_k = \frac{1}{2}mv^2$
- Potential energy:
  - Gravitational potential energy $E_p = mgh$
  - Elastic potential energy / strain energy
- Electric
- Thermal / heat
- Chemical
- Nuclear
- Sound
- Light
- Internal energy
Energy transfers
Conservation of Energy

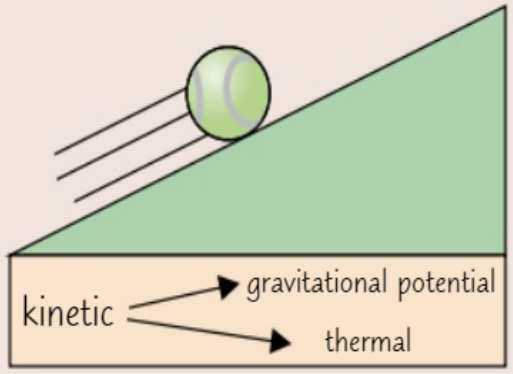
Energy

- Energy, in physics, is the capacity for doing work.
- An object may have energy because it is **moving** or because of **its position**.
- Energy can be transferred from one place to another, transformed from one type to another or stored.
- *The unit of energy is the **joule (J)**.*

Forms of Energy

Gravitational potential	The energy gained as an object is moved away from the Earth
Kinetic	The energy of an object due to its movement
Chemical	Stored energy which can be released via a chemical reaction
Strain / elastic	The energy stored when an object changes shape
Electric	Energy carried by electric current
Sound	Energy carried by a sound wave
Thermal (heat) energy	Energy released when the temperature of a hot object decreases due to a reduction in its internal energy
Nuclear	Stored energy which can be released in a nuclear reaction
Light	Energy given off the form of electromagnetic radiation
Internal energy	Total kinetic and potential energies of all particles in an object

Energy Transfers

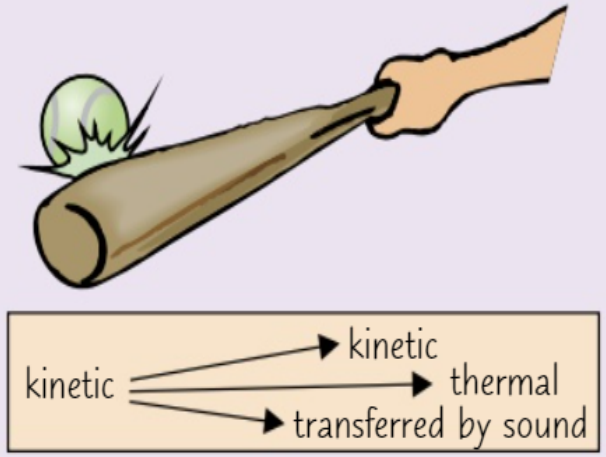


A BALL ROLLING UP A SLOPE:

Energy is transferred mechanically from the kinetic energy store of the ball to its gravitational potential energy store. Some energy is transferred mechanically to the thermal energy stores of the ball and the slope (due to friction), and then by heating to the thermal energy stores of the surroundings — this energy is wasted.

A BAT HITTING A BALL:

Some energy is usefully transferred mechanically from the kinetic energy store of the bat to the kinetic energy store of the ball. The rest of the energy is wasted. Some energy in the kinetic energy store of the bat is transferred mechanically to the thermal energy stores of the bat, the ball and their surroundings. The remaining energy is carried away by sound.



Energy Transfers

thermal → thermal

AN ELECTRIC KETTLE BOILING WATER:

Energy is transferred electrically from the mains to the thermal energy store of the kettle's heating element. It is then transferred by heating to the thermal energy store of the water. Some energy is wasted, and transferred by heating from the thermal energy stores of the heating element and the water to the thermal energy stores of the surroundings.

A BATTERY-POWERED TOY CAR:

Energy is usefully transferred electrically from the chemical energy store of the battery to the kinetic energy store of the car and carried away by light from the headlights. Wasteful energy transfers also occur, to thermal energy stores of the car and surroundings, and wastefully carried away by sound.

chemical → kinetic
chemical → thermal
chemical → transferred by sound
chemical → transferred by light

Energy Transfers

A BUNSEN BURNER AND BEAKER:

Energy is usefully transferred by heating from the chemical energy store of the gas to the thermal energy stores of the beaker and the water. Energy is also wastefully transferred by heating to the thermal energy stores of the stand and the surroundings. Some energy is also carried away by light.

Energy Transfers

Template:

Describe the energy transfers for….

Energy is transferred _____ (adv.) from _____ (adj.) energy store of _____ (n) to _____ (adj.) energy store of _____ (n).

Energy Transfers

Study question:

1. Describe the energy transfers for a falling ball landing on the ground without bouncing.

Energy Transfers

Study question:

1. Describe the energy transfers for a falling ball landing on the ground without bouncing.

As the ball falls, energy is transferred **mechanically** from its **gravitational potential energy store** to its **kinetic energy store**. [1 mark] When the ball hits the ground, energy is transferred away by **sound waves**. [1 mark] The rest of the energy is carried away by heating to the **thermal energy stores** of the ball, the ground and the surroundings. [1 mark]

Energy Transfers

Study question:

2. Describe the energy transfers that occur when a piece of wood is burning.

Energy Transfers

Study question:

2. Describe the energy transfers that occur when a piece of wood is burning.

Energy in the **chemical energy store** of the wood is transferred **by heating** to the **thermal energy stores** of the surroundings. [1 mark] The rest of the energy is transferred away by **light**. [1 mark]

Principle of Conservation of Energy

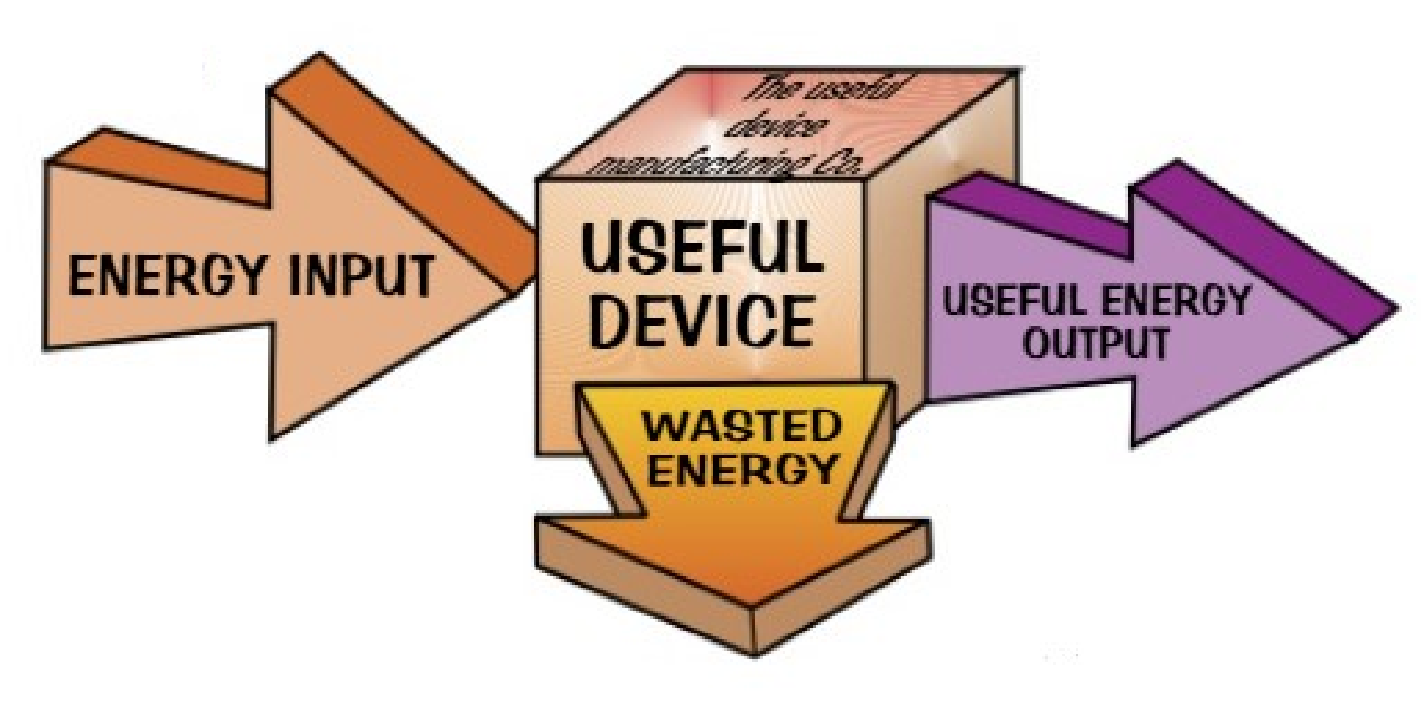
- Energy can be **stored**, **transferred** between stores, and dissipated – but it can **never be created or destroyed**. **The total energy of a closed system has no net change.**
- A **closed system** is just a system (a collection of objects) that can be treated **completely on its own**, without any matter being exchanged with the surroundings.

Principle of Conservation of Energy

Most energy transfers involve some **losses**, often **by heating**:

- **Energy** is only useful when it is transferred from one store to **a useful store**.
- Some of the input energy is always **lost or wasted**, often to thermal energy stores by heating. For example, a motor will transfer energy to its kinetic energy store (useful), but will also transfer energy to the thermal energy stores of the motor and the surroundings (wasted).
- The law of **conservation of energy** means that: total energy input = useful energy output + wasted energy
- The **less energy that's wasted**, the **more efficient** the device is said to be.

Principle of Conservation of Energy



Kinetic Energy

Kineitc energy is the energy of a moving object

$$KE = \frac{1}{2}mv^2$$

Practice:

A lorry of mass 4000 kg is travelling at a speed of 4.0 m/s.

A car has a mass of 1000 kg. The kinetic energy of the car is equal to the lorry.

What is the speed of the car?

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$$\mathrm{KE}_{\mathrm{lorry}} = \mathrm{KE}_{\mathrm{car}}$$

$$\frac{1}{2}(4000)(4^2) = \frac{1}{2}(1000)\mathrm{v}_{\mathrm{car}}^2$$

$$\mathrm{v}^2 = 64$$

$$\mathrm{v} = 8$$

Gravitational Potential Energy

Lifting an object in a gravitational field causes a transfer of energy to the gravitational potential energy store of the raised object.

$$GPE = mg\Delta h$$

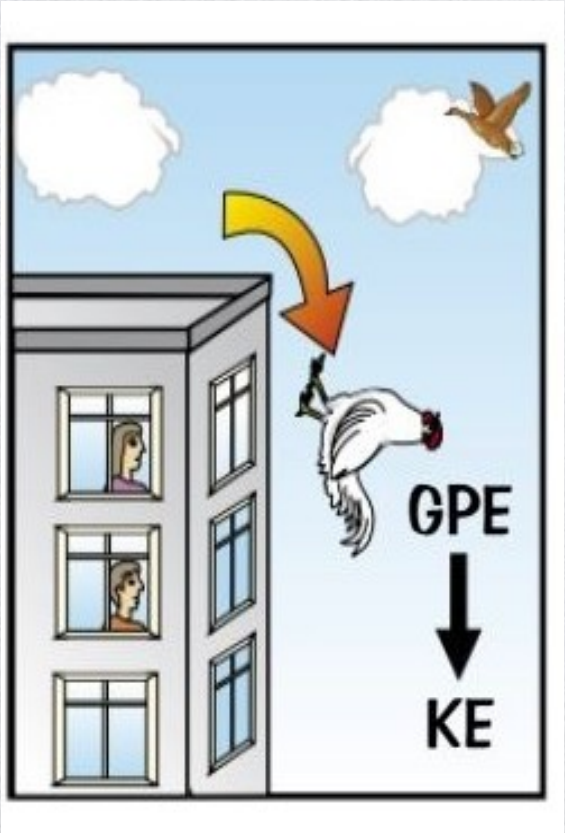
where

m = mass (kg)

G = gravitational field strength (10 m/s^2)

Δh = change in height (m)

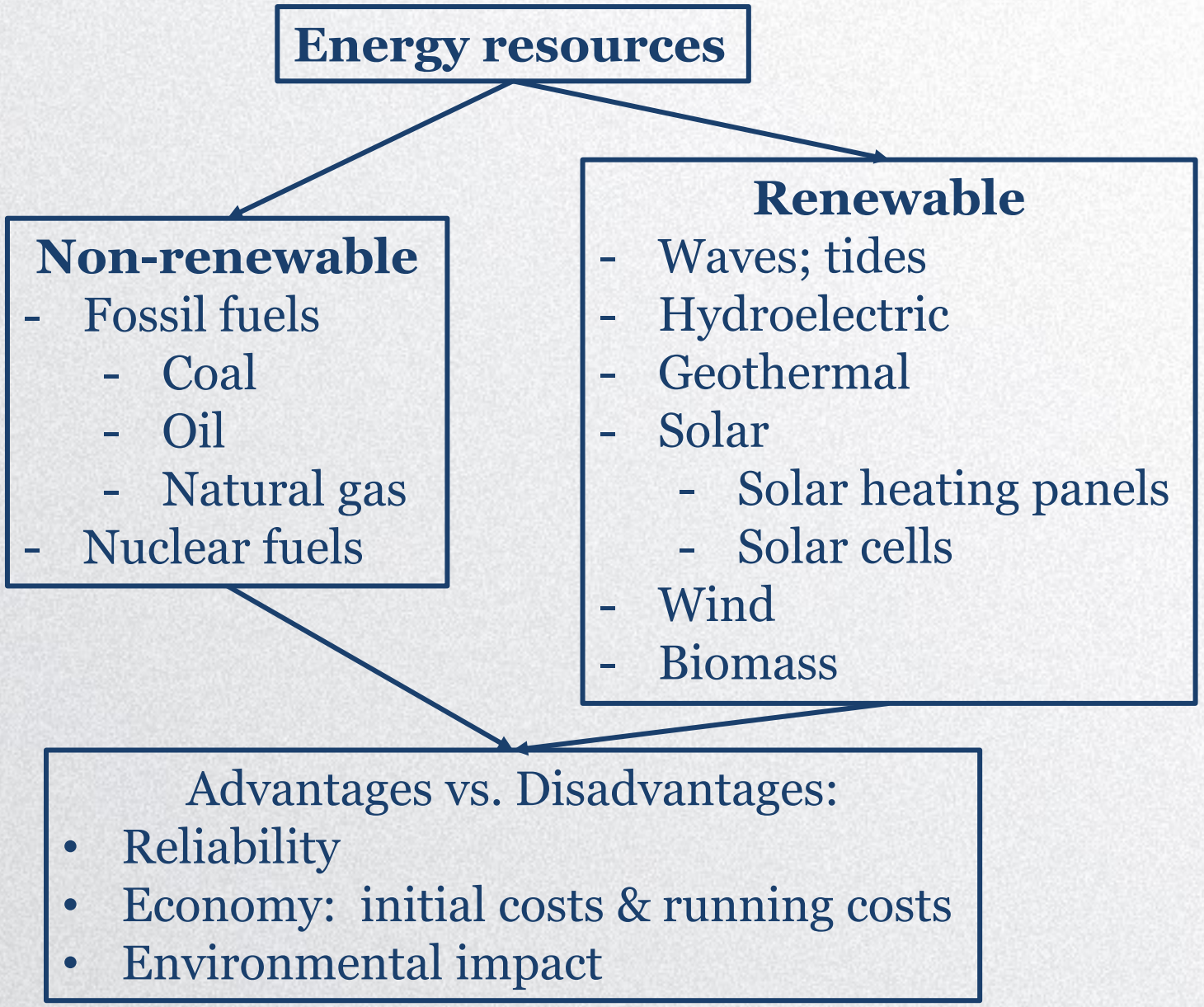
Falling objects also transfer energy



- When something falls, energy from its GPE store is transferred to its KE.
- For a falling object when there's no air resistance:

  Energy lost from GPE = Energy gained in the KE
- In real life, air resistance acts against all falling objects – it causes some energy to be transferred to other energy stores, the thermal energy stores of the object and surroundings.

Energy Resources


Energy resources
Non-renewable
- Fossil fuels
  - Coal
  - Oil
  - Natural gas
- Nuclear fuels
Renewable
- Waves; tides
- Hydroelectric
- Geothermal
- Solar
  - Solar heating panels
  - Solar cells
- Wind
- Biomass
Advantages vs. Disadvantages:
• Reliability
• Economy: initial costs & running costs
• Environmental impact

Energy resources

Resources are characterized as renewable or nonrenewable;

A renewable resource can **replenish** itself at the rate it is used, while a non-renewable resource has a limited supply, it will **run out** one day.

Energy resources

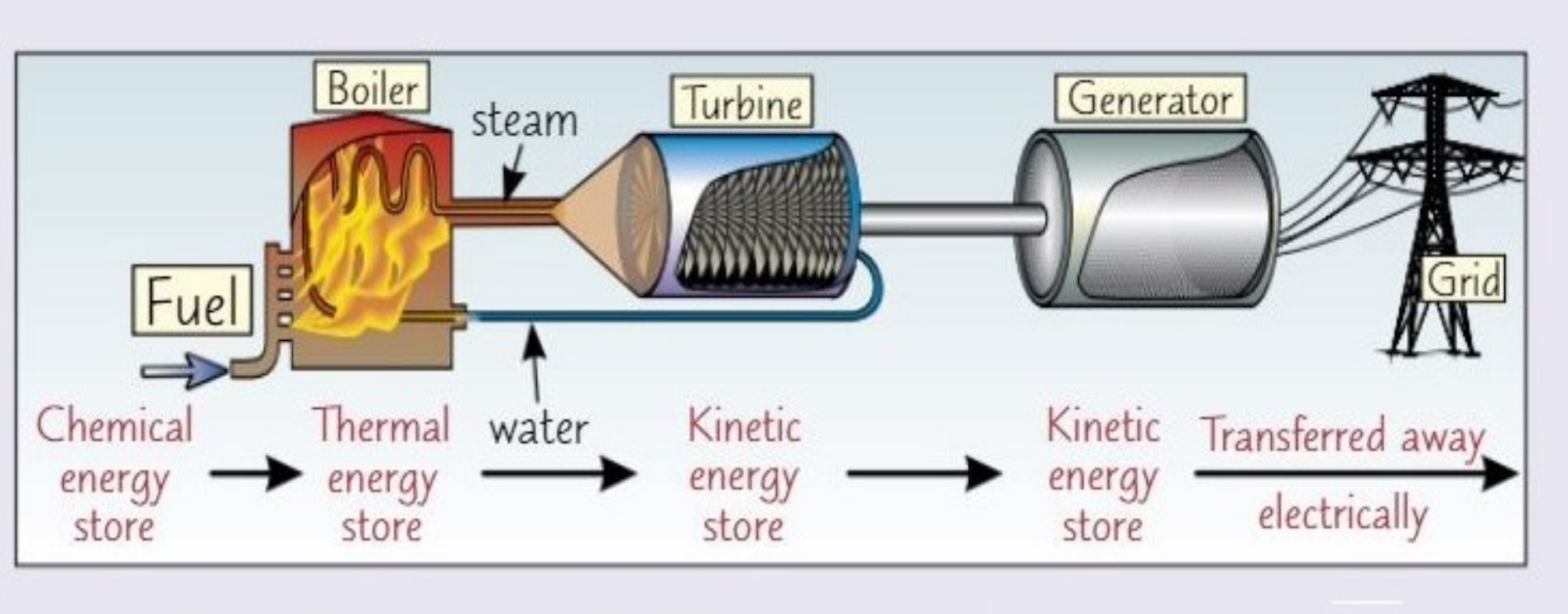
Energy may be obtained, or electrical power generated, from:

Fuel (**fossil** fuels, **biomass** fuels, **nuclear** fuels)	**Chemical energy** in the fuel is released by burning. The chemical energy can then be transformed into **heat energy** which turns water into steam. The steam turns turbines which transforms the heat into **kinetic energy** in the generator.
Waves, tides, hydroelectric dams	The **gravitational potential energy** of falling water is transformed into **kinetic energy** which passes through turbines to produce **electrical energy** via the generator
Geothermal power stations	Water is pumped underground and gains **heat energy** from the hot rocks beneath. The heat energy is then converted into **kinetic energy** in turbines which is used to produce **electric energy** via the generator.
Nuclear fission	The nuclear energy stored in uranium-235 is released via *nuclear fission*. The **nuclear energy** transforms into **heat energy** which is used to turn water into steam. The steam turns turbines and its kinetic energy becomes **electrical energy** in the generator. (Energy is released by **nuclear fusion** in the Sun)
Solar power station	The **heat energy** from the sun is concentrated via mirrors which focus the hat. The heat energy which is used to turn water into steam. The steam turns turbines and **its kinetic energy** becomes **electrical energy** in the generator.
Solar cells (photo cells)	**Light energy** from the sun can be transformed into **electrical energy**.

Non-renewable energy

The non-renewables are the three fossil fuels and nuclear fuels: **1) Coal** **2) Oil** **3) Natural gas** **4) Nuclear fuels** (e.g. uranium and plutonium)	
Advantages	**Provide most of the energy**
Disadvantages	Non-renewables will all **run out** one day They all do **damage to the environment**

Non-renewable energy



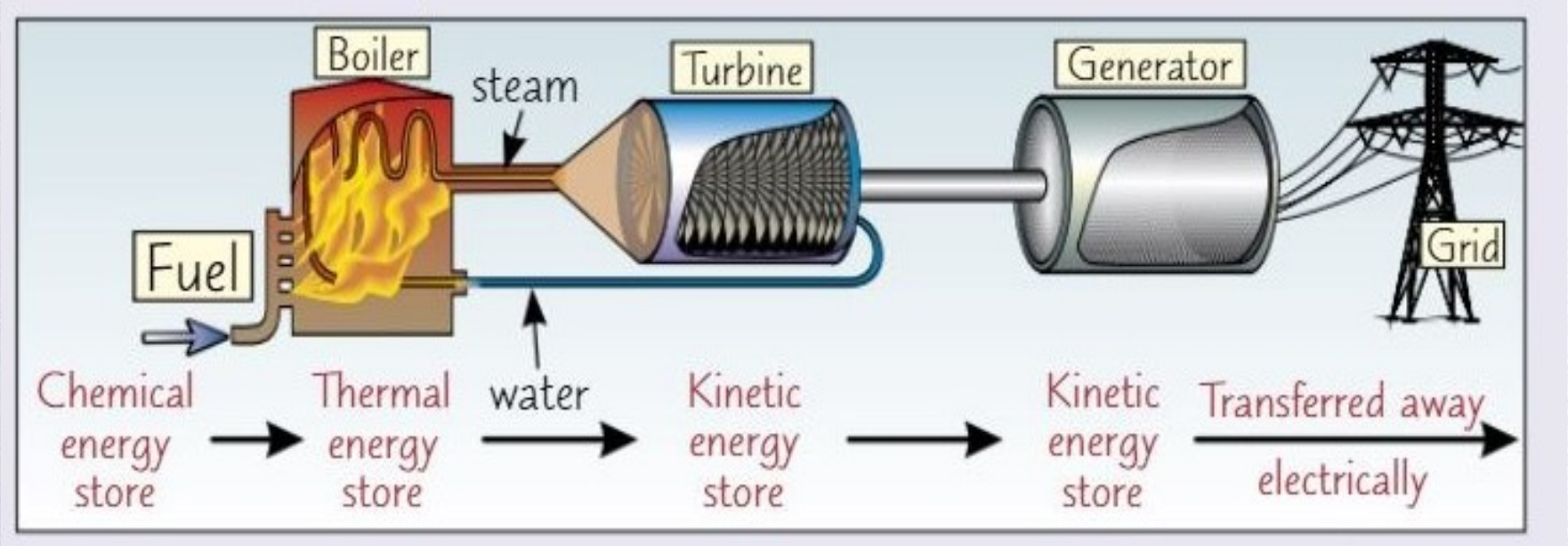
Non-renewable energy

Most power stations use steam to drive a turbine:

As the fossil fuel burns the energy in its chemical energy store of the water by heating.

The water boils to form steam, which turns a turbine, transferring energy mechanically to kinetic energy store of the turbine.

As the turbine revolves, so does the generator, which produces an electric current. The generator transfers the energy electrically away from the power station, via the national grid.



Fossil Fuels

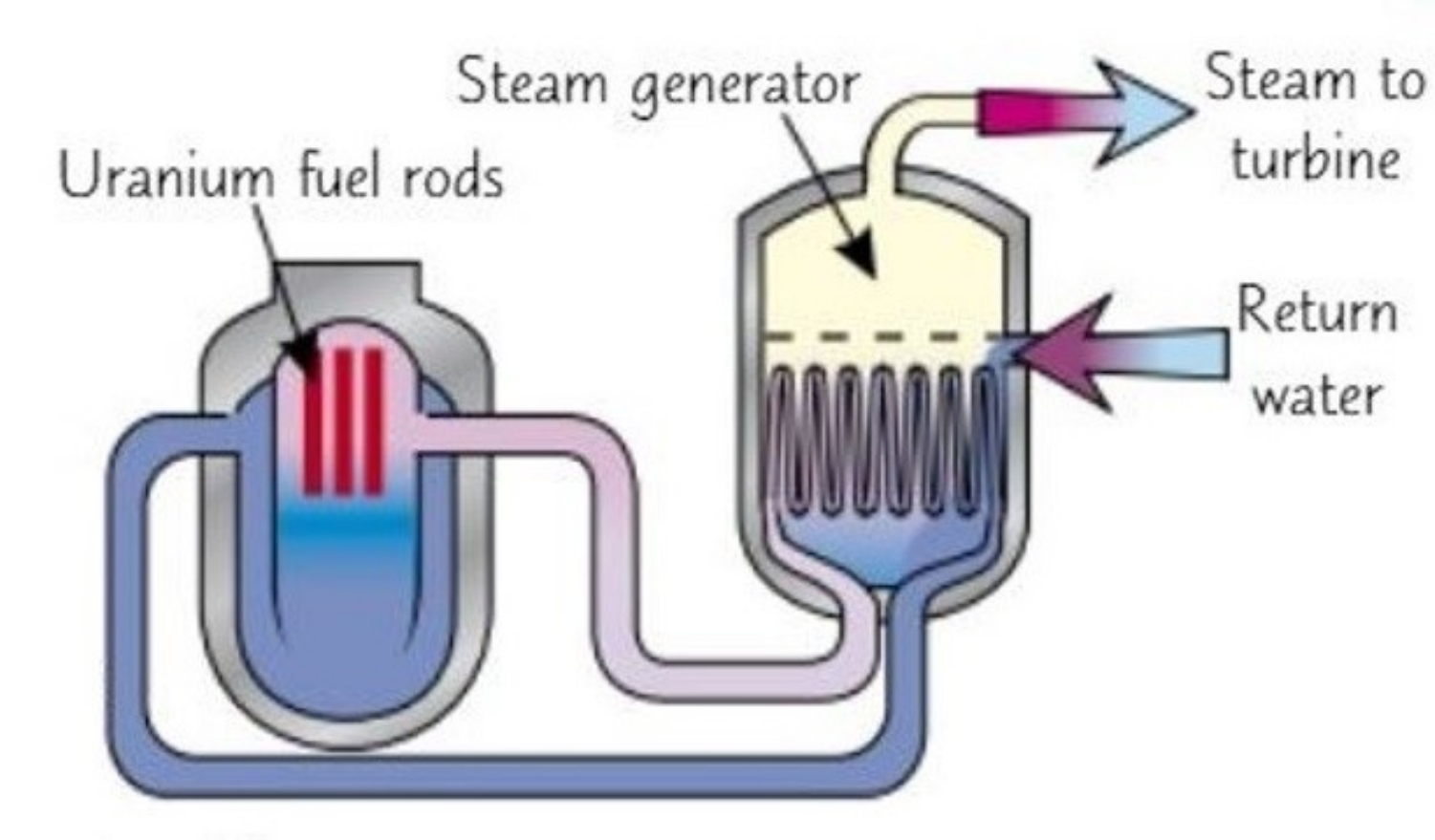
Fossil fuels: oil, natural gas, and coal	
Advantages	1) Burning fossil fuels releases a lot of energy, **relatively cheaply**. 2) Energy from fossil fuels doesn't rely on the weather, like a lot of renewable energy, so it's **reliable**. 3) It doesn't need to spend money on new technology to use them.
Disadvantages	1) All three fossil fuels release carbon dioxide (CO_2) into the atmosphere when burned in power stations. All the CO_2 contributes to **global warming and climate change**. 2) Burning coal and oil also releases sulfur dioxide (SO_2), which causes acid rain. Acid rain can harm trees and soils and can have a huge impact on wildlife. 3) A massive disadvantage of using fossil fuels is that they're eventually going to run out. They are **non-renewable**.

Nuclear Energy

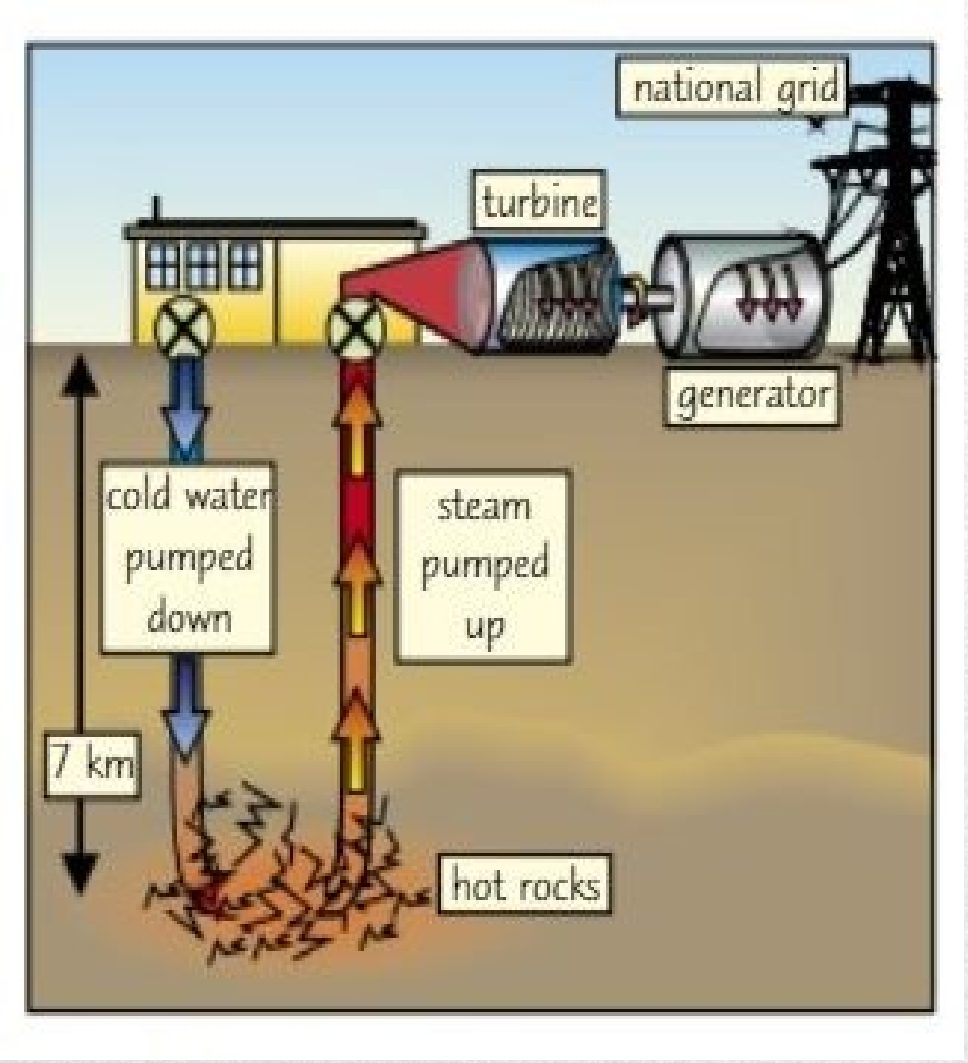
A nuclear power station uses **nuclear fission** to produce the heat to make steam to drive turbines, rather than burning, so the boiler is a bit different.
During the process, energy is transferred from **nuclear energy stores** to **thermal energy stores** by heating, then mechanically to **kinetic energy stores**, and finally transferred **electrically** through the national grid.

Advantages	1) Nuclear energy doesn't produce any of the greenhouse gases which contribute to global warming. 2) There is still plenty of uranium left in the ground
Disadvantages	1) Nuclear reactors are expensive to build and maintain and take longer to start up than fossil fuel ones. 2) Processing the uranium causes pollution, and there's always a risk of leaks of radioactive material, or even a major catastrophe like at Chernobyl. 3) A big problem with nuclear power is the radiative waste 4) When nuclear power stations are too old and inefficient, nuclear power stations have to be decommissioned – that's expensive, too.

Nuclear Reactors



Geothermal Energy



Geothermal Energy

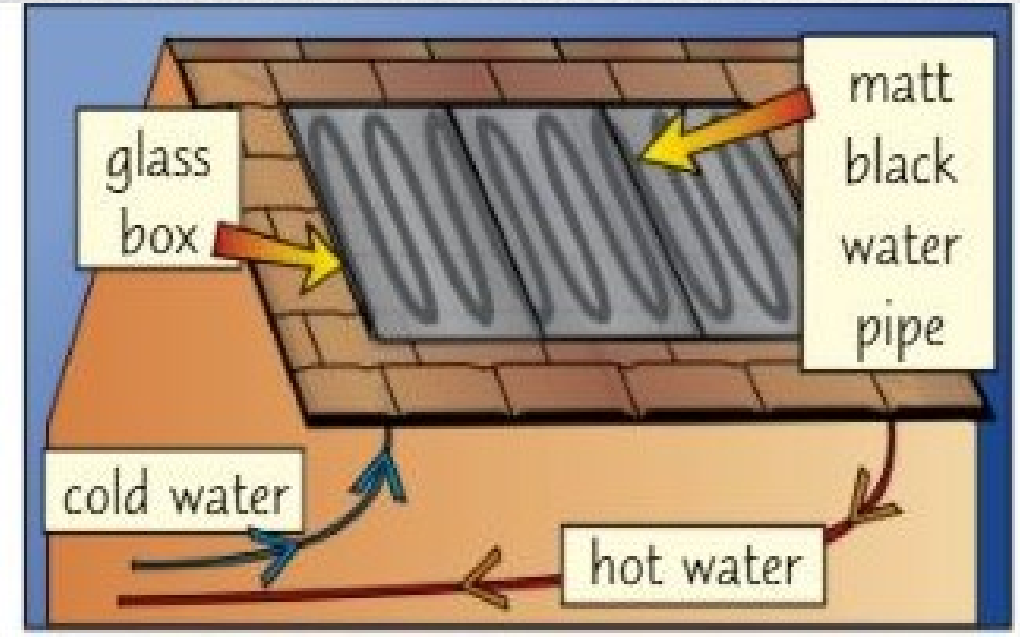
Geothermal is **only possible in certain places** where **hot rocks** lie quite near to the surface. The source of much of the energy is the slow **decay** of various radioactive elements including uranium deep inside the Earth.

Water is pumped in pipes down to the hot rocks and forced back up due to pressure to turn a turbine which drives a generator. So the energy is transferred from **thermal energy** stores to **kinetic energy** stores and used to **generate electricity**.

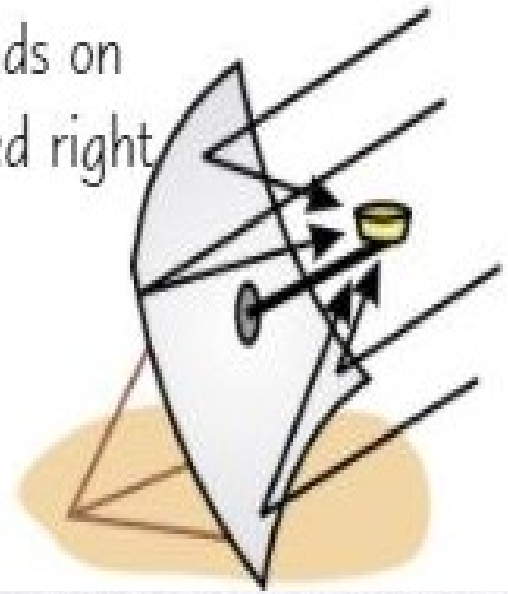
In some places, geothermal energy is used to heat buildings directly.

Advantages	Geothermal is free, renewable, with no real environmental problems.
Disadvantages	1) Cost of drilling is high. 2) The cost of building a power pant is often high compared to the amount of energy we can get out of it. 3) Very few places where this seems to be an economic option.

Solar Energy



All the radiation that lands on the curved mirror is focused right on your pan.

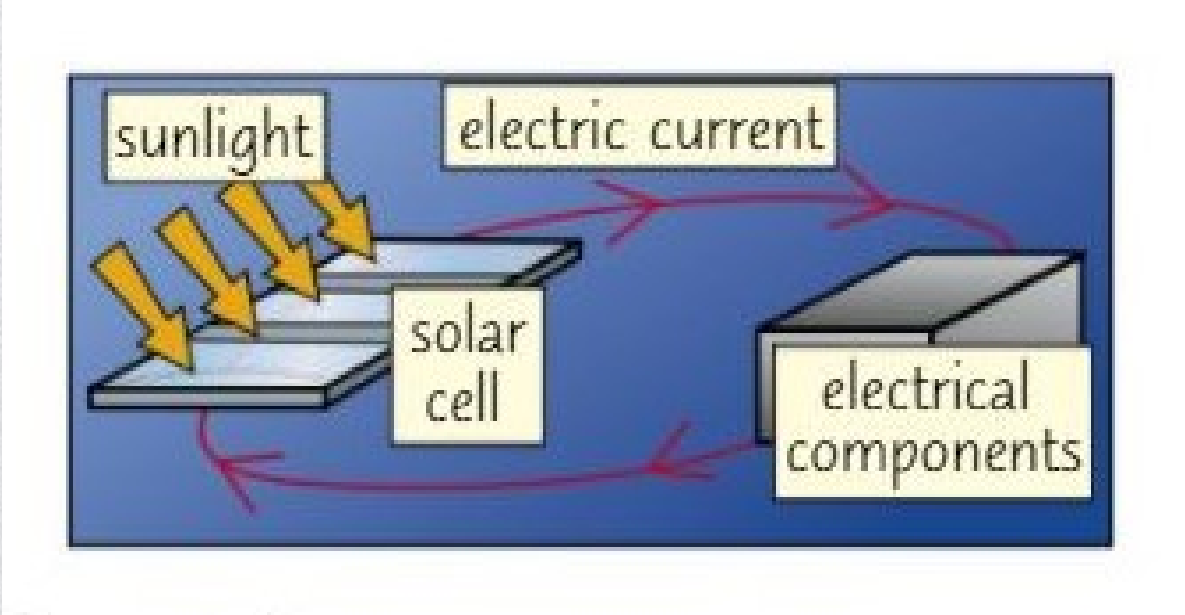


Solar Energy

Solar heating systems	
Solar water heating panels	Solar water heating panels are more simple than solar cells – they are basically just black water pipes inside a glass box. The glass let energy from the Sun in, which is then **absorbed** by the black pipes and heats up the water. Like solar cells, they cost money to **set up**, but are **renewable** and **free** after that. They are only used for **small-scale energy production**.
Cooking with solar power	If you get a curved mirror, then you can focus the Sun's light. This is what happens in a solar oven. They provide a renewable energy resource for outdoor cooking. But they are **slow, bulky and unreliable** – they need **strong sunlight** to work.

Solar Energy

*The process of **nuclear fusion** is carried out in the **Sun**. Hydrogen nuclei collide at great speed in the Sun and fuse together to form helium nuclei. This releases energy in the form of heat and light.*

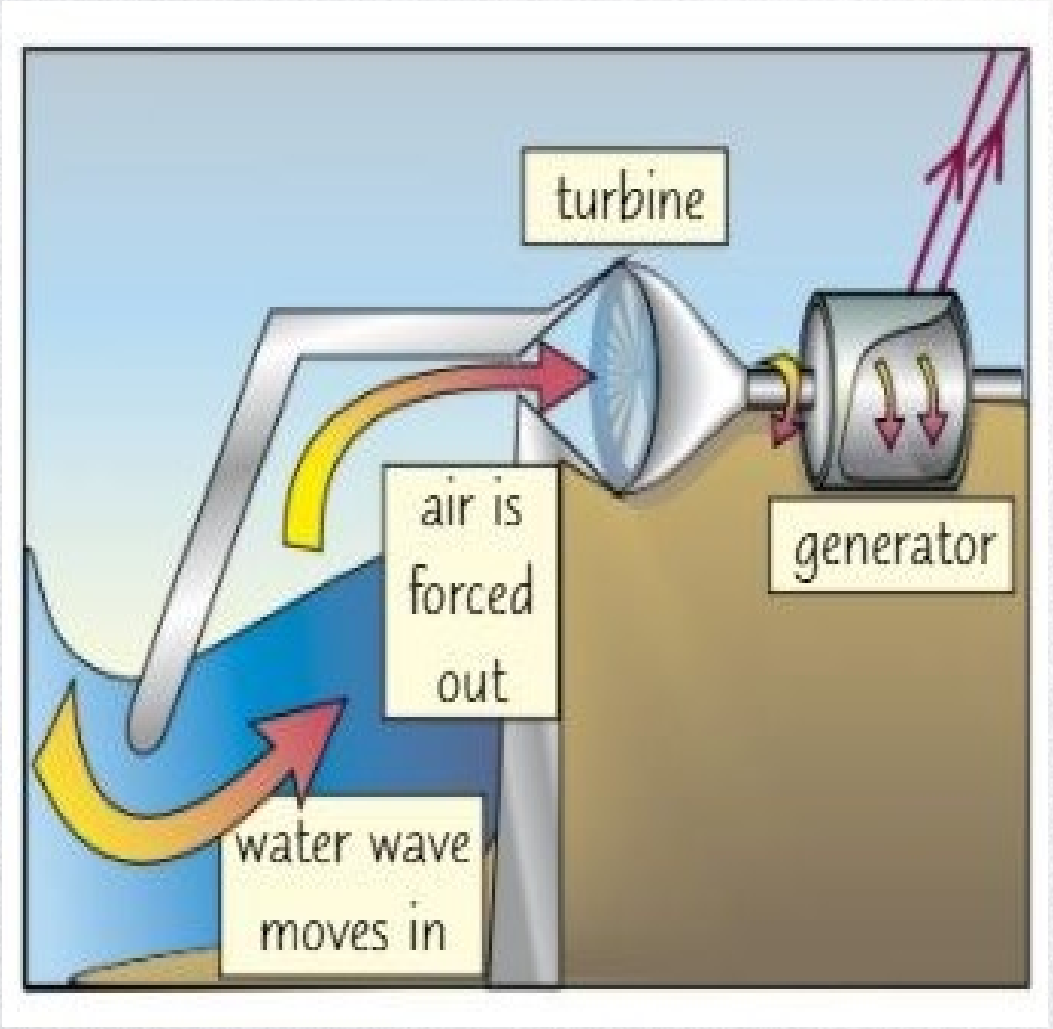


Solar Energy

Solar cells

Solar cells (photocells) use energy from the Sun to directly generate electricity. They generate direct current (d.c.) – the same as a battery. Solar cells are often the best way to power calculators or watches that don't use much energy.	
Advantages	Solar cells provides a renewable energy resource – it won't run out. Solar energy is free and running costs are almost nil. There's no pollution produced while using them.
Disadvantages	Initial costs are high. Solar cells are used to generate electricity on a relatively small scale. Solar cells can only generate enough electricity to be useful if they have enough sunlight – which can be a problem at night.

Wave Energy



Wave Energy

Wave converters

One way of harvesting wave power is with lots of small wave converters located around the coast.

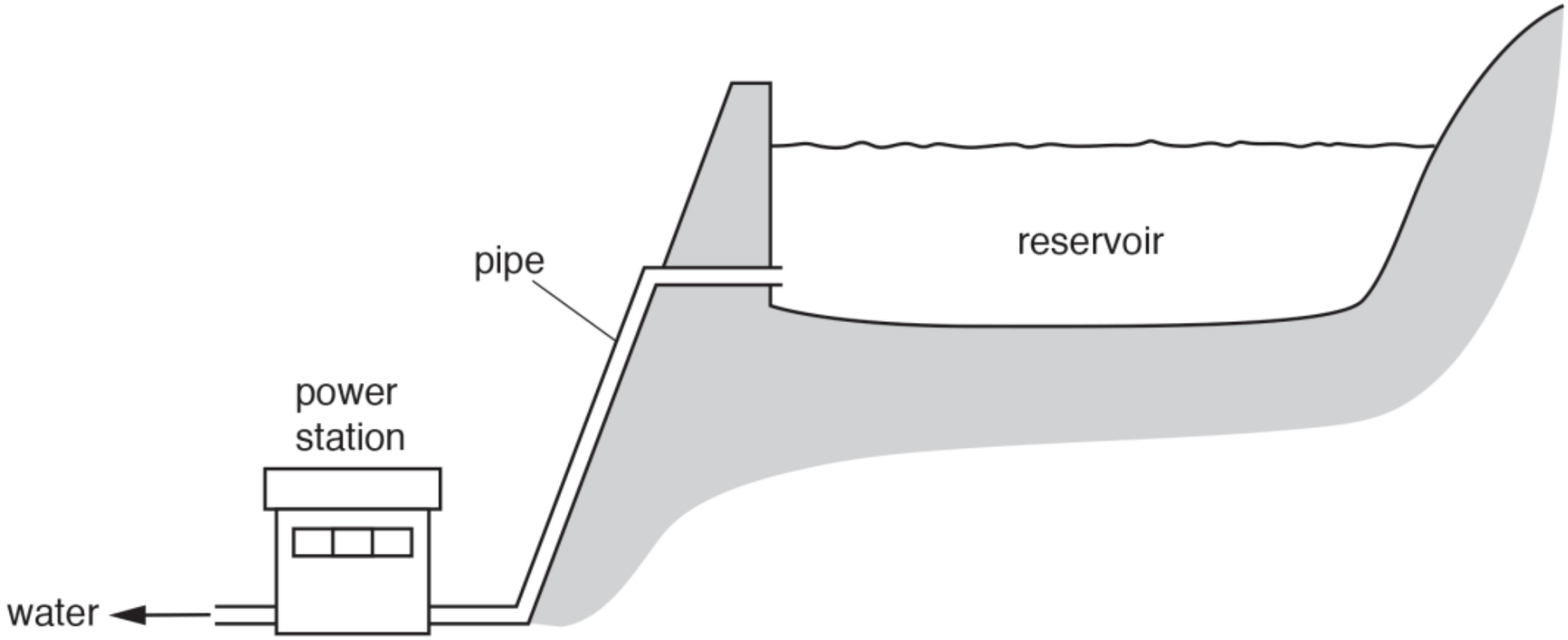
As waves come in to the shore they provide an up and down motion which can be used to drive a generator.

The energy is transferred from the **kinetic energy store of the waves** to **the kinetic energy store of the turbine**, and used to **generate electricity**.

Advantages	It provides a renewable energy resource – it won't run out. Wind energy is free, almost no running costs. There's no pollution produced while using them.
Disadvantages	Initial costs are high. Spoiling the view and being a hazard to boats. It is fairly unreliable, since waves tend to die out when the wind drops.

Hydroelectric

The diagram represents a hydroelectric system for generating electrical energy.



Describe how the power station uses the water in the reservoir to generate electrical energy.

Hydroelectric

any three from:

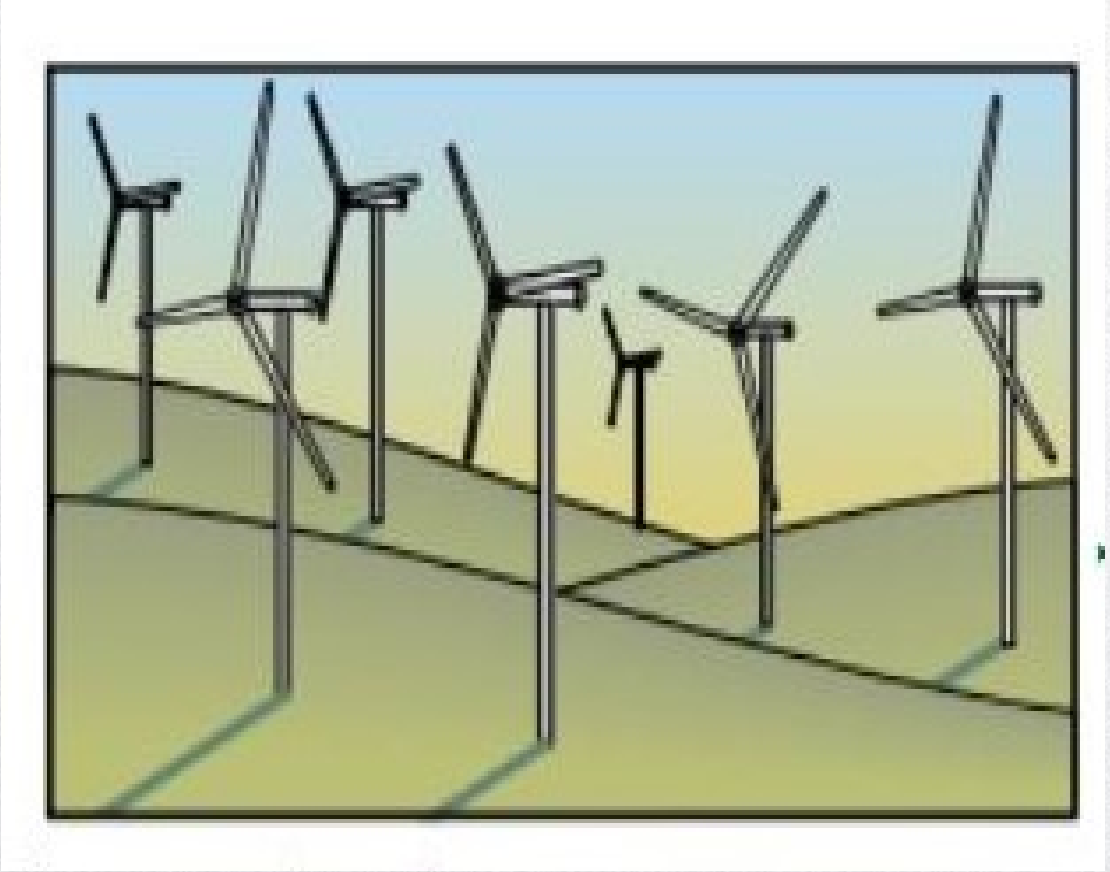
water flows down (from reservoir)

idea of gravitational / potential

energy (transferred to kinetic energy)

water turns turbine, turbine turns generator

Wind Energy



Wind Energy

Wind farms

Wind power involves putting lots of wind turbines up in exposed places. Wind turbines use energy from the kinetic energy store of moving air to generate electricity. Wind turns the blades, which turn a generator inside it.	
Advantages	It provides a renewable energy resource – it won't run out. Wind turbines are quite cheap to run – they're tough and reliable. Wind energy is free, almost no running costs. There's no pollution produced while using them.
Disadvantages	It's expensive to set up a wind farm. Spoiling the view, have a big effect on the scenery. It can be very noisy. It is fairly unreliable, since sometimes the wind isn't strong enough to generate any power. It is also impossible to increase supply when there's extra demand.

THANK YOU