Energy Production Examples
8.1

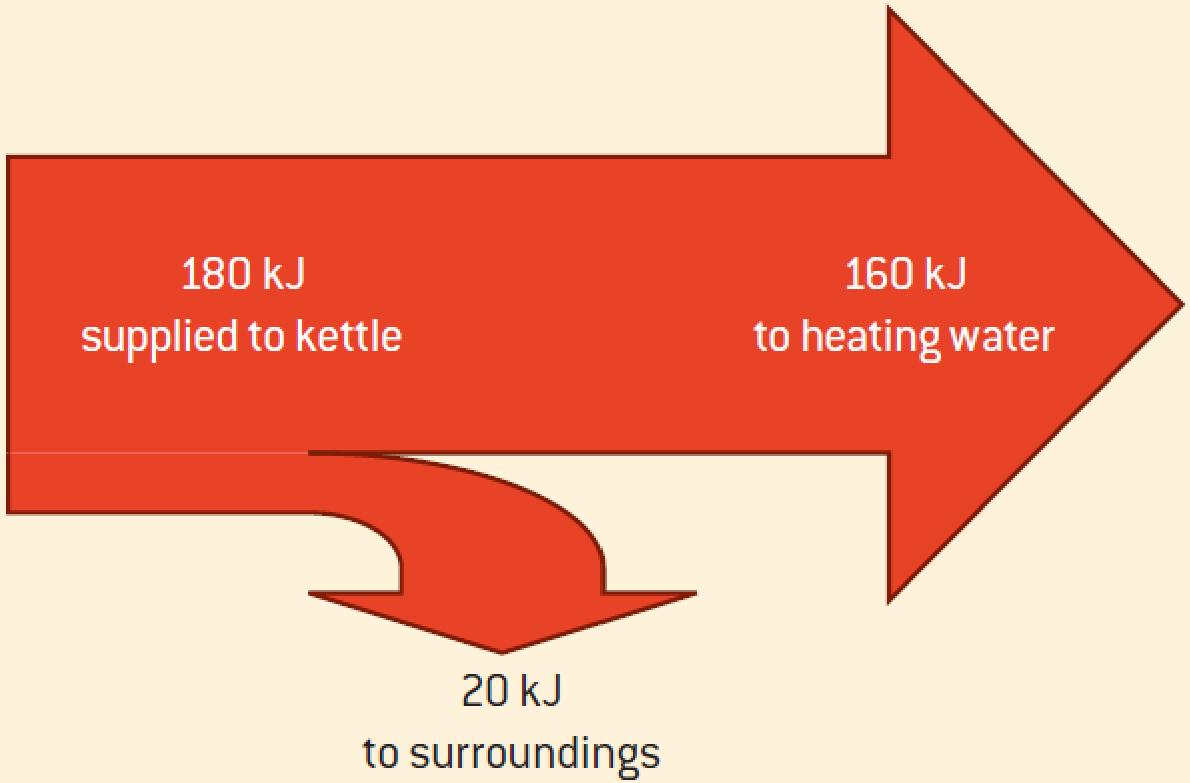
A fossil-fuel power station has an efficiency of 25% and generates 1200 MW of useful electrical power. The specific energy of the fossil fuel is 52 MJ kg^{-1}. Calculate the mass of fuel consumed each second.

If 1200 MW of power is developed then, including the efficiency figure, $\frac{1200 \times 100}{25} = 4800$ MW of energy needs to be supplied by the fossil fuel.

The specific energy is 52 MJ kg^{-1}, so the mass of fuel required is $\frac{4800}{52} = 92$ kg s^{-1}. (That is roughly 1 tonne every 10 s, or one railcar full of coal every 2 minutes.)

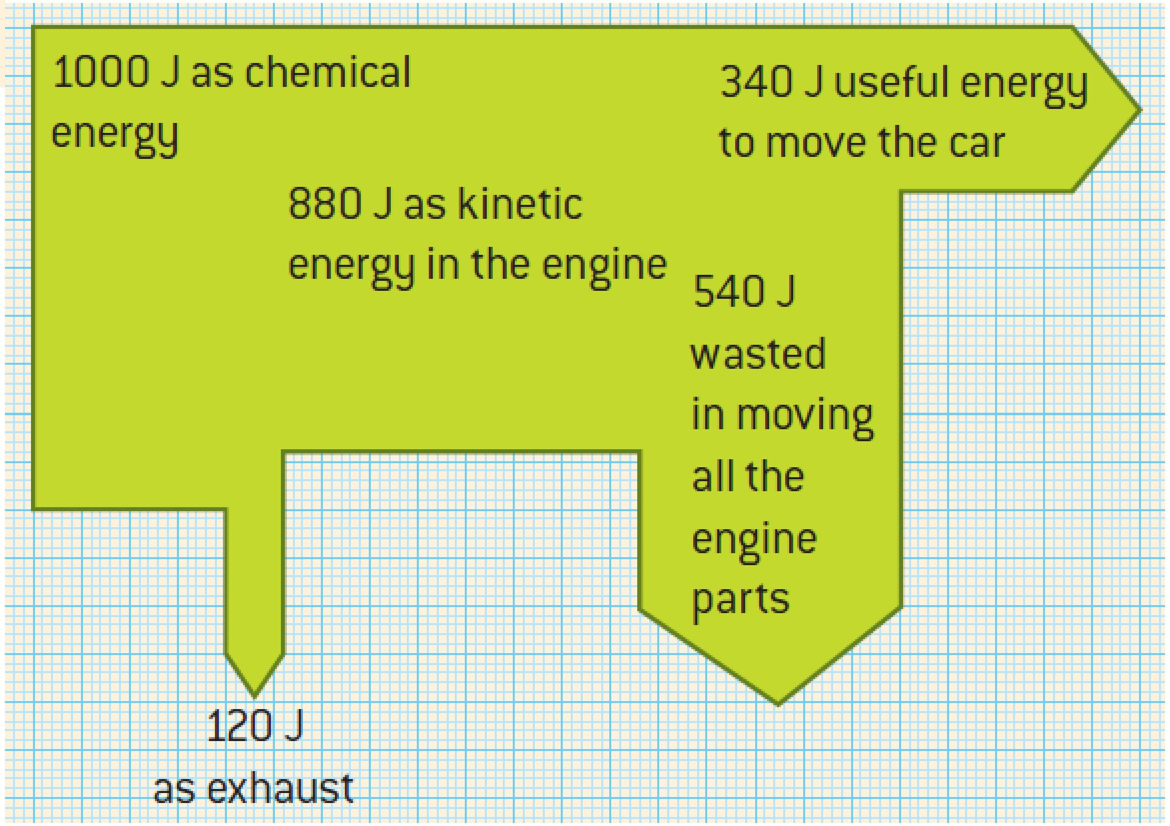
An electric kettle of rating 2.0 kW is switched on for 90 s. During this time 20 kJ of energy is lost to the surroundings from the kettle.

Draw a Sankey diagram for this energy transfer.



In a petrol-powered car 34% of the energy in the fuel is converted into the kinetic energy of the car. Heating the exhaust gases accounts for 12% of the energy lost from the fuel. The remainder of the energy is wasted in the engine, the gearbox and the wheels.

Use these data to sketch a Sankey diagram for the car.



Explain what will happen in a pressured water reactor if the moderator is removed.

The role of the moderator is to remove kinetic energy from neutrons so that there is a high probability that further fissions will occur. When neutrons are moving at high speeds, there is a very high probability that uranium-238 nuclei will absorb them without fission occurring. So the removal of the moderator will mean that neutrons are no longer slowed down, and will be absorbed by U-238. The fission reaction will either stop or its rate will be reduced.

A wind turbine produces a power *P* at a particular wind speed. If the efficiency of the wind turbine remains constant, estimate the power produced by the turbine:

a) when the wind speed doubles

b) when the radius of the blade length halves.

The equation for the kinetic energy arriving at the wind turbine every second is $\frac{1}{2}\rho\pi r^2 v^3$.

a) When the wind speed v doubles, v^3 increases by a factor of 8, so the power output will be $8P$.

b) When the radius of the blade halves, r^2 will go down by a factor of 4 and (if nothing else changes) the output will be $\frac{P}{4}$.

A wind turbine with blades of length 25 m is situated in a region where the average wind speed is 11 m s^{-1}.

a) Calculate the maximum possible output of the wind turbine if the density of air is 1.3 kg m^{-3}.

b) Outline why your estimate will be the maximum possible output of the turbine.

a) Using the wind turbine equation:

the kinetic energy arriving at the wind turbine every second is $\frac{1}{2}\rho\pi r^2 v^3$,

this will be the maximum power output and is $\frac{1}{2} \times 1.3 \times \pi \times 25^2 \times 11^3 = 1.7$ MW.

b) Mechanical and electrical inefficiencies in the wind turbine have not been considered. The calculation assumes that all the kinetic energy of the wind can be utilized; this is not possible as some kinetic energy of the air will remain as it leaves the wind turbine.

Water from a pumped storage system falls through a vertical distance of 260 m to a turbine at a rate of 600 kg s^{-1}. The density of water is 1000 kg m^{-3}. The overall efficiency of the system is 65%.

Calculate the power output of the system.

In one second the gravitational potential energy lost by the system is $mg\Delta h = 600 \times g \times 260 =$ 1.5 MJ.

The efficiency is 65%.

$$\text{Output power} = 1.5 \times 10^6 \times \frac{65}{100} = 0.99 \text{ MW}$$

A house requires an average power of 4.0 kW in order to heat water. The average solar intensity at the Earth's surface at the house is 650 W m^{-2}. Calculate the minimum surface area of solar heating panels required to heat the water if the efficiency of conversion of the panel is 22%.

4000 W are required, each 1 m^2 of panel can produce

$$650 \times \frac{22}{100} = 140 \text{ W}$$

$$\text{Area required} = \frac{4000}{140}$$

$$= 28 \text{ m}^2$$

Identify the energy changes in photovoltaic cells and in solar heating panels.

A solar heating cell absorbs radiant energy and converts it to the internal energy of the working fluid.

A photovoltaic cell absorbs photons and converts their energy to electrical energy.