Topic 8: Energy, Power and Climate Change

Energy Degradation and Power Generation

Laws of Thermodynamics

1. "The complete conversion of energy from a heat source into mechanical work is not possible"

This means that a heat engines can never be 100% efficient – even if we could reduce all friction to zero. So, for example, if the heat engine burns fuel to create 100J of heat energy, we can never get 100J of useful mechanical work out. The maximum amount of energy we get out actually depends on the temperature that the engine runs at, and the temperature of the surroundings.

2. "To maximise conversion of thermal energy to mechanical work, a cyclical process must be used"

This means that we must convert heat energy to mechanical energy in continually repeating stages and not in one single stage. We can see this in all practical applications. Mechanical devices that burn fuel, to create heat, to make an engine run, always work in cycles. For example petrol and diesel engines often work at several thousand cycles per second. (The cycles in a 4-stroke car engine are as follows: (i) air/fuel is drawn in (ii) air/fuel is compressed (iii) fuel is ignited and power is created (heat converted to work) (iv) exhaust gases are expelled. This cycle is then repeated several thousand times per second.)

Energy Degradation

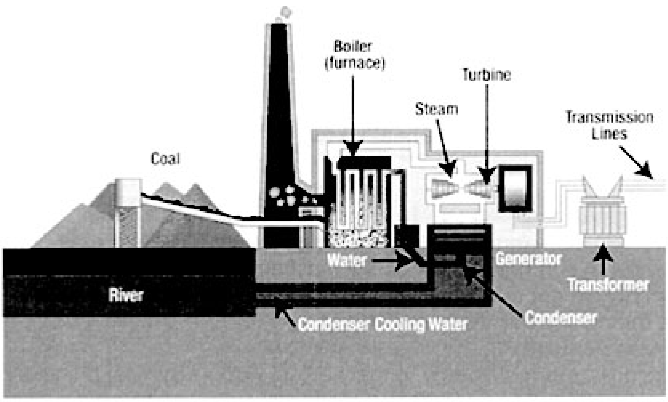
Energy degradation is the process whereby energy is transferred out of a useful system. The most degraded energy is heat energy and is difficult to utilise.

Power Production

A variety of power stations are now employed, with the increasing use of renewable fuel power stations such as hydroelectric power stations.

However, fossil fuelled power stations such as coal, gas and oil are still the world's main producers.

A typical coal fired power station



Simplified description of processes

Coal, containing chemical energy, is burned and the thermal energy released is used to heat up water to produce pressurized steam. This pressurized steam is used to drive turbines. Turbines are very large cylindrical drums constructed so as to rotate using the force of the steam. The turbines are connected to huge coils of wire, in generators. The coils of wire move through a magnetic field (generators are constructed with very large electromagnets to create this field) and this causes an electric current to be induced (produced) in the wires of the coils. Therefore electricity has been produced. Of the total energy available originally in the fuel (coal, oil etc.) somewhere between around 30% and 50% is actually converted into electrical energy. The remainder is dissipated (wasted) as heat. This loss of heat is largely unavoidable and in accordance with the laws of thermodynamics. However, the efficiency of a power station can be significantly improved by actually using this dissipated heat for other purposes. This is increasingly being done, with rising fuel prices and increasing political pressure to increase energy efficiency. For example, in the Middle East, power stations often use this excess heat for desalination of salt-water. Power stations that re-use this heat by-product are termed CHP (Combined Heat and Power) plants.

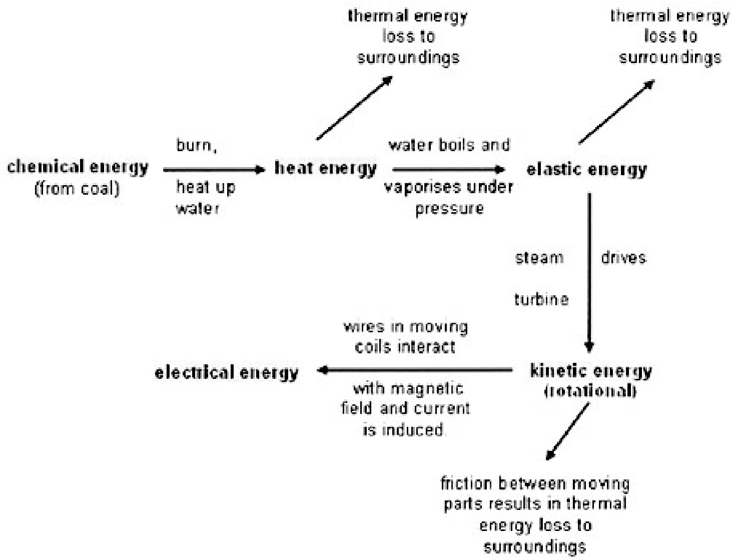
Energy Diagrams

We represent the energy processes happening in a power station such as this using either energy chain diagrams or Sankey diagrams.

Energy Chain Diagram

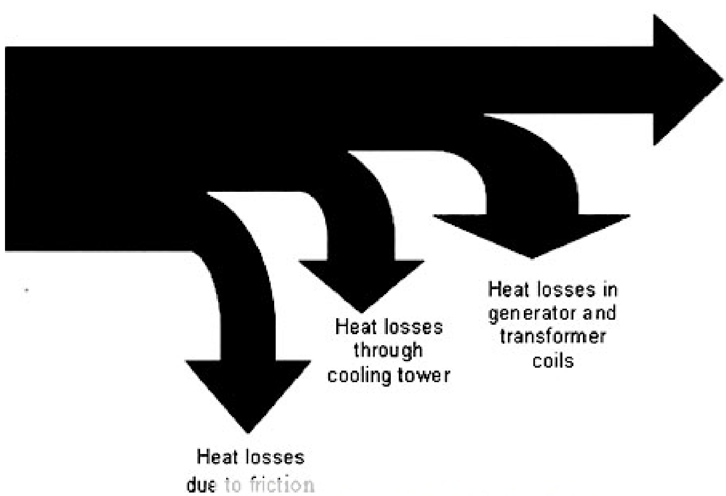
This shows the basic energy transfers taking place, from the input energy (in the fuel) to the output: the electricity.

The following is an annotated energy chain for a coal fired power station.



Sankey Diagram

A Sankey diagram is an arrow representation of the flow of energy and its transfers and energy dissipations in the process from input to output. The relative thickness of each part of the arrow (shown with little arrows) corresponds to the amount (proportion) of energy involved in each stage. In a very visual way, the diagram gives an idea of the overall efficiency of the process by comparing the thickness of the useful energy output with that of the input (energy from fuel).
By making approximate measurements you will find that the efficiency of the process represented by the Sankey diagram below (showing, again the coal fired power station process) is approximately 40%.



Note that the diagram is not very useful for making any precise measurements.

Note also that the Sankey diagram would be very similar for any thermal (heat producing) power station.

World Energy Sources

An energy resource is something that can provide us with usable energy.

A renewable energy resource is one that is replenished naturally and within a short time scale.

A non-renewable resource is one that cannot be replaced (in the foreseeable future) once used.

Renewable:	**Non Renewable:**
Hydroelectric Power	Oil and gas
Geothermal Power	Coal
Tidal Power	Nuclear Power (but virtually unlimited)
Solar Power	
Wind Power	
Wave Power	
Biomass	

CO_2 emission and environmental issues

Since all fossil fuels (and, essentially all organic substances) burn to produce CO_2, the three non-renewable fuels above all involve a contribution of carbon to our atmosphere (and contribute to possible global warming). In addition, Biomass is a CO_2 producer, since this form of energy production also involves burning organic matter. However, if biomass is not burned it decomposes into methane gas. Methane gas is a much more harmful gas to our environment that CO_2, so overall using Biomass is beneficial.

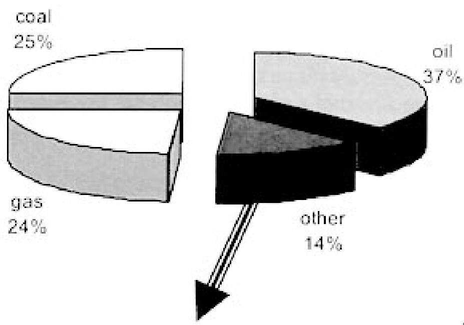
Energy Density

The energy density of a fuel measures the energy release from the fuel per kilogram of the fuel. It is a useful way of comparing fuel economy, particularly where transport of the fuel is involved.

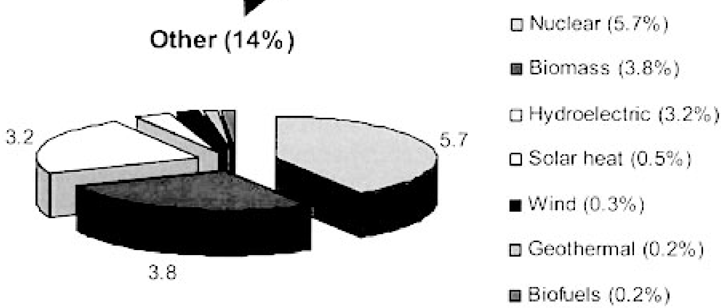
Equation: $energy\ density = \dfrac{energy\ released\ from\ fuel}{mass\ of\ fuel\ used}$

In the exam, you will be expected to be able to compare fuels with different energy densities – the values will always be given.

World's Energy Resources Utilisation Breakdown (in 2004)



Other (14%)



You are expected to learn these approximate proportions and to discuss relative advantages and disadvantages of each, as an energy resource.

Key arguments will be fuel cost, set up cost (power station) environmental factors (e.g. CO_2 emission, pollution including sight, noise), sustainability, safety (nuclear presents problems), social acceptability and political pressures.

Ultimate Source of Energy

The vast majority of energy available on the Earth has come, directly or indirectly, from the sun.

Production of carbohydrates and thus all organic animal and vegetable material, including fossil fuels, came from the sun via photosynthesis and the food chain.

In addition to storages of energy on the earth in all the resources discussed, the sun continues to provide energy as it shines on to the Earth.

Approximately $8.5\times10^{16}\,J$ of the sun's energy reaches the Earth every second. The total world energy consumption in 2005 was approximately $5\times10^{20}\,J$ Using these figures, if we were able to collect all the sun's energy it would take less than 2 hours to give us enough energy for a whole year!!!

So energy shortage is not the problem. Collection and utilisation of energy perhaps is a problem. Producing a "greenhouse" layer of gases in the Earth's atmosphere to trap all the heat perhaps is a problem. Increasing the level of warming by burning and degrading resources to heat is possibly a problem too. You are the generation that may find out for sure!!

Fossil Fuel Power Production

It may be surprising to you, with all the focus these days on global warming and "greener fuels" that over three quarters of world energy production still comes from the burning of fossil fuels. The reasons are largely historical and geographical. Industrialisation led to a hugely increased rate of energy usage and industries were developed near to large deposits of fossil fuels.

If you do some internet research you will see many arguments suggesting that energy usage and power station efficiencies have not changed significantly over the last several decades and that this has much to do with short term economy and profit. The next decade or two will be very interesting times in seeing what changes are made and what new energy technologies are developed.

Using Energy Densities to calculate rate of fuel consumption

The following table shows approximate energy density figures for various fuels:

Fuel	**Energy Density** ($MJkg^{-1}$)
natural gas	50
crude oil	45
coal	25
water in a dam (100m high)	0.001
Uranium-235 (nuclear power)	88.25×10^{6}

Example T8.1

Find the mass per day of each of the above "fuels" that would be needed to output a power of 400MW (a fairly typical value for a power station)

Clearly, energy density of fuels is an important factor to consider when choosing a suitable fuel for a power station.

Power Station Efficiencies

The figures are similar for all three types of power station: Approximate maximum efficiencies are:

Coal fired power stations: 42%
Oil fired power stations: 45%
Natural gas fired stations: 52%

Typical power stations may run at between 5 and 10% lower than these efficiencies.

Environmental Problems associated with fossil fuel use in Power Stations

Pollution (acid rain, greenhouse gases), damaged environment when extracting, pollution when transporting large masses of fuels to power stations (increased traffic), non-renewable so will eventually run out

Non-fossil fuel power production

Nuclear Power

Overview

Nuclear power is the power associated with energy produced as a result of nuclear reactions.

When a nuclear reaction takes place an enormous amount of heat energy may be liberated (given out) so nuclear power is potentially very useful.

Nuclear reactions, unlike chemical reactions, involve nuclear changes. Atoms, thus, are not conserved. Total mass number and total proton number, however, are conserved (after the reaction, compared with before the reaction).

There are two kinds of nuclear reactions: nuclear fusion and nuclear fission. Fusion is where two light nuclei come together to form a heavy nucleus. Fission is where a heavy nucleus breaks apart to form two (or more) lighter nuclei.

The Nuclear Fission Power Plant (Power Station)

A nuclear fission power plant works essentially in the same way as a fossil fuel power plant, as discussed earlier. The key difference is the fuel that is used to produce the heat.

Some important terms:

- **(Nuclear) Chain reaction** – a nuclear reaction that causes one or more other nuclear reactions to take place.
- **Fissionable** – a fissionable material is one that can undergo nuclear fission
- **Fissile** – a fissile material is one that can undergo nuclear fission (is fissionable) by neutrons with low kinetic energy
- **Isotopes** – two or more nuclei with the same atomic number but different atomic masses. Uranium 235 and uranium 238 are isotopes of uranium. Most naturally occurring elements occur as a mixture of more than one isotope.

Fuel

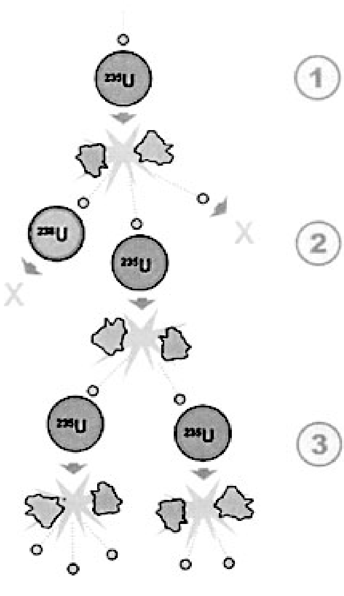
The fuel in a nuclear fission power plant must be able to sustain itself: once the reaction is started it must be able to continue on its own (i.e. we must have a chain reaction). If high energy neutrons (very fast) are targeted at uranium 238 nuclei, they undergo fission. However, the extra neutrons produced are quite slow and do not have enough energy to cause further fission reactions with uranium 238. Hence uranium 238 is fissionable but not fissile.

However, uranium 235 is different. When a U-235 nucleus is bombarded with a low energy neutron, it undergoes fission to produce more low energy neutrons and lots of thermal energy. Uranium 235 is fissile. It is the only relatively abundant naturally occurring fissile isotope.

Enrichment

Naturally occurring uranium contains only about 0.7% uranium 235, the required isotope for power plant chain reactions. The remainder is mainly uranium 238, the non-fissile isotope. Enrichment is the process whereby the quantity of uranium 235 in a sample of natural uranium is increased. The remaining uranium 238 after enrichment is called depleted uranium. Countries that have nuclear power capabilities have the ability to easily further enrich uranium to concentrations sufficient to produce nuclear bombs – so these countries must be considered to also have nuclear weapon capability.

The chain reaction – Diagram showing the mechanism for a possible fission chain reaction:



1. A uranium 235 atom (nucleus) absorbs a neutron and causes it to fission into two fission fragments (smaller daughter nuclei) and to release 3 new neutrons along with a large amount of thermal energy

2. One of the 3 neutrons released collides with a uranium 238 nucleus. But Uranium 238 nuclei are not fissile so this nucleus does not release further neutrons. Another neutron escapes without being absorbed. However the third of the released neutrons collides with another uranium 235 nucleus. It splits into two fission fragments and two additional neutrons and also releases more thermal energy.

3. Both of the released neutrons collide with uranium 235 nuclei so even more energy is released, along with further fission fragments and more neutrons.

Note that usually two or three neutrons are released after each fission. Studying this diagram, one can see that there is the chance that all released nuclei are absorbed by uranium 238 or escape the material without collisions. If this happens, then the reaction is not sustained and we have only a very short-lived chain reaction.

Critical chain reaction and critical mass

A critical chain reaction is one which sustains itself. For a nuclear plant to work we must have critical chain reactions taking place. The chance of achieving this is increased by increasing the concentration of uranium 235 (enriching), by reducing the speed of the nuclei released and by increasing the mass of uranium present. The mass of uranium required to achieve a self sustaining chain reaction is called the **critical mass**. The critical mass of uranium 235 is a mass about the size of a grapefruit.

Moderation / Moderators

As stated, slowing down the neutrons will increase the chance of achieving a critical chain reaction. This is because slowing down the neutrons increases the chance of them causing fission when they collide with a uranium atom. The material used for this slowing down process is called a moderator. Regular water is the most commonly used moderator.

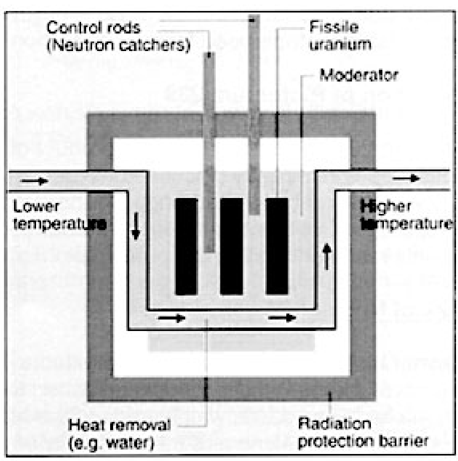
Control Rods

If the chain reaction is left as it is, more and more neutrons cause more fissions and the chain reaction becomes uncontrolled. The heat produced is then explosive. Such chain reactions are how fission bombs work. Control rods are used to control fission chain reactions. Control rods simply absorb neutrons. So if the reaction is going too fast, control rods are inserted into the reactor to absorb more neutrons. If the reaction is going too slow, they are removed. Control rods can be made of many different materials. One example is boron.

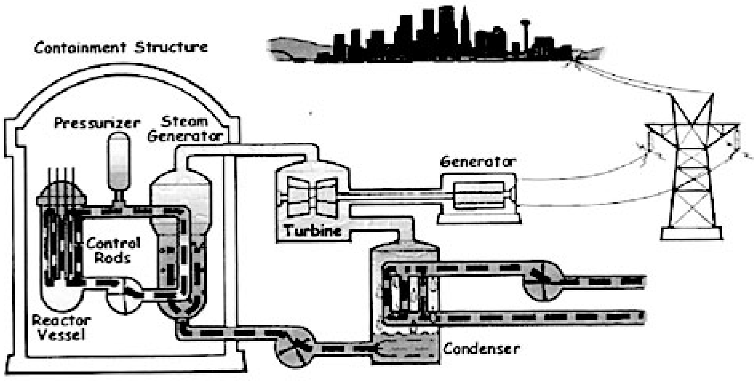
Nuclear Reactor

A nuclear reactor is a device that contains, initiates and controls nuclear chain reactions at a steady and sustained rate. The purpose of a nuclear reactor is to convert nuclear energy into thermal energy (heat).

The diagram on the right (credit: European Nuclear Society) shows a schematic (simplified) view of a nuclear reactor.



Schematic Diagram of a Nuclear Power Station



(Credit: http://www.nrc.gov/reading-rm/basic-ref/students/animated-pwr.html)

The reactor has already been discussed. Its purpose is to generate heat. The heat exchanger transfers heat away from the reactor. The heat is used to produce high pressure steam which then drives a turbine. The turbine is connected to a generator which converts this energy into electricity.

In the diagram above, the condenser converts the used and cooled steam back into water so it can be circulated again.

Plutonium 239

This is another fuel used in nuclear reactors. It has a higher probability for fission that uranium 235, so a lower critical mass is required. Plutonium 239 (Pu – 239) is the primary fissile isotope used for the production of nuclear weapons.

Production of Plutonium 239

Plutonium 239 is produced as a by-product of a collision with uranium 238, in the nuclear reactors already discussed. When a neutron strikes a U-238 atom, there is a chance of this reaction occurring. So there will be a significant amount of Pu-239 in the "spent fuel" of a uranium reactor. The Pu-239 can easily be chemically separated from this material to give high purity plutonium 239 metal.

<u>Risks of Nuclear Power</u>

Thermal meltdown – this is the term used to describe a severe nuclear accident. A nuclear (or thermal) meltdown occurs when the reaction is not controlled properly and extreme heating occurs, which leads to the highly reactive fission products becoming overheated and melting and the possibility of containment failure. There have been several nuclear meltdowns in history, the most famous being the Chernobyl disaster in 1986. Due to cover-ups, it is not known how many died, but the overall cost of the disaster is estimated at 200 billion US dollars; the costliest disaster in modern history.

Radioactive nuclear waste – remains radioactive for millions of years. often buried in geologically secure sites.

Dangers of mining and transporting radioactive materials (uranium) – mining is already dangerous. This has the added danger associated with radioactive materials.

Risk of inappropriate use for nuclear weapons

Nuclear Fusion Power

If we could harness the energy of nuclear fusion, this would produce safe products, since fusion reactions are between light nuclei and results in the production of another light and radioactively inactive nucleus.

The problem with this kind of power is that such extremely high temperatures are required to initiate a fusion reaction and it is very difficult to maintain and confine a high temperature, high density plasma that would be produced.

Solar Power

Solar power is harnessed in two possible ways: using photovoltaic cells ("solar cells") or using solar panels.

Photovoltaic cells convert light energy (sun's radiation) into electrical energy. This form of energy collection requires a large surface area for a relatively small amount of electrical energy. Solar cells, therefore, are commonly used to power smaller devices or the electrical energy produced can be fed into the grid system.

Solar heating panels (solar thermal collectors) convert light energy (sun's radiation) into thermal energy (heat). Solar heating panels are used increasingly on house roofs to assist in the heating of water for central heating and washing use.

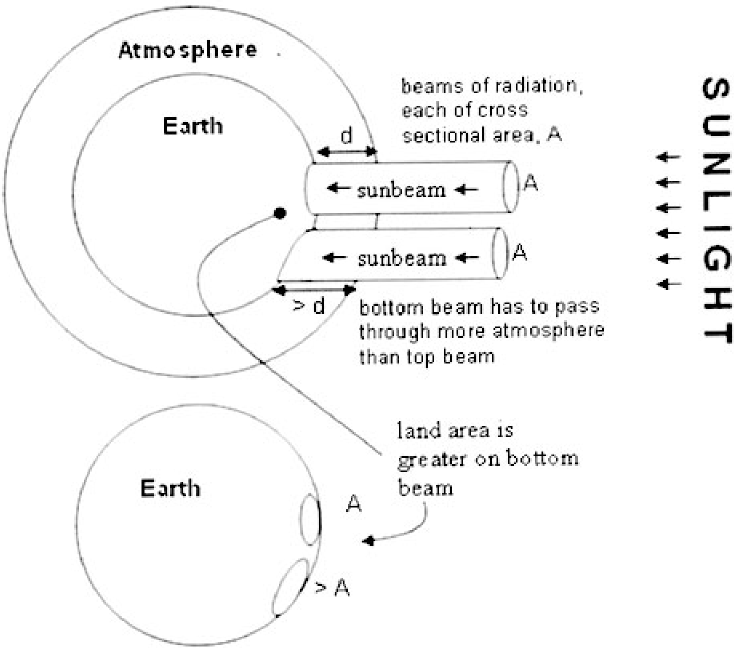
Regional variations in solar power

Solar energy arriving at the Earth does so with an average power of approximately 1400 joules per second per square metre of the cross section of the beam ($1400Wm^{-2}$)

However, as the diagram below shows, the power intensity is less than this when the sunlight does not strike the Earth's surface straight on. The same energy is spread over a large land area. Generally, the further from the equator, the less intense the power.

Additionally, a beam of radiation from the sun has to travel though a greater thickness of the Earth's atmosphere when it is further from the equator. Since radiation is partially absorbed by the Earth's atmosphere, the intensity is weakened when it reaches the Earth's surface – and to a greater extent as you move further from the equator.

Diagram showing how sunlight intensity at surface of Earth varies with position



Hydroelectric Power

Hydroelectric power is power derived from gravitational potential energy of water: so, when water flows downwards, the gravitational potential energy is released and may be converted into electrical energy.

Energy Chain:

gravitational potential energy (water)	→	kinetic energy (water)	→	kinetic energy (turbines/generator)	→	electrical energy

Hydroelectric power is the most widely used renewable energy resource. In 2005, hydroelectric power produced 19% of the world's electricity.

It is a clean and free fuel. Emissions are (usually) clean. Running costs and maintenance are low.

On the other hand, dam construction can damage the environment and enormous quantities of methane gas (a potent greenhouse gas) can be produced by rotting vegetation when an area of land is flooded. Population relocation can be socially unjust and there is always a risk of dam failure: a big safety hazard.

You need to be aware of three different hydroelectric schemes:

Water storage in lakes and dams – the stored water can then be released, dropping to a lower level and, as it does, passing through turbines connected to generators and producing electricity.

Tidal water storage – water is trapped at high tide then released via turbines etc. once the tide drops.

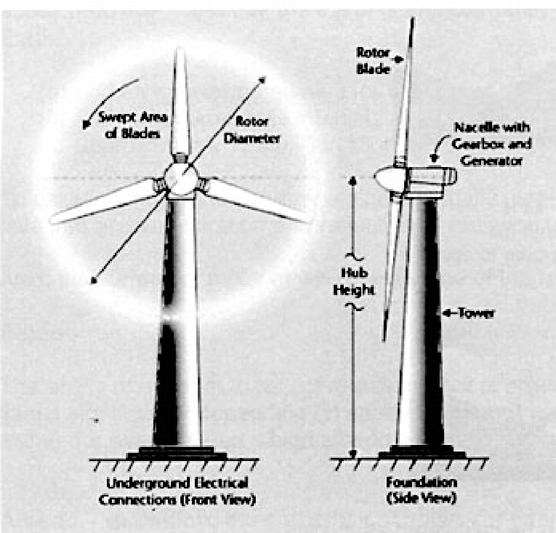
Pump storage – water is pumped from a low reservoir to a high reservoir. The idea is that the pumping occurs at low demand periods, ready to provide extra power in times of demand. Clearly this method is not energy efficient, since at least as much (and in fact more) energy is required to pump the water up than is released when it falls back down.

Wind Power

Wind turbines like the one below essentially convert the kinetic energy of the wind into electrical energy. Note, though, that in accordance with the laws of thermodynamics, one can never convert all the energy from wind into mechanical, then electrical energy.

Construction/workings of a typical wind turbine.

A mechanism (called a "yaw") directs the turbine so that it optimises wind energy into mechanical energy in the turbines. Another mechanism stops the turbine and directs it away from the wind to prevent damage if the wind is too strong. The gearbox increases the rotation speed of the generator, maximising efficiency of mechanical → electrical energy conversion. The generator is also housed with the gearbox, inside the "Nacelle"



Credit ESN

If the windspeed of air passing through the turbine blades is known, you can easily calculate the maximum power delivery of a wind turbine, as follows:

$m/second = \rho V/second = \rho \pi r^2 v$ ($m/second$ =mass of air per second)
(ρ = density of air, r = turbine radius)
(v =windspeed)

Maximum Power available $= \frac{1}{2}(m/second)v^2$

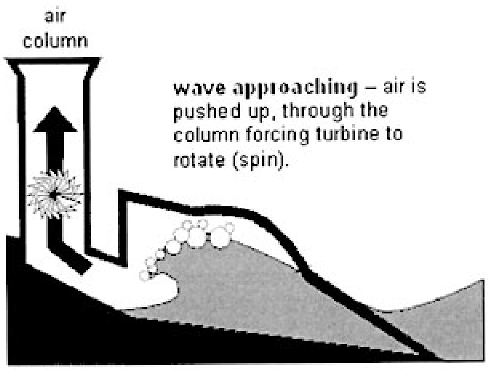
$= \frac{1}{2}(\rho \pi r^2 v)v^2$

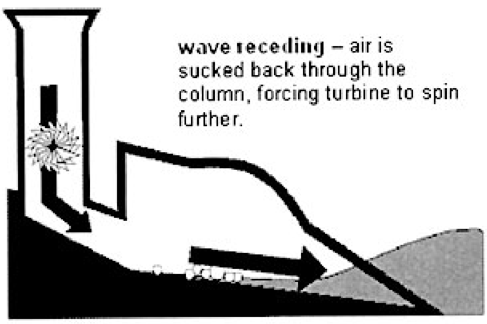
$= \frac{1}{2}\rho \pi r^2 v^3$

Wave Power

Wave power converts wave energy (essentially kinetic energy) into electrical energy. An oscillating water column (OWC) is a device that captures wave energy, converting it into electrical energy.

Oscillating Water Column (OWC)





The energy delivery of a wave can be calculated as follows:

Power per metre-width of wave $= \dfrac{\rho g A^2 v}{2}$ (equation in data book)

where:

$$\rho = water\ density,\ \ g = gravity,\ \ A = wave\ amplitude,\ \ v = wave - speed$$

Greenhouse Effect

Solar radiation

The sun emits radiation from the whole of the electromagnetic spectrum (gamma rays, X-rays, Ultraviolet, Visible and Infrared). However, the atmosphere filters out many wavelengths and ultraviolet, visible and infra red radiation are the three main types of radiation reaching the Earth's surface.

The amount (intensity) of radiation reaching the surface of any planet can easily be calculated using the "inverse square law", but we would need to assume negligible radiation absorption by the atmosphere – which may not always be realistic.

Inverse square law

$$I = \frac{power}{area}\ (in\ data\ book) = \frac{P}{4\pi r^2}$$

where I is the intensity at a distance r from the point source

Example T8.2

Given that the intensity of the sun at the surface of the Earth (the solar constant) is about 1400 Wm^{-2} and that the Earth is approximately 150 million kilometres from the Earth:

(a) find an approximate value for the power of the sun
(b) find the approximate intensity at the surface of Jupiter, given that Jupiter is approximately 780 million kilometres from the sun.

To calculate how much energy a planet actually receives of course you would need to take into account filtration and reflection of radiation by the planet's atmosphere.

Also, the surface of a planet will reflect some of the radiation straight back into space.

Albedo

The ability of a planet to reflect radiation back is called albedo. The Earth's albedo varies significantly depending on season (colours) and surface: snow (being white and shiny), for example has a high albedo, whereas oceans have low albedos.

Albedo – definition: the proportion of power (or energy) reflected compared to the total power (or energy) received.

Equation: $albedo = \dfrac{total\ scattered\ power}{total\ incident\ power}$ (given in data book)

The albedo of snowy surfaces, for example, is about 0.85 – indicating that this type of surface reflects 85% of the sun's radiation back. The global annual mean albedo of the Earth is 0.3 (so approximately 70% of the radiation reaching the sun is absorbed by the Earth.

The greenhouse effect

The greenhouse effect is the warming effect that the atmosphere has on the earth.

To understand the greenhouse effect, we first need to understand that the Earth is always absorbing energy from the sun and it is also always emitting radiation. All bodies possessing thermal energy emit radiation. The type of radiation emitted depends on the temperature of the body. The Earth emits mainly infrared radiation.

The greenhouse warming effect occurs because some gases in the atmosphere are able to absorb infrared radiation emitted from the Earth. As the gases increase in temperature, they then begin to emit radiation. However, they emit radiation in all directions, so some of the energy is sent back to Earth. Hence warming occurs.

Greenhouse gases are gases that easily absorb infrared radiation. Examples include carbon dioxide, water vapour, methane and nitrous oxide. These gases all have bonds that oscillate with the same range of frequencies as part of the infra-red range of frequencies. They are therefore able to absorb energy by a process known as resonance (the driving frequency, infrared radiation) is the same as the natural frequency as the oscillator being driven (the greenhouse gases)).

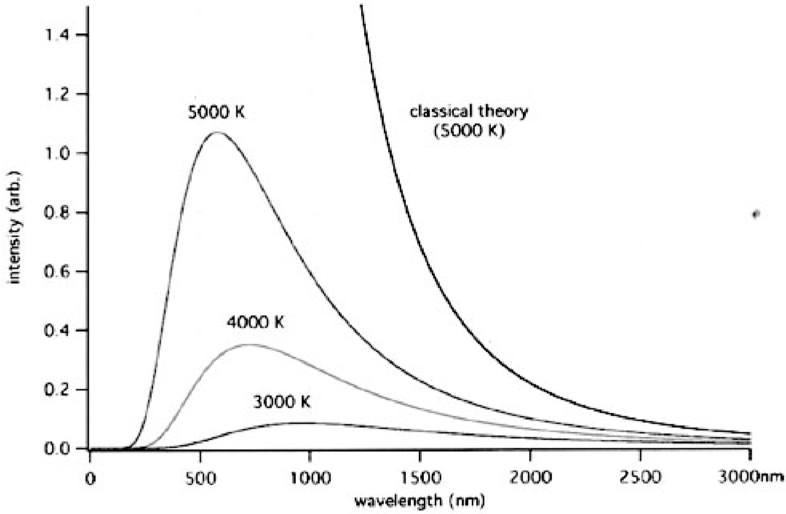
Black Body Radiation

A "black body" absorbs all radiation that falls on it and reflects none; hence it is black (reflects no light) when it is cold.

However, when a black body is hot it emits radiation. If it is at the same temperature as the surroundings it will emit exactly as much radiation as it absorbs and at every wavelength. So, (hot) black bodies always emit radiation at all wavelengths.

The relative proportions of radiation emitted depend on the temperature of the body.

The following diagram shows the emission spectra of black bodies at different temperatures:



As the temperature increases, the peak intensity moves to higher intensity and shorter wavelength.

The theory of black body radiation explains and can be used to predict the colour of very hot objects. A heated metal, for example, first appears red hot, then white hot (at very high temperatures) this colour corresponds to the peak intensity on the above diagram.

Most objects at "everyday Earth" temperatures emit radiation mostly in the infrared region of the spectrum – so the peak would be in the infrared region in above diagram.

Stefan-Boltzmann Law

This law links the total power emitted (radiated) by a body to its temperature, in the following equation:

For a black body: $power = \sigma A T^4$ (given in data book)

For any body: $power = e\sigma A T^4$ (given in data book)

where: σ = Stefan-Boltzmann constant = $5.67 \times 10^{-8} Wm^{-2}K^{-4}$
A = surface area of the emitter
T = absolute (Kelvin) temperature of the emitter
e = the emissivity of the surface

Emissivity

The emissivity is a number (from 0 to 1) measuring of how well a surface emits radiation. Good emitters have emissivities close to 1 (A perfect emitter, a black body, has an emissivity equal to 1).

Example T8.3

Find the approximate radiation power of the Sun and the Earth, given the following data:

Radius of Sun:	$7.0\times10^{8}\,m$
Radius of Earth:	$6.4\times10^{6}\,m$
Surface temperature of Sun:	$5800K$
Surface temperature of the Earth:	25°C

(Surface area = $4\pi r^2$, assume $e(Earth)=0.7\ \ and\ \ e(sun)=0.95$)

Surface Heat Capacity

Surface heat capacity is a measurement of how much energy is required to heat up 1 m^2 of a surface by 1°C (or 1 K). It is therefore measured in $Jm^{-2}K^{-1}$.

Equation: $$C_s=\frac{Q}{A\Delta T}$$

where: C_s =surface heat capacity, Q= energy, A =land area, ΔT =temperature difference

Example T8.4

Find an approximate value for the surface heat capacity of Lake Zug (Switzerland) given that the average radiation intensity is approximately $300\ Wm^{-2}$, that the surface area of the lake is approximately $38km^2$ and that it takes 3 weeks for the lake to warm up by 2°C.

Global Warming

Global warming is the term we use to describe the recent trend that the Earth's temperature is increasing.

Global surface temperature (oceans and near-surface air) has increased by approximately 0.75°C in the last one hundred years. Whilst this may not seem alarming, it is worth noting that small affects can lead to larger effects (as described later) and that predictions show that there is little we can do to prevent continued increases.

Enhanced Greenhouse effect

There is evidence to show that there have been large fluctuations in global temperatures before humans inhabited the Earth. Indeed, the presence of the atmosphere in its natural state has a greenhouse effect.

Many people (including scientists) believe that the recent global warming trends are a result of human activity and that we need to change some of these activities.

The enhanced greenhouse effect is the expression used to describe the greenhouse effect due to human activities.

Possible causes of enhanced greenhouse effect (and global warming)

- increased burning of fossil fuels
- deforestation
- increased pollution upsetting the chemical balance of the atmosphere
- increased energy consumption

Evidence to link global warming to increased level of greenhouse gases

ice-core research - drilling cores of ice, age of ice increases with depth. Composition of ice gives information about atmospheric composition (trapped air in bubbles) and temperatures (structure of ice). Ice-core drilling has revealed information from up to 420000 years ago. This evidence shows that there is a strong link between global temperatures and the quantity of CO_2 in the atmosphere.

Some Mechanisms

Ice/snow melting – global warming causes ice and snow to melt. This reduces the albedo of the surface so less radiation is reflected back to space, so more thermal energy is absorbed by the Earth.

Solubility of CO_2 in sea water decreases as the temperature increases. This, in turn, leads to greater atmospheric concentrations of CO_2, which leads to further global warming.

Deforestation – not only causes CO_2 release (when burned) but trees take up CO_2 (by photosynthesis) "fixing" the carbon in starch (i.e. the wood). Less trees means less carbon fixing and more in the atmosphere

Coefficient of Volume Expansion

The coefficient of volume expansion is the fractional change in volume per unit (°C or K) change in temperature.

This measurement has relevance with global warming since we can calculate the expansions of the oceans caused by an increase in temperature.

For water, this coefficient changes as the temperature of water changes. As the temperature of water is increased from 0 to 4°C water actually decreases in volume. Also ice is less dense than liquid water (water is unusual in this respect). Water behaves in a more conventional manner at temperatures above 4 °C, expanding as its temperature increases.

Add these complications to the complexity of ice in water and ice on land (does a melt, then, cause an increase or a decrease in water heights?) and you have some complicated calculations. Current predictions project significant sea level rises over the next 50-100 years.

Possible Suggestions to reduce the enhanced greenhouse effect

- **greater efficiency of power production**, leading to less energy degradation and less greenhouse gas emissions

- **replacing the use of coal and oil with natural gas** – coal and oil effectively fix carbon (it cannot escape into atmosphere unless fuel is burned). Natural gas power also tends to be more efficient than coal/oil.

- **Increased use of combined heating and power (CHP) systems** – this is where power stations make use of excess heat instead of releasing it into the atmosphere. The effective use of the heat (for example to heat homes or factories) then means less power demand from the grid system and other power stations. Overall efficiency is increased.

- **Increased use of renewable energy resources** – that way, carbon is continually recycled rather than continually released into the atmosphere (as it is with fossil fuel combustion)

- **Increased use of nuclear power** – no greenhouse gas emission (but other safety issues)

- **Carbon dioxide capture and storage** – rather than releasing CO_2 into the atmosphere when fossil fuels are burned, it could be collected and used (for example, in brewing industry or for greenhouses)

- **Use of hybrid vehicles** – replace diesel and petrol engines with hybrids (run on electricity or fuel).

- **Reforestation** – so that carbon can be fixed via plant photosynthesis

International Efforts

If the enhanced greenhouse effect is indeed a real threat to our future livelihoods it is pointless for one country to make take action if others do not. Climate and air mass is shared and the environment is not possible to divide up into safe and unsafe places: international action and cooperation is necessary.

There are various international initiatives to reduce the enhanced greenhouse effect. Examples include:

- **Intergovernmental Panel on Climate Change (IPCC)** – regularly assesses current evidence from international research

- **The Kyoto Protocol** – Part of the United Nations: a treaty agreeing certain measures to reduce the enhanced greenhouse effect. Countries can sign the protocol. If they do not (e.g. USA and Australia, currently) there is increased international political pressure to do so.

- **Asia-Pacific Partnership on Clean Development and Climate (APPCDC)** – an agreement between Australia, China, India, Japan, Korea and the USA (representing 50% of world's energy users) to make efforts to consider climate change and pollution reduction, amongst other things, with a view to promoting sustainable economic growth and poverty reduction.