# Climate Change Experiment

**Please consider the environment if printing this document. Copies of this will be available on-board the lab when you arrive.**

**This document is also available online at http://www.fifex.co.uk/lial**

## What's it all about then?

Climate change is probably the biggest challenge facing our planet today with the majority of scientists agreeing that the effects of human activity on the climate could have disastrous consequences. Global increases in temperatures are forecast to lead to more extremes of weather, resulting in more natural disasters, such as flooding and drought, with huge effects on humanity and ecosystems.

This experiment is designed to raise the awareness of the issues associated with climate change with a particular focus on ways of reducing carbon dioxide emissions through renewable energy sources and energy efficiency. After introducing students to the importance of climate change and what affects it along with an introduction to the concepts of work and power, students will then investigate different sources of energy. They will then have a look at the variety of renewable energy sources before focusing on wind and touching briefly on photovoltaic cells before being introduced to the energy debate. In addition, students will also investigate energy efficiency through the doll's house provided.

## MAIN RISKS ASSOCIATED WITH EXPERIMENT

**Before conducting experiment please read the risk assessment document (Appendix 3)**

**For the remainder of this document:**

- **Sub Titles in Black and underline**
- **Headings in Green**
- **Keywords in Red**
- **Essential Notes in Orange**

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## Introduction

Below is a summary of the steps for this experiment. This is to be used as a guide and we would certainly encourage you to make it your own in terms of bringing on board any of your own experiences.

- **Part 1 - Welcome and introductions** – introduce yourself and ask some exploratory questions. Introduce them to the multimedia provided – 5 mins
- **Part 2 – Generating Electricity** (Exhibit) – 5 mins
- **Part 3 – Wind Power Generation** – 10mins
- **Part 4 – Microgeneration and energy efficiency in the home** – 5 mins

*Note, you can swap part 3 and 4 round, spending less time on house and more time on the wind turbine investigation, depending on time and audience.*

## The Sections in Detail

### Activity 1 - Introduction to experiment

**Time:** 5 mins
**Equipment:** Multimedia clips on DVD
Lump of coal
**Keywords:** **Climate change, greenhouse gases, global warming, carbon dioxide ($CO_2$) fossil fuel, renewables, non-renewables.**


Start the experiment by saying who you are and what you do for a living. Tell the students that they are going to do an experiment relating to climate change and energy.

The slide show provided introduces students to the concept of **climate change** and should last no more than 5 minutes. It is displayed on the monitor at the side of the bench. The key point of the slide show is to show the evidence of man induced climate change with the majority of the world's scientists agreeing that it is happening. You may want to show them the lump of coal to show that as an energy resource, coal burning power plants are some of the biggest polluters around.

**See Appendix 1 – multimedia transcript including slides**
*It should be fairly easy to understand and you don't have to read it word for word nor do you have to show every slide. The main thing is getting the key messages put forward. See below.*

**Key messages from multimedia**

1. Climate change is caused by changes in the amount of **greenhouse gases** in the atmosphere. If these increase then this can lead to **global warming**.
2. **Carbon dioxide ($CO_2$)** is one of the main gases associated with climate change and its increase in the atmosphere is attributed to **fossil fuel (most non-renewables)** burning through human activity.

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3. The majority of scientists throughout the world strongly believe that human activities are the main contributor to Climate Change.
4. If nothing is done and $CO_2$ concentrations are allowed to increase then there will be serious consequences to our environment such as severe floods and drought
5. These emissions can be reduced by using **renewable sources of energy** and also being more efficient with the energy we use.
6. Climate Change affects everyone. Countries, businesses and individuals all have a part to play in reducing $CO_2$ emissions through the reducing measures above.

**What the LIAL volunteer should be doing in this part**

Prior to this section and immediately after it, the volunteer should reinforce the key messages that are highlighted above. The students may ask questions during the slideshow and the volunteer should decide whether it is worth pausing the slideshow to answer the questions at the time or whether he/she should wait till the end.

**Supplementary information**

There's an abundance of information on there but one document you may find useful is the accompanying document produced by the Royal Society – "Climate Facts and Fictions". This should help with any tricky questions. Also see links at the end of document.

At the end of slideshow, inform them that they're going investigate some of the measures that can be done to reduced $CO_2$ emissions.

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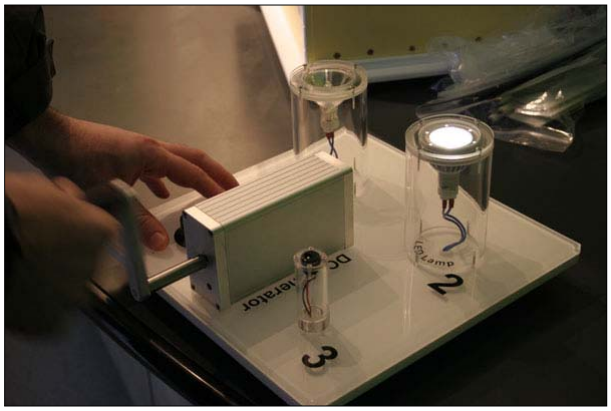
## Activity 2 – Generating Electricity

**Time:** 5 mins

**Equipment:** Hand generator
LEDs
Filament bulb
Other devices, e.g. small fan, radio.

**Keywords:** **Work, power, Watt, generator**



Given the relationship between the energy we use and the $CO_2$ emitted from burning fossil fuels, this section aims to give students an introduction to the concepts of **work and power**, through the use of a 'hand-**generator**.' Energy sources will also be touched upon.

Introduce students to the 'hand-generator' and ask them if they've ever seen a dynamo on a bike. The hand generator they are using in this experiment works in exactly the same way. As they will discover, if the hand generator is turned, electricity is generated.

**Important Point - Terms Used**

**We are intentionally using the terms work and power for this experiment, referring to energy only when necessary. Remember that the teaching of energy is only really useful for doing calculations; it is less useful for understanding the processes going on; usually it is better to refer to processes – forces, movement etc – rather than energy. Energy is not a substance or currency that changes its nature (conversion) as it flows between objects so we should try to avoid using or reinforcing the idea that it is. If referring to energy it is more useful to talk about energy stores and transfers; it is also useful to define start and end points rather than trying to piece together a sequence of all the intermediate states. For example, the starting point is before the handle is cranked; at this time there is a chemical store of energy (the student). At the end (after all the cranking) the room will have warmed up slightly; so there is a thermal store that has been filled a bit whilst the chemical store has emptied. Note that the process is that the student does work to turn the handle, the generator does electrical work to light the LED and the LED lights up and heats up the room (ever so slightly). Therefore energy is mentioned for the start and end points but not for the processes involved. And certainly it is best to NOT to refer to conversion and you should certainly not talk about creating energy (refer to 1st law of thermodynamics). The notes for this experiment intentionally mention the processes involved which should give the students a greater insight into what is going on.**

Get one of the students to operate the hand generator. Ask them to turn the handle. What happens to the LED bulb? The more the handle is turned, the brighter it is. Why?

*The more work the students put into turning the handle forces the current round the circuit even more which in turn causes more electrical work to be done in the LED bulb, making it give out more light.*

The hand generator generates electricity and does electrical work on the LED bulb. The more effort they put into turning the handle per unit time e.g. per second means more power. Power is the amount of work done per unit of time and has the unit of **Watts**. Also try attaching the other devices to the hand generator and get the students to see how much power they have to use.

Can students think of devices at home that would need a lot of power? How hard would you have to turn it to keep a TV running, a heater, a games console?

In this example, the energy source was the students' breakfast or lunch, but there are other sources of energy available to provide the power to generate electricity. Some natural energy sources, renewable sources, include solar (sun), wind (related to sun) and water. They also have the advantage that they don't emit $CO_2$ gases when used unlike non-renewable forms of energy such as oil, gas and coal.

The layout of the exhibit is simple with the three devices being labeled clearly with numbers. The rotational dial can be moved to allow users to select the device they wish to power. Devices 1 and 2 are the bulbs and device 3 is the external power, which can be used for a radio or mp3 player or other lower power devices. Users should hold the exhibit down by placing their hand on top of the generator as they use it.

**Key messages**

1. The student has to do mechanical work to turn the generator handle. They have to push against the force of the handle (see 3 below).
2. The generator does electrical work in the LED by forcing electrons around the circuit.
3. The more LEDs that light up, the more electrical work is done. Therefore the more mechanical work that has to be done by the student.

   *You can think of this as an energy issue (work in must equal work out), Or you can think of the process; the generator behaves like a motor when a current flows through its coils – there is a bigger current flowing so the force on the coils increases, making it harder to turn the handle.*

4. The amount of work done in a set time such as per second is called power and is measured in Watts.
5. Some devices in the home use a lot of power, for example kettles, electric heaters and tumble dryers.
6. Different energy sources can be used to do the work on the generator to produce electricity.

**What the volunteer should be doing in this part**

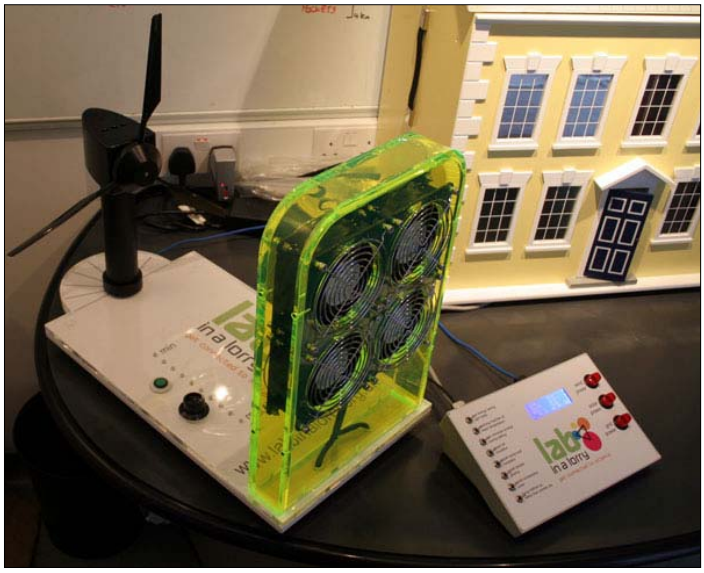
Using this exhibit will be fairly straightforward but it is essential that the volunteer communicates the messages about this part. We want the students to appreciate how electricity is generated and to understand the term 'watt' as a unit of power. We also want the students to understand how different devices have different power needs and to realise how much energy is required to operate large devices compared to the LED and filament bulb on this exhibit.

See appendix 2 for information relating to power ratings of devices in home.

**Note**
As this part of the experiment is quite hands-on, students may wish to spend a lot of time competing to light the light. The volunteer should ensure that no more than 5 minutes is spent on this part.

## Activity 3 – Wind Power Generation

| | |
|---|---|
| **Time** | 10 mins |
| **Equipment** | Wind Turbine model with sets of blades<br>House model with devices<br>Control panel to control devices and power input |
| **Keywords** | **Wind turbine, anemometer, grid network, base load, carbon capture and storage.** |



Having been introduced to work and power, students can now investigate what renewable sources could be used to turn a generator. Ask for the students' thoughts on how they think this can be achieved. Water and wind was already mentioned in the last part. Whilst discussing the benefits of all renewable energy sources, this part of the experiment will focus on wind power.

Where possible the students will split into two groups to do this experiment so that at least two different designs of turbine can be compared.

The **wind turbine** works in the same way as the hand held generator only this time a fan is supplying the wind and it is this wind that is doing the work on the generator to make it turn the crank which generates the electricity. Each group will be asked to design their own 'hub' using the different blades available to achieve the maximum power output which can be viewed on the LED meter on base of kit. Each group should also decide what number of blades would be best. The aim of this part of the experiment, through investigating the variables listed below, is to gain an understanding of how a wind turbine works and its pros and cons for generating electricity.

The wind generator used has the following variables

- Angle of blades
- No. of blades
- Type of blades
- Orientation of the turbine head relative to the wind source

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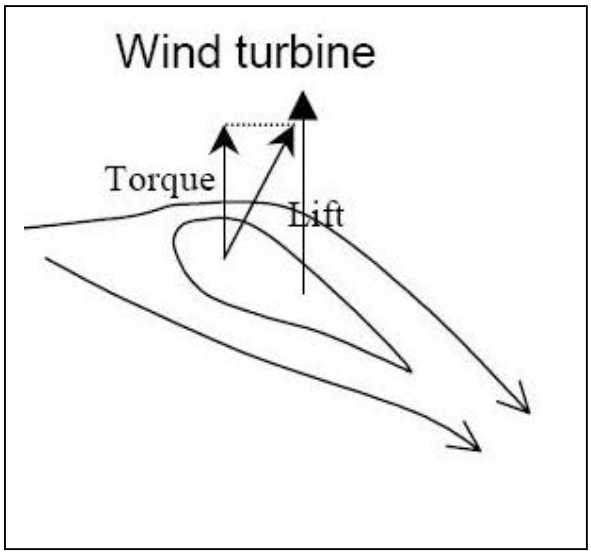
There are two hubs for the students so you may find it useful to split into two groups. Each group has to design their own turbine blade hub, taking into account the best combination of variables based on points above (type of blade, angle etc). Once complete, they then get an opportunity to test their designs.

What conclusions have the students come to? Ask students which design is best and why. A wind turbine can be used to generate electricity which can be supplied to the **grid network** or straight to a home. This is called a wind turbine generator.

**How does it work?**

Wind turbines generate power by taking kinetic energy from the fluid flow and transferring it to the wind turbine as mechanical energy. This in turn generates torque on the turbine making it turn (see left diagram).




You can actually observe the change in kinetic energy across blade before and after wind connects with it by using the anemometer provided. For example it may say 6m/s before hitting blade and 3m/s after.

The **power output from a wind turbine is directly proportional to the area swept out by the rotor, to the density of the air and the cube of the wind speed**. For example if wind speed doubled, the power output would go up by a factor of eight!

**Multimedia**

Show multimedia and refer to Appendix 1 Wind Turbine Designs and Power Output from Wind Turbines slides and associated transcripts (if applicable)

Having discovered the pros and cons of wind as an energy resource, a minute or two should be devoted to discussing the relative merits of other energy sources such as hydro, biofuels, nuclear, gas, oil and coal. Mention that **base load**, the minimum amount of power required to meet power demand, is always required and has to be 100% reliable. Nuclear is one example of this.

**Multimedia**

Show multimedia and refer to Appendix 1 Scotland's Renewable Energy, Pros and Cons of energy resources, **Carbon Capture and Storage**, What are your views? slides and associated transcripts (if applicable)

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**Key messages**

1. Wind as an energy source can be used to generate electricity using a wind turbine generator and is just one example of many different renewable energy sources.
2. Wind turbines are limited to locations that have high average wind speeds. Typically wind turbines are located on hills and on coasts including offshore.
3. In addition to the turbine location, power output depends on size of turbine, number, size and angle of blades, orientation and wind speed incident on turbine.
4. Wind energy is intermittent, that is it only produces electrical power when the wind is blowing. Base load power (see glossary at end) is required for the national grid comprising of the most reliable fuel sources – mainly gas, coal and nuclear power generation. However, wind energy can be used to feed into the grid when power is produced.
5. There is a variety of energy resources out there, each with their relative pros and cons. Carbon capture and storage (CCS) has potential to make fossil burning fuels more environmentally friendly.

**Optional**

A final activity in this part of this experiment will be a hand-held **anemometer**. Where time allows, the group should be taken outside to monitor the wind speed on the day. This will allow discussion about the practicality of using wind-power and should allow discussion of the comparison with other renewable energy sources. This particular activity is open-ended and should flow easily into the next part.

**Operating the Test Anemometer**

When switching the device on the default setting should be in metres per second and temperature in Celsius. In the unlikely situation where it isn't refer to accompanying manual provided. To ensure correct readings, align the instrument so that it has its back to the wind flow. Once done you can easily see the reading on the display screen. To hold reading press mode button until 'hold' comes up and just press at required setting. However, the best method is the timed value calculation and to do this you:

1. Press **mode button** several times, until **hold** and **avg** appear in the display. The last result of mean value calculation is displayed.

2. Hold **mode button** down until **-----** appears. Releasing **mode button** starts mean value calculation automatically, the current readings are displayed.

3. End measurement: press **mode button**. The mean value is displayed.
4. For further mean value calculation: hold down **mode button**.
5. End mean value calculation: press **mode button** briefly.

**What the volunteer should be doing in this part**

During this section, the volunteer should be overseeing the experimentation. It is hoped that the groups will discover that there are a number of important factors that contribute to the successful generation of power from a wind-turbine and the volunteer should reinforce this. It is important to consider all the other factors of running a wind turbine such as cost, location, maintenance cost, accessibility, the effect on the landscape, wind speed etc.

## Activity 4 – Microgeneration and Efficiency in the home

**Time:** 5mins

**Equipment:** Doll's house fitted with solar panels and 20 LEDs
Wind turbine – fan set up.
Switching box with readings for solar, wind and grid input power along with switching options for energy efficiency measures.

**Keywords:** **Microgeneration, energy efficiency, solar/photovoltaic cells**

**Connecting wind turbine and solar cells only**

Students have investigated the factors that can influence the power output of one renewable energy resource, now they can investigate a situation of powering their home using a wind turbine (and/or solar cells) which is called **microgeneration** and the issues it raises. This part of the experiment will also introduce students to grid supplied power and **energy efficiency** measures in the home.

The equipment for this home includes a doll's house with solar cells fitted to roof and also various LEDs throughout house. LED colours represent – yellow, lights; blue, appliances and red heating. Each LED has an associated power associated with it, with yellow being lowest and red highest. The switching box allows power from the wind and/or solar cells to be connected to the house with an additional switch allowing grid connection which essentially fills in the energy 'gap' left by renewables as they can't supply all of the houses needs.

Introduce students to the house and explain the set-up to them. With the wind turbine connected, the turbine will start to light objects (through LEDs) in the various rooms according to how much power is generated. Get students to compare both hubs again but with varying wind speeds. The purpose is to show students the limitations of wind power (dependence on wind speed).

**Solar Cells**

**Solar or Photovoltaic (PV) cells** can also used to generate electricity and should be familiar to students who have used a solar powered calculator. These cells consist of a layer or two of semiconductor material (typically silicon). When light shines on the cell it creates an electric field across the layers causing electricity to flow. The more intense the light is, the greater the power, up to a maximum rating for the cell.

Let the students briefly investigate the varying power output of the solar cell by switching off lights above work station or covering up the cells. This can illustrate cloud cover.

When the wind turbine is connected at max power, this may be enough, for a few lights and a

number of appliances At average power then it may only be useful for the hairdryer, TV and stereo. The LEDs will reflect this and students will see using the kit provided that there is a limit to how much power you can use. Students can make up the rest of the power from the grid by pressing the switch, when the power consumption from the grid is shown on the meter.

Having investigated both renewables ask students what they think would be the ideal conditions for these renewables. Full sunshine with lots of wind would be best with the solar cells facing south.

**Important Point - Terms Used**

**This experiment has been rescaled to reflect a real life house so maximum power output from turbine has been calibrated at 1200W which is typical for a domestic wind turbine. For solar cells this is calibrated at 480W max output. Therefore maximum renewable power is 1680W. Same applies to all of the appliances in the home which are all calibrated e.g. 2300W cooker. The actual power output is of course significantly less!**

See Appendix 2 for full list of appliance power ratings and energy saving options.

Students should see that even at ideal conditions, the renewables still can't satisfy the demand from the house. Therefore power from the grid has to be supplied though we can reduce the power from this by being more energy efficient.

**Energy Efficiency**

Begin by turning off the contribution from renewables. The students can now select some energy saving options from the list below which also relates to Appendix 2. There are eight switches with each reflecting a different energy saving measure. To make it more interesting students are only allowed to select three options. The aim here is to highlight those options that make the biggest difference which they may not necessarily know about. By saving energy the load required from the grid will reduce.

Ask students what measures could be made to the house to make it more efficient. Show them the array of switches next to the house and explain that each switch corresponds to a different energy saving for the home. They are:

- Switch 1 - replace light bulbs with energy efficiency ones.
- Switch 2 - washing machine lower power
- Switch 3 -energy saving setting on laptop
- Switch 4 - loft insulation
- Switch 5 - cavity wall insulation
- Switch 6 - double glazing
- Switch 7 - replace boiler
- Switch 8 - hang clothes up rather than tumble

The challenge is to be as efficient as possible using just three switches and they're only allowed one try at it! For example if one student selects options 1, 2 and 6 then the total energy saved would be 1140W but for switches 4, 5 and 6 this would be 2000W highlighting the importance of conserving heat. Note that for the sake of this experiment heating is electrical

though the power ratings are typical for average homes.

If time allows let students try different combinations. Finally, let students re-attach the renewables and switch all the energy saving measures on. How does the power requirements from grid compare with the scenario of no renewable or no energy saving options. They should see a significant difference, perhaps at least 40% saving which it is fair to say correlates with 40% less CO2. So our house may now contribute one or two tonnes of CO2 **LESS** per year as opposed to the average home's contribution of six (according to Energy Saving Trust).

**Key messages**

1. Microgeneration can be used to supplement a home's power requirements. Other examples include solar water heating and biomass.
2. We can be more efficient with the energy we use by using different energy saving options. Remember being efficient also applies to how we use appliances so leaving TVs and lights on for no reason are a very inefficient way to use energy.
3. Through micro generation and energy efficiency we can reduce our power requirements from the grid which in turn reduces CO2 emissions (also known as Carbon Footprint) from power plants through decrease in demand thus slowing down the effects of climate change and global warming.
4. Empower students with the knowledge that they can contribute to tackling climate change through their own habits and their friends and family! Also mention cost saving benefits of energy saving measures.

**What the volunteer should be doing in this part**

The key part is showing them how they can supplement their energy through wind and solar cells and above all showing them the energy gap which can be reduced through energy efficient means. Time is a big factor in this experiment so you may not have too much time to cover the solar cells for example. Key point about this experiment is to highlight the relationship between what we do as individuals in terms of the energy use and the causes of climate change.

## Web Resources

The following is a list of websites that have been used in the design and production of this exhibit and for developing the accompanying resources

- **Science Issues, Climate Change by the Royal Society**
  http://tinyurl.com/av4fdb

- **Climate change: A guide for the perplexed - environment - 16 May 2007 - New Scientist**
  http://tinyurl.com/db8dov

- **Other Links**
  http://tinyurl.com/c64jvc
  http://tinyurl.com/ccpez3

## Interesting Facts

The following list is an un-ordered list of facts and figures pertaining to this experiment. It may be useful to have these to hand, either to quote to users to gain their attention or to reinforce one of the points made elsewhere in the experiment.

**The biggest ever (instantaneous) demand for electricity in the UK**
The event that created the largest instantaneous demand for electricity was during Italia '90, the World Cup semi-final between West Germany and England on 4 July 1990. Following the penalty shoot out demand rose 11% from 26GW (approx) to 28.8GW - a massive 2,800MW increase in demand in an instant!

From National Grid - http://tinyurl.com/d2wc4l

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## Glossary

The following are the accepted and recommended definitions of key terms that are used on LIAL.

| | |
|---|---|
| **Anemometer** | Device for measuring wind speed. |
| **Base Load** | The minimum amount of power required to meet power demand. |
| **Carbon Capture and Storage (CCS)** | The method for capturing carbon dioxide before or after combustion of fossil fuels and its subsequent storage which can be deep underground in geological formations or injected directly into deep oceans. This technology has someway to go before it is mature enough to operate in a commercial environment. |
| **Carbon Dioxide (CO2)** | Greenhouse gas emitted through burning of fossil fuels and plants. |
| **Carbon Emissions** | Carbon dioxide produced through fossil fuel burning released into the atmosphere as a greenhouse gas. |
| **Carbon Neutral** | Offsetting the amount of carbon dioxide produced for a person, business country through sustainability policies. *For example carbon offsetting exactly the amount of carbon dioxide emissions from cars by growing trees which absorb the exact same amount.* |
| **Climate Change** | Also known as global warming. The result of too much greenhouse gases in atmosphere leading to an increase in the earth's temperature. |
| **Energy** | A measure of system's ability to do work and is measured in joules |
| **Energy Efficient** | Using less energy than normal to achieve same desired outcome. E.g. Energy saving light bulbs. |
| **Fossil Fuels** | Non-renewable forms of energy formed by extremely old organic matter compacted and "cooked" under the earth's surface. *E.g. oil, gas and coal.* |
| **Grid network** | System of power lines which distribute power to users from power stations. |
| **Greenhouse effect and gases** | The effect whereby incident radiation from the sun on the earth is absorbed and reflected as infra red radiation and cannot escape through the earth's atmosphere thus heating up the earth. Greenhouse gases in the atmosphere cause this effect and include carbon dioxide (CO2), water vapor, methane and ozone. |
| **Global Warming** | See Climate Change |
| **Microgeneration** | Generating electricity for small scale use such as home and business. E.g. solar water heating for home. |
| **Power** | Work done per second. Unit is Watts. |
| **Solar/Photovoltaic cells** | Device for generating electricity from solar energy. Cells consist of a layer or two of semiconductor material (typically silicon). When light shines on the cell it creates an electric field across the layers causing electricity to flow. The more intense the light is, the greater the power, up to a maximum rating for the cell. |
| **Watts** | See power. |
| **Wind turbine** | Device for generating electricity through wind. |

## External Resources, Appendices and Web Links

- **Appendix 1 - SLIDES AND TRANSCRIPT**
- **Appendix 2 - DEVICE LIST**
- **Appendix 3 - RISK ASSESMENT**