Lesson 3

GENERATING ELECTRICITY

Aim

Compare different methods of generating electricity.

ELECTRICITY SUPPLY

Electricity may be generated by various methods including: a chemical reaction, the sun's energy or by physical methods such as turning a turbine.

Turbines and Generators

Turbines are made up of a set of blades or cups (impellers) and an axle which are caused to rotate rapidly by the action of a physical or mechanical force such as wind, water or steam. The turbine axle is connected to a **generator** and the inner section of the generator is also caused to rotate. This inner section contains a magnet with a strong magnetic force. Around this magnet is a large coil of wire which is connected at each end to an electrical system (solenoid).

A very important natural effect is brought into action when the magnet rapidly spins near the wire coil: an electrical current is **induced** (this is somewhat like static electricity from a balloon causing hair to rise, even though the balloon is not touching the hair). The induced current will be AC voltage due to the spinning causing the voltage to rise and fall with each rotation. If the magnet is rotated at 50 revolutions per second (i.e. 3000 rpm) the frequency will be the same as that of mains electricity, 50 Hertz. In practice, the production of electricity by generators is more complicated, but the principles are the same.

This electricity is generated at power stations, most commonly through the heat of uranium break-down or burning fuel (e.g. coal). The heat is used to boil water, producing steam under pressure which spins the turbines. More simply, wind energy, the flow of water in a river or from a dam (i.e. hydro electricity) can be harnessed to spin the turbines.

Windmills and small-scale hydro systems are self-contained systems which trap natural mechanical energy and convert it to electrical energy. These can be operated independently of the mains electricity supply or as a supplement. Portable petrol or diesel generators may be hired or purchased to be used in similar way. They are useful in isolated situations or during power strikes.

Fuel Cells

As we have already discussed batteries (chemical reaction) can range from small torch batteries to large vehicle or industrial batteries. One advantage is that they can be used in remote situations or when a mains supply is unavailable. Batteries generate electricity by a chemical reaction which slowly occurs between layers of different chemicals encased in the battery. As the reaction takes place, electrons are released allowing them to move and create an electrical flow or current. Unlike turbine generated electricity which is AC voltage, battery power is DC voltage. That is because it is produced by a continuous, even source.

Primary batteries are non-rechargeable. When the chemical reaction is completed, the battery is finished. However, secondary batteries can be discharged and recharged again. The recharging occurs when electrical energy is fed back into the battery and reverses the chemical reaction.

The two main types of rechargeable are Lead-Acid batteries which are cheap and used in cars; and Nickel-Cadmium batteries which are expensive and long-lasting.

WIND POWER

One of the advantages of wind power is that the wind may still blow even if the sun is covered by clouds. Developing a two-energy source system by using both these resources is an excellent method for alternative energy self sustainability, however initial costs may be daunting.

Assuring the wind has the strength for the turbines is essential. Just because a site looks windy, it may not produce the necessary wind velocity to produce sufficient energy. Turbulent wind can negate benefits of a rotating propeller. Turbulence can be developed from nearby trees, buildings, etc. It is therefore important to ensure the proposed turbine site is above any "external" influence.

To ensure an even air flow in the area under scrutiny, place a ribbon on the end of a long pole and position this in the wind stream. If the ribbon flows strong and evenly, then this is a good indication of a good site. Air speed is best measured by an anemometer. Note that air speed increases with height due to no ground surface friction. At a height of 26 metres, the wind speed reportedly is about 50% more than at ground level, which can equate to about 300% increase in power at this height.

Wind Speed Conversions

	mph	knots	kmh	metres/sec
1 mph	1	0.608	1.609	0.447
1 knot	1.152	1	1.853	0.515
1 kmh	0.621	0.540	1	0.278
1 m/s	2.237	1.943	3.6	1

(Source: Earth Garden Magazine: March/May 1998)

Operational Wind Speeds

Most large wind turbines will operate best at wind speeds from 3 m/s (cut in wind speed) to 25 m/s (cut out wind speed).

The amount of power generated by a wind turbine will depend upon several factors these are: the generator size; the blade length and the wind speed.

LARGE SCALE DESIGN

Up and Down Wind Design

Upwind design is the more common. This means that the rotor blades are facing into the wind direction - in downwind design the rotor blades are facing the opposite direction of the wind. There are pros and cons to both. It is argued that downwind design can offer greater capacity in higher wind speeds due to the ability of the rotor blades to 'fold' away from the wind. Upwind design on the other hand is considered a tried and true technology.

Other Considerations

In a large scale design the wind turbine towers are often between 50 – 80 meters high. Blades are usually between 25m – 40m (and occasionally longer) in length and may range from just 2 to up to 4 and occasionally more.

The nacelle is the term used to refer to the housing which protects the generator, cooling gear and the bearings). Such systems are designed to rotate at a constant angular velocity by using gears.

Typically this is about 20 r.p.m. regardless of wind speed. As the wind increases the r.p.m. will stay the same however the energy generated will increase. This is done to maximise the aerodynamic performance of the wind turbine.

The nacelle is designed to rotate using gears so that the rotor blades can line up with the wind direction. To do this the turbine has an anemometer which can measure wind direction and speed and provide information to ensure the optimal position.

In exceptionally strong winds the rotor blades are turned and locked to 90^{o} of the wind direction to minimise torque to the blades.

Pros and Cons of Large Scale Wind Turbines	
Pros	Cons
Virtually no pollution is produced aside from initial production and installation	Danger to birds and bats due to the very large surface area of large scale turbines.
There is no need for centralised production.	Can be visually disturbing
No green house gasses are produced	Can generate noise pollution at a pitch that is in audible to humans but can still affect stress levels.
Wind is a renewable resource	The land taken up by a wind farm can be also used for agriculture
Wind turbines are low maintenance	Turbines are vulnerable to severe weather.
	Large areas of land are required for wind farms
	Wind strength can vary considerably

SMALL SCALE DESIGN

A small scale wind turbine is one that might be used by a household or farm. Its energy supply is not constant and the turbine will need to be used to charge storage batteries in order to ensure constant energy supply.

The general design of a small scale wind turbine is similar to the large scale design however the orientation of the rotor blades is controlled by a wind vane which is attached to the nacelle. When the wind is strong enough to push on the vane, it moves away from the wind and aligns the rotor blades broadside to the wind. As the wind turns the rotor blades, it makes the generator rotate. Note that unlike large scale wind turbines, the strength of the wind determines the speed of the blades, thus resulting in a variable AC output.

If you are using a wind generator to charge a 12 volt battery, the wind generator must produce more than 12 volts to be of any affect. It is worth noting that voltage output of an alternator is directly proportional to its speed or RPM. Wind generators may be similar in style to a car alternator and require a high r.p.m. to operate well, or it may be a permanent magnet DC motor type. This later style of wind generator is much more efficient and newer models can be stopped and locked in light winds for servicing.

Wind generators also need some form of regulation to control the amount of energy going to the battery to prevent overcharging. The regulator may be referred to as a controller. Regulation is achieved by dumping the load when the battery becomes fully charged. The controller should also convert the AC from the wind turbine to DC for the battery. The energy stored in the batteries is 12V and can be directly used or it may need to go through an inverter to change to 120V output (the actual voltage may vary from country to country).

Wind generators can also be grid connected using a battery fed inverter. Newer inverters are becoming available which do not require the battery to prevent surges from the grid. When connected up the grid there is also the option of using grid power to keep the batteries charged during times of low wind or if the systems does not use batteries, being connect to the grid allows for power during such times.

Small wind turbines can regulate their wind load by several methods. They can be set to turn 90o to the weather in very strong conditions to prevent damage. The pitch of the blades can also be changed so that there is less loading on them in strong wind conditions.

Pros and Cons of Small Scale Wind Turbines	
Pros	**Cons**
Reduce householder dependency on grid electricity	Wind is unpredictable and therefore energy supply is not continuous
Virtually pollution free	Vulnerable to storm and strong weather conditions.
Aside from initial purchase and installation the turbines is low maintenance.	The system may take a long time to pay itself back.
Wind is a renewable energy source	They can be quite noisy.
Can be part of an independent system (not grid connected) or part of a connected system.	Cannot work in strong wind conditions.

SOME FACTS ON WIND GENERATION

- Power generated from wind is an indirect form of solar energy.
- Wind generators can run day and night depending on the presence of winds.
- Wind turbines for power generation have low environmental costs.
- The southern coastline of Australia and New Zealand is in the "Roaring Forties" one of the best wind regimes for power generation in the world.
- Wind generators occupy only a small space for the tower with the rest of the land available for other uses (e.g. agriculture).
- A wind generator will produce the energy used in its manufacture in 1 to 4 years depending on its location.
- In 1993, a joint Australian-French research project was established to investigate alternative energy options for Antarctic stations. Installation of a 10 kW wind turbine was undertaken at Casey station in Antarctica. By 2007 they hope to have a large proportion of the power requirements of their continental stations provided by renewable energy sources.

SOLAR ENERGY

Solar energy makes use of a small portion of the electromagnetic radiation (EMR) that comes from the sun. Electromagnetic radiation is energy that travels in waves, the higher the wavelength the higher the energy. We can see only a small proportion of EMR as visible light. A microwave makes use of a higher wavelength than we can see, and many animals can see ultraviolet radiation. This is important to understand as cheaper or lesser quality solar panels may only capture a smaller range of EMR than those of better quality.

The basic component that actually captures the energy is the photovoltaic cell. They rely on the fact that photons (small parcels of light) act as both matter and radiation. These cells convert EMR in the visible light, infra red and ultraviolet spectrums directly into electrical energy. Photovoltaic cells are generally made from treated silicon (S) and are known as silicon PV cells. These cells are actually highly specialised superconductors which are formed from purified silicon with a crystalline structure. This structure has specific electrical properties. Essentially when light hits the panel the photons travel through to the crystalline silicon, the photon dislodges an electron and this is what causes the electrons to flow. The crystalline structure can be either *monocrystalline* or *polycrystalline.*

Monocrystalline	Polycrystalline.
Cost is high	Cost is lower
Efficiency is high	Efficiency is also lower
Can use less space	Takes up more space

During manufacturing the purified silicon has special impurities added to it to change the availability of electrons. These are known as P Type and N Type impurities.

P Type	N Type
Manufactured to produce a shortage of electrons	Manufactured to produce an abundance of electrons

\When the cells are assembled the two types of silicon are layered with a sheet of silicon dioxide between them. This is known as the P-N Junction. The silicon dioxide prevents the electricity flowing until light is present, when a potential difference is developed between the two layers. This is very similar to what we have discussed with batteries. In a solar panel a positive electrode is formed by metal ribbing connected to the P type silicon. The ribs are connected with wires. The negative electrode is formed by a base under the N type silicon known as the substrate.

The current developed is proportional to the intensity of the light hitting the cell. However past a certain point the current will level off having achieved the maximum current, this is known as the saturation current. Generally, current solar cells generate about 0.5 V DC.

Like a battery, a solar panel consists of many cells. This provides more power than one large cell.

In a solar panel, the cells are connected in **series-parallel.** This is to provide maximum V_{out} (full output voltage) from the series connect and maximum I_{max} (maximum deliverable current – there is a limit to how much current can come from the PV cell regardless of the light intensity) from the parallel connection. By simply multiplying V_{out} and I_{max} we can obtain P_{max} which is the measurement of maximum deliverable power.

A set connected in series is referred to as a PV module, when the modules are connected in parallel they are known as a PV panel.

For example: if we had a panel with 24 series connected cells in sets of 10 parallel connected sets and assuming Imax = 2.2 A

$$V_{out} = 24 \text{ X } 0.5 \text{ V} = 12 \text{ V}$$

$$I_{max} = 10 \times 2.2 \text{ A} = 22 \text{ A}$$

$$P_{max} = V_{out} \times I_{max} = 12 \text{ V} \times 22 \text{ A} = 264 \text{ W}$$

Note that P_{max} is theoretical. V_{out} may differ when the demand on the current is near I_{max}. When cells are connected in series some voltage is lost due to internal resistance.

POSITIONING OF THE SOLAR PANEL

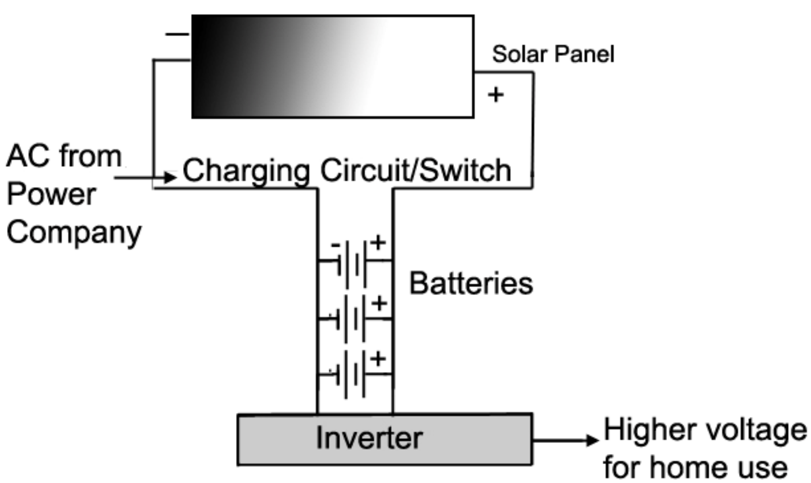
Panels need to be positions so that they are broadside to the sunlight. The orientation while important has a fair degree of leeway. For example if a panel is 45^o to the rays it will still receive approximately 70% as much energy as it would if aligned more accurately.

Obviously the panel should be placed in a location that receives as much sunlight hours as possible with minimum shade. High temperatures can actually be a hindrance, with many solar cells operating working more efficiently at lower temperatures. Panels are frequently positioned on pitched roofs that are facing either north or south. In large installations panels are driven by mounts that are similar to those used in telescopes, however for home installations they are generally mounted on a bearing that allows for the panel to be tilted.

SMALL SCALE SOLAR

As mentioned previously a small stand alone solar set up requires connect to rechargeable batteries for energy storage. As the solar panel will charge a 12V DC battery which in turn will need to be connected to an inverter to create 120 V AC (the actual voltage required may vary between countries) power to run appliances and general home use. It is also possible to connect a solar panel installation to grid power for backup with or without batteries. With batteries it allows the grid to keep them charged during low light conditions, or without batteries, the grid can supply the required power. Additionally surplus power generated can be sold back to the utility providers.

Pros and Cons of Small Scale Solar	
Advantages	Disadvantages
Sunlight is free and unlimited	System cannot produce energy in low light situations.
Running costs are low	Initial costs are high
Quiet	Vulnerable to hail damage
Minimal visual disturbance	Load imbalances can occur



An example of a small grid connects solar system

FUTURE DEVELOPMENTS

Currently there are many new solar technologies in development. These aim to reduce the costs of PV cells and to increase their efficiency. Cell efficiency is generally 16%, there are cells available that are more efficient but they are too expensive for the home market. Under development is a flexible film that could be placed over entire roofs, it's expected efficiency is only 12%. Plastic organic cells are under trial which can be printed like a bank note, with an expected efficiency of 10%.

The following comments summarise points raised in a brochure produced by the Australian & New Zealand Solar Energy Council to clarify issues and dispel myths held about solar energy.

- Solar is not only used to heat water, but can be used to supply electricity for any use (can be generated from photovoltaic cells).
- Good housing design can provide 60-100% of your heating and cooling requirements.
- Solar energy can be stored in thermal mass (e.g. building materials, rocks, water, oils) or thermo-chemical reactions so that it is available at any time, including at night, and on overcast days.
- Electricity produced in photovoltaic cells can be stored in batteries.
- Some solar equipment costs less than conventional alternatives to buy, install and run.
    - 'Solar' clothesline save considerable energy when compared with electric driers.
    - Solar pool heaters can save a lot of pool heating costs when compared to gas heaters, and don't have the same pollution costs.

  Some solar equipment may cost more initially, but will be cheaper overall due to reduced running, maintenance and environmental costs (e.g. water heaters).
- Photovoltaic cells can provide power in areas where it is too costly to connect to power from an electricity grid.
- Current solar devices are already effective in comparison to established energy sources, and improvements are continuing to be made.
- Photovoltaics are now cost effective in many applications.
- Each day there is sufficient sunlight on the land masses of Australia and New Zealand to provide energy to those populations for 25 years!
- There is sufficient roof space on homes alone in Australia and New Zealand to produce, using photovoltaics, and the total electricity requirements of those countries.
- A solar water heater will 'repay' the energy used in its manufacture in only 6 to 18 months, depending on location, and will last in excess of fifteen years.
- A photovoltaic cell will collect four times the energy used in its manufacture during its lifetime.

GEOTHERMAL ENERGY

"*Geothermal*" comes from the Greek words geo (earth) and thermal (heat). So, geothermal means earth heat. Our earth's interior, like the sun, provides heat energy from nature. This heat, geothermal energy, yields warmth and power that we can use without polluting the environment.

Internationally, geothermal sources are prevalent in the U.S., Iceland, New Zealand, Italy, the Philippines, Indonesia, Mexico, and Central and South America.

The heat from the earth's core continuously flows outward. It conducts to the surrounding layer of rock, the mantle. When temperatures and pressures become high enough, some mantle rock melts, becoming magma. Because the magma is lighter and less dense than the surrounding rock, the magma rises, moving slowly up toward the earth's crust, carrying the heat from below.

Sometimes the hot magma reaches all the way to the surface, where it is known as lava. But most often the magma remains below earth's crust, heating nearby rock and water (rainwater that has seeped deep into the earth). Some of this hot geothermal water travels back up through faults and cracks and reaches the earth's surface as hot springs or geysers, but most of it stays deep underground, trapped in cracks and porous rock.

Geothermal energy can be harvested. We can drill wells into the geothermal reservoirs to bring the hot water to the surface. Geologists, geochemists, drillers and engineers do a lot of exploring and testing to locate underground areas that contain this geothermal water. Then, once the hot water and/or steam travels up the wells to the surface, they can be used to generate electricity in geothermal power plants or for energy saving non-electrical purposes.

In geothermal power plants steam, heat or hot water from geothermal reservoirs provides the force that spins the turbine generators and produces electricity. The used geothermal water is then returned down an injection well into the reservoir to be reheated, to maintain pressure, and to sustain the reservoir.

There are 3 types of power plants which harness geothermal power:

Dry Steam Power Plants
Steam plants use hydrothermal fluids that are primarily steam. The steam goes directly to a turbine, which drives a generator that produces electricity. The steam eliminates the need to burn fossil fuels to run the turbine. This is the oldest type of geothermal power plant. Steam technology is used today at The Geysers in northern California, the world's largest single source of geothermal power.

Flash Steam Power Plants
A geothermal reservoir that produces mostly hot water is called a "hot water reservoir" and is used in a "flash" power plant. Hydrothermal fluids above 182°C can be used in flash plants to make electricity. Fluid is sprayed into a tank held at a much lower pressure than the fluid, causing some of the fluid to rapidly vaporize, or "flash." The vapour then drives a turbine, which drives a generator. If any liquid remains in the tank, it can be flashed again in a second tank to extract even more energy.

Binary-Cycle Power Plants
Most geothermal areas contain moderate-temperature water. These temperatures are not hot enough to flash enough steam but can still be used to produce electricity. In a binary system the geothermal water is passed through a heat exchanger, where its heat is transferred into a second (binary) liquid. This binary liquid boils at lower temperatures than water. Heat from the geothermal fluid causes the secondary fluid to flash to vapour, which then drives the turbines.

The vapour is then condensed to a liquid and is reused repeatedly. Because this is a closed-loop system, virtually nothing is emitted to the atmosphere. Moderate-temperature water is by far the more common geothermal resource, and most geothermal power plants in the future will be binary-cycle plants.

WHAT ARE THE ADVANTAGES?

- Geothermal energy is clean. Geothermal power plants do not have to burn fuels to manufacture steam to turn the turbines. Generating electricity with geothermal energy helps to conserve non-renewable fossil fuels, and by decreasing the use of these fuels, we reduce emissions that harm our atmosphere.

- Geothermal installations don't require damming of rivers or harvesting of forests and there are no mine shafts, tunnels, open pits, waste heaps or oil spills.

- Geothermal power plants are designed to run 24 hours a day, all year. A geothermal power plant sits right on top of its fuel source.

- Geothermal energy produces minimal air emissions and offsets the high air emissions of fossil fuel-fired power plants. Emissions of nitrous oxide, hydrogen sulphide, sulphur dioxide, particulate matter, and carbon dioxide are extremely low, especially when compared to fossil fuel emissions.

- Geothermal energy conserves freshwater resources. Geothermal plants use 5 gallons of freshwater per megawatt hour. This compares with 361 gallons per megawatt hour used by natural gas facilities.

HOW IS GEOTHERMAL POWER USED

Heated water from geothermal resources can be circulated by pipes through a home or building in order to provide heat. In Iceland, for example, the entire city of Reykjavik is heated by geothermal energy.

Hot water is useful in many other commercial and industrial applications. For example a dry cleaning store may use geothermal hot water for its processes if located in a geothermal area.

Geothermal sources are also used for health reasons. The warm, healing waters are used to soothe aching muscles in hot springs and health spas.

One such example is the Blue Lagoon in Iceland. The temperature in the swimming area averages about 40C (104F), and the soothing, mineral-rich water is rumoured to have curative powers (such as curing eye and skin diseases). The lagoon is man-made. It was created by run-off from the Svartsengi power plant, which pumps up the geothermal heated water from a full mile below the surface. After being used to generate both heat and electricity, the excess (which is absolutely clean) is ejected into the lagoon.

Geothermal heat pumps (GHP)
With these heat pumps (GHP's), we take advantage of stable earth temperature - about 45 - 58 degrees F just a few feet below the surface to help keep our indoor temperatures comfortable. GHP's circulate water through pipes buried in a continuous loop next to a building. Depending on the weather, the system is used for heating or cooling.

Aquaculture (fish farming) is an important uses of geothermal energy in the agribusiness industry.

One disadvantage is that there are not many places where you can build a geothermal power station. You need hot rocks of a suitable type, at a depth where we can drill down to them. The type of rock above is also important, it must be of a type that we can easily drill through. Hazardous gases and minerals may also come up from underground, and can be difficult to safely dispose of.

HYDROPOWER

Just as moving air can be used to generate electricity so can moving water. This form of alternative energy is most commonly found in massive hydroelectric power plants with dams which the release of stored water (dammed) to drive massive turbines. Hydropower is one of the oldest energy sources, and has been used to mechanically drive mills for centuries.

Hydroelectric Power Plants
When a river is dammed in mountains or hilly regions it creates a massive reservoir of water. This body of water contains potential energy which is measured in Newton-meters (N.m). A Newton is a measure of force typically $1m/s^2$ which is found by combining elevation of the water in meters, the acceleration of gravity in meters per second ($9.8\ m/s^2$) and the mass of the water in kg.

In a traditional hydroelectric power plant water is released through the dam wall from the reservoir into a penstock (like a big tube), it then passes through the turbine which drives the electricity generator. A dam is not always required, in a diversion hydroelectric power plant part of a river with considerable natural fall where the water is diverted into a canal and used to drive the turbine. This type of power plant can be adapted to small scale use.

Small Scale Hydro Electricity
As mentioned previously, a diversion system can be well adapted to a small system. If there us a fast moving stream or an adequate vertical fall in the stream it is possible to produce up to 20kW of power.

Like solar and wind the system can be configured to either run as a stand alone with or without batteries, and/or with or with grid connection as previously discussed in solar and wind power.

Pros and Cons of Small Scale Hydro Electricity	
Advantages	Disadvantages
Can be self reliant for power	Large initial costs
If the stream is large enough it is a more constant energy source that wind and solar (location dependant)	Need to have access to a stream/river with sufficient mass or drop to move turbine.
Virtually pollution free	Weather depend if stream freezes over or dries up in drought
	May require installation of a mall dam/wall.

TIDE & CURRENT POWER

Tidal Barrage

A tidal barrage uses the natural movement of the tides to generate power. The tides are generated by the moon and the sun's gravitational fields. Essentially a tide is a very long wave. Most locations have two high tides and two low tides daily. The size of the tide can vary considerably depending on location and the moon's cycle. A barrage is basically a dam wall across a body of water adjacent to the sea. This creates uneven water elevation between the water and sea level. The barrage has sluice gates which can be opened to allow water to flow between the two bodies of water generating a turbine which in turn runs a generator.

To operate the tide is allows to flow in and fill up the basin, when the tide turns from its peak, the gates are opened to allow the accumulated water to flow out to the sea which is by now at a lower elevation. When the tide is at its lowest water from the basin will still flow out, but once this has occurred and the water levels are equal between the two bodies the sluice gates are shut and water is let into basin to form a reservoir again. There are alternative systems that can also use the incoming tide to generate electricity by the use of two basins.

Tidal Turbines

A tidal turbine makes use of the ocean currents that flow consistently. Tidal turbines are anchored to the ocean floor and can form a tidal stream farm. The turbines are very similar to wind turbines, however ocean currents have much greater mass than wind and produce a much greater force, thus the tidal turbines have smaller blades.

Pros and Cons of Small Scale Hydro Electricity	
Advantages	Disadvantages
Minimal maritime hazard	Costs are very expensive to install
Virtually pollution free	Can cause localised flooding
A barrage can also double as a bridge	Difficult installation
Long lifespan and easy maintenance	Can impact upon marine life
Tides and current are renewable and very reliable.	The water reservoir created by a barrage can impact upon water quality.

WAVE POWER

The movement of the waves contains a tremendous amount of energy. Most of this is dissipated when the waves crash onto the shore. A wave electricity generator can capture some of this energy by using an air turbine. This is achieved by anchoring a chamber at sea level to the ocean floor so that the chamber cannot rise or fall. The chamber has a hole at the top to allow air to pass through. As a wave moves past the chamber the water inside will rise and fall, this in turn will push air through the hole at the top, the air then moves past an air turbine causing it to rotate and in turn drives an electrical generator. The power generated is converted to the require AC level to be carried over transmission lines. There are other designs which utilise the wave undertows and some that use the pressure created by breaking waves against solid objects.

Pros and Cons of Small Scale Hydro Electricity	
Advantages	Disadvantages
If well designed can have minimal impact on marine life.	Dependant upon waves being present, in calm conditions will not be so effective.
Virtually no pollution	Marine hazard
Not visually disturbing	Vulnerable to massive storms
Not expensive to install	Can generate a lot of noise
Can produce a great deal of energy	

NUCLEAR ENERGY

Although there are some very significant problems with nuclear energy if properly managed it does have the potential to provide incredible amounts of energy. It is important to understand how this process works. Currently nuclear energy harnesses the energy released by splitting heavy atoms like uranium. This process is known as fission. Another process call fusion has been proposed as it would be safer but there are no working reactors.

An atom has at its core the nucleus. The nucleus is made up of protons (positively (+ve) charged) and neutrons (electrically neutral – no charge). Around the nucleus is a cloud of electrons (negatively (-ve) charged). Normally the number of electrons will equal the number of protons plus neutrons, thus balancing the charges and creating a neutrally charged atom.

An **isotope** however is an atom that has the same number of protons but a different number of neutrons. The isotope therefore has an unbalanced charge and an unstable nucleus. Due to this instability the nucleus can ‘decay’ spontaneously. This is called radioactivity. When a nucleus decays, it breaks apart and emits gamma radiation and particles (neutrons).

Fission Reactors

In nuclear fission this is a control reaction. Using a uranium isotope U-235, it is bombarded by neutrons, this in turn splits the atomic nucleus of the U235 creating two lighter nuclei, and this releases gamma radiation and more neutrons, these neutrons then hits other atoms and splits their neutrons thus creating a chain reaction all the way until all of the u-235 is split. What remains is nuclear waste. For this to be effective in a nuclear power plant it must be maintain in what is referred to as a 'critical state'.

This means that the reaction proceeds in a steady fashion until it is all spent. This is achieved by regulating the temperature and the mass and shape of the U-235. Due the refining process there is danger that the U-235 can go 'super critical'. This is not an explosion like a nuclear weapon but a process of super heating and melting the uranium. This is what is referred to as a 'meltdown' and it can be very dangerous to the surrounding environment. Thus the design and maintenance of nuclear reactor is crucial to safety.

Electricity is generated via a steam turbine. Heat from the reactor is moved to a water boiler via separate heat transfer system. The steam from the boiler then drives the turbine which is attached to a generator which passes electricity through to the grid. After passing through the turbine, the steam is condensed is moved back to the boiler. Note that for safety reasons the water to drive the turbine and the heat transfer system from the reactor are separate systems.

Fusion

It is believed that the sun uses nuclear fusion to generate its power by converting hydrogen to helium, which demonstrates the incredible amount of energy available. Solar fusion and the fusion used in a hydrogen bomb are different by means of the type of hydrogen used. The hydrogen used in a hydrogen bomb is known as deuterium (H 2) and tritium (H 3). Regular hydrogen (H) contains just one electron and one proton - deuterium contains these, plus one neutron, while tritium contain two neutrons. Essentially the two nuclei of deuterium and tritium are forced to merge which results in a nucleus of Helium (He 4) with an extra neutron emitted and energy. In order to start and sustain this type of reaction an incredible amount of heat is necessary. It works for the sun due to the massive gravitational pressure generating heat, however, it seems to be impossible in a terrestrial environment.

Half-lives and radioactivity

One of the reasons there is so much debate about nuclear energy is the fact that radioactivity can linger for millions of years. A half life of an isotope is the amount of time it takes for one half of the nuclei in the sample to day. This is the common way of expressing the time for radioactive decay. Half lives of known radionuclides vary widely, with highly radioactive substances decaying much faster than those that are weak. Additionally rates of decay can and are measured precisely nor does the rate of decay vary in differing conditions. Note that the ratio refers to the percentage of atoms that decay during a half life (50%). However the actual numbers of parent isotopes will decline continuously while the number of daughter atoms will rise in proportion. For example: If there are 100 parent isotopes and 0 daughter atoms the half life will be equal to zero. If there are 50 parent isotopes and 50 daughter atoms the half-life is 1. If there are 25 parent atoms and 75 daughter atoms, then the half life is equal to 2.

Parent Isotope	Daughter atom (stable)	Half Life Value
Rubidium 87	Strontium 87	50 billion years (error of 30-50 million years)
Uranium 235	Lead 207	700 million years
Uranium 238	Lead 206	4.5 billion years
Potassium 40	Argon 40	1.3 billion years

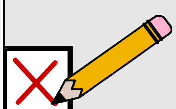
Table 2: Half life of some common isotopes

WASTE TO ENERGY

Waste to energy is the process of recovering heat energy from waste incineration. This energy is generally used to provide heat and/or electricity. This is a common form of waste and energy management in many developed countries. Aside from the advantage of providing energy there is also the benefit of reducing landfill. By combusting (incinerating) waste material landfill is reduced by up to 95%. Emission regulation is extremely important and the control standards have been increased in the last 20 years. Energy is gained by a system of heat exchange with the combustion gases.

SET READING

Spend no more than 1 or 2 hours reading about the generation of electricity from alternative resources from available material such as textbooks and websites. Make sure you investigate the positioning of solar panels.



SELF ASSESSMENT
Complete Self Assessment Test 3.1.
If you answer incorrectly, review the notes and try the test again.

SET TASK

Contact a number of suppliers of alternative energy generating systems (e.g. wind, solar). Find out all that you can about the types of systems they supply. Collect any relevant leaflets and brochures. If possible observe such systems in action.

ASSIGNMENT
Complete Assignment 3.