Renewable energy and climate change

ALPHA

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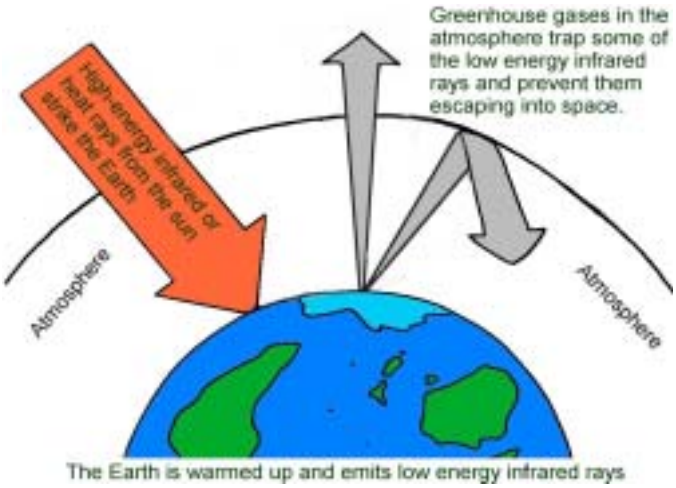
The greenhouse effect

Greenhouse gases

During the past 10,000 years (until the mid 1850s) the average global surface temperature has been relatively constant at 14°C. If greenhouse gases were not present in the atmosphere the average global surface temperature would be as low as –19°C. As a result of human activity over the last 150 years there has been a major increase in the release of greenhouse gases into our atmosphere. Earth's average temperature is rising – by 2100 it may be somewhere between 16 and 20°C – leading to major changes in wind and rainfall patterns



Urban motorway CW

The main greenhouse gases are: carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, sulphur hexafluoride, and perfluorocarbons.

The proportion of these gases in the atmosphere is increasing due to human (anthropogenic) activity.

Carbon dioxide is the main greenhouse gas. The atmospheric concentration of CO_2, has increased from 280 parts per million (ppm) in pre-industrial times to 370 ppm at present, due mainly to the burning of fossil fuels. Fossil fuels provide 85% of the world's industrial energy and their use continues to increase. Reserves will last for many hundreds of years at current rates of consumption.

Predictions

Based on scientific evidence the United Nations sponsored Intergovernmental Panel on Climate Change (IPCC) believes global average surface temperature increased by about 0.6°C during the 20th century. Based on evidence, it believes that most of the 0.4°C of observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations. Temperatures are expected to increase by between 1.5–5.8°C over the next 100 years.

The International Energy Association (IEA) projects a 65% growth in energy demand between 1995 and 2020 with a 70% increase in CO_2 emissions if we continue to consume fossil fuels without any more constraints.

Industrial smoke emission RS

Facts

- The last two decades have seen considerable global warming. Sea levels are rising.
- In this period, insurance company losses from extreme natural events including floods, drought, and storms have shown a substantial increase (but part of this increased loss results from increased development in vulnerable areas.

The links – CO_2 levels and climate change

The link between CO_2 levels, burning fossil fuels and global mean temperature was first made 100 years ago by a Swedish chemist, Arrhenius. However, evidence was lacking and his ideas remained dormant until the 1950s, when Charles Keeling of the Scripps Institute in California started measuring atmospheric CO_2 levels. Keeling observed that the rising CO_2 levels corresponded to increased burning of fossil fuels.

CO_2 levels can be measured from air pockets trapped in ice. Analysis of pockets of air obtained from ice core samples drilled at Vostok in Antarctica revealed a record of the Earth's climate for the last 420,000 years, during which there were three ice ages. Further analysis from ice cores also led climate scientists to believe that the last ice age ended abruptly giving rise to speculation that climate changes occur rapidly rather than gradually. It is now recognised that there is a strong correlation between atmospheric CO_2 levels and global mean temperatures.

Fox Glacier in retreat CW

Seventy years ago Milankovitch, a Yugoslavian geophysicist, proposed that the ice ages were a response to changing solar intensity due to changes in the Earth's elliptical orbit around the sun, along with other factors such as the tilt of the Earth's axis. There is a good correlation between the cycle described by Milankovitch and the period between ice ages. However, the differences involved are not sufficient on their own to produce large climate changes. It has been proposed that the Milankovich cycle tips the balance of CO_2 levels in some way.

Growing evidence has led to a general acceptance among scientists that, overlying these natural changes, global warming due to human activities is a reality. The scientific debate evolved into a political one and gave birth to the Kyoto Protocol.

The Kyoto Protocol

In 1988, the IPCC was formed by the United Nations to research the impacts of global warming. The IPCC proposed that control of anthropogenic greenhouse gas emissions was necessary.

In 1990, the Intergovernmental Negotiating Committee was formed to discuss emission reductions. This led to the United Nations Framework Convention on Climate Change whose objective was to stabilise emissions of greenhouse gases from developed countries at their 1990 levels. It was at the 1992 United Nations convention in Rio de Janerio, now known as the Rio Earth Summit, that all parties signed the convention. Following this signing it became apparent that the promised reductions were not being made and the Kyoto Protocol was added to the Convention in 1997.

The 7th meeting of The Conference of the Parties to the Protocol (COP 7) in Marrakesh, Morocco in November 2001 made good progress towards settling disputes over trading emission quotas, credits for sinks and the Clean Development Mechanism. In March 2001, US President George Bush rejected the Kyoto Protocol in its present form as he claimed reductions would only come at a high economic cost, and developing countries should also be included. He has been heavily criticised by many other countries for his stance particularly because developing countries have not caused the problem.

Islands will be affected by rising sea levels CW

Main points of the Kyoto Protocol

1. Industrial countries agree to legally binding targets to reduce their greenhouse gas emissions by an average of 5% below 1990 levels over the period 2008–2012.
2. Targets vary. The US cut is 7%, Japan 6%, the European Union 8%; Australia is allowed to increase emissions by 8%. New Zealand has to return to 1990 levels.
3. Developing countries assume no emission obligations at this early stage and this is a cause of concern by US.
4. The Clean Development Mechanism allows developed countries to claim credit against emissions by providing developing countries with funding and technologies that reduce emissions.
5. Trade Emission Quotas allow those countries that cut more than their quota to sell the excess savings to those who cannot meet their targets.
6. Developed countries can offset emissions by the use of carbon sinks. Sinks include plantation forests planted into pasture land after 1990.
7. The protocol comes into force after 55 countries ratify their acceptance of it accounting for at least 55% of the total 1990 emissions from developed countries.

What is New Zealand's position?

In signing the Kyoto Protocol in 1997, New Zealand pledged to reduce its greenhouse gas emission back to 1990 levels during 2008–2012. (To be ratified in 2002)

The Energy Efficiency and Conservation Act 2000 was passed to promote energy efficiency, energy conservation and the use of renewable sources of energy. One of the aims of the Act was to develop a National Energy Efficiency and Conservation Strategy, which was launched in October 2001.

Forests act as carbon sinks CW

Trends in New Zealand's energy use

Energy consumption has increased at 1.7% a year over the last decade. New Zealand is becoming more reliant on fossil fuels and the growth in the use of transport fuels is significant. Transport now accounts for 15% of all greenhouse gas emissions. Thermal generation of electricity is increasing. The percentage of electricity from hydro generation dropped from 73% in 1990 to 64% in 1999. Assuming "business as usual" continues, CO_2 emissions are projected to be 40% above 1990 levels by 2010.

Will oil and other fossil fuels run out?

There is conflicting information about oil, coal and gas reserves. Some sources suggest that oil reserves are close to halfway depleted. The International Energy Agency (IEA) expects there is sufficient for at least 20 years, even with increasing demand. The IPCC states that the known fossil fuel reserve remaining is five times greater than that consumed in the past 150 years. Other new sources of fossil fuels e.g. oil shales could be exploited when economically viable.

Improvements in exploration and extraction technologies have increased the amount of oil and gas available. Oil and natural gas will continue to be the dominant form of energy over the next four to five decades, if not longer, and large sums of money have been invested in the infrastructure. Improving the efficiencies of engines and gas turbines along with initiatives such as hybrid cars may be a solution. Hybrid cars use an efficient internal combustion engine for long journeys and an electric motor for town use. There is major concern about the volatility of world crude oil prices, and this along with climate change and environmental pollution issues, are encouraging the search for alternative energy sources.

Natural gas is increasingly being used as an energy source because it is cleaner and more efficient than coal or oil but it too will run out one day.

Alternative biofuels e.g. bio-diesel and bio-ethanol are available in several countries RS

"Today the world will use 77 million barrels of oil. By 2010, the demand for oil, even on conservative assumptions about economic growth, could be as much as 90 million barrels a day. A 15% increase in just nine years – and it could well be more….

The world needs to diversify its source of energy away from traditional petroleum products, and to begin a shift in the energy mix. This will be as important as the shift from coal to fuel oil was nearly a century ago. We believe there could be real long term potential in photovoltaics – solar power – and in the use of hydrogen. But the key to this phase is long term".

Peter Griffiths, Managing Director, BP Oil New Zealand Ltd.

Nuclear power

Nuclear power stations produce substantially less CO_2 per kWh (the measure of energy equivalent to that used by a one-bar 1000 watt heater for one hour) of electricity generated than burning coal, oil or natural gas. Nuclear power stations are expensive to build and decommission. Accidents (such as at Chernobyl in 1986), safety and radioactive waste disposal are concerns.

Improved energy efficiency

Implementation of New Zealand's National Energy Efficiency and Conservation Strategy is based on improved energy efficiency and the increased use of renewable sources of energy.

Improved energy efficiency can be achieved in many ways. One way is the installation of small combined heat and power plants into buildings. Electricity is generated for use in the building, surplus electricity is sold, and the heat produced is used within the building instead of being wasted.

Renewable energy sources for generating electricity

Wind

The largest wind farm in the southern hemisphere is operating successfully near Palmerston North. Another smaller one is operating near Martinborough and Wellington has a single wind turbine that holds world records for electricity generated.

New Zealand has enormous potential to install more wind turbines. A wind farm was proposed for Baring Head near Wellington and another planned for Makara. The proposals were blocked because local residents objected to the visual pollution they would create.

For more information on wind power see Alpha No. 95, "Windpower".

Photovoltaic solar panels

Photovoltaic cells produce electricity when the sun shines on them. Several photovoltaic technologies exist. Most are based on silicon. Thin film cells of amorphous silicon are cheaper but not as efficient as thick film cells of crystalline silicon. The cost of photovoltaic panels has decreased dramatically in recent years but prices can vary due to supply and demand. It remains an expensive option.

Micro-hydro

There are many small streams on farms that can be used for generating electricity on a small scale with minimal disruption to the stream. Sufficient head (fall) and flow rates throughout the year are required.

Wind Turbines – Hau Nui, Wairarapa RS

Solar Panels provide electricity for this BP service station
Bruce Jarvis

A diverted stream powers a turbine to generate electricity RS

Wave energy and ocean currents

It has been estimated that wave energy could provide 10% of the world's energy needs. However, wave energy is a difficult resource to exploit because of the damage storms can inflict on the plant. Several technologies that have been designed for shoreline operation have successful prototypes, which include the tapered channel and oscillating water column. Various rafts and buoys have been built to harness the energy of waves but most are still in the experimental stage.

Tidal barrages built across estuaries are used to generate electricity in France, Russia, Canada and China. A mean tidal range of at least 5 metres is required to make such plants viable. Unfortunately in New Zealand, the mean tidal range is only 3 metres.

Underwater turbines similar to wind turbines are being developed to generate electricity from ocean currents. French Pass between D'Urville Island and the South Island is believed to be an ideal site.

Marine Current Turbines,
IT Power Ltd, UK

Geothermal

Is geothermal power generation renewable and sustainable? Do geothermal power stations have a limited life because, to be economic, they must exploit the resource beyond its rate of renewal?

Renewable energy sources for heat and heating

Passive solar and thermal mass

Houses can be built to face the sun with north facing windows to collect solar heat. Thermal mass is a material such as concrete that can absorb, store and re-emit heat. Thermal mass helps to keep homes warmer in winter and cooler in summer. Well-designed ventilation can reduce the need for air conditioning.

Innovative, privately developed, solar thermal collector for concentrating heat from the sun for use in home heating RS

Solar water heating

Solar water heating uses the sun's energy to heat water. The technology is well proven. The initial cost puts people off but solar water heaters can pay for themselves in a few years through reduced electricity bills.
Should solar water heaters be made compulsory for new houses?

Solar cookers

Solar cookers are being successfully used in many developing countries. They work by reflecting the sun's heat onto a cooking pot, but cooking has to be done during the heat of the day.

Wood burners/stoves

Wood burners/stoves are successfully used where wood is available. For people who live in a city without access to waste wood is it more economic to purchase firewood, use gas heating or use electrical heating?

It has been claimed that wood burners damped down so they remain alight all night can cause significant pollution in cities as they can also if wet wood is used as fuel.

Wood fired power station – Vermont, USA. Coppiced wood ready for burning RS

Biomass

Waste biomass such as forest and wood process residues can be used to generate power via conventional steam boilers or gasified to fuel gas turbine generators. Municipal waste can be burnt to generate power. Some countries such as the UK and Holland use quick growing, coppicing trees such as willow to provide fuel for power stations.

Renewable energy for transport Fuels

Ethanol

Large amounts of ethanol are produced via fermentation in Brazil from sugar cane waste and in USA from maize. Sugar beet and other crops can be grown to produce ethanol.

Recently, patents have been taken out on genetically modified micro-organisms that can produce ethanol from woody wastes.

Methanol

Methanol for use as a fuel in engines or fuel cells can be produced from biomass.

The biomass is first gasified to produce carbon monoxide and hydrogen, which is then converted into methanol. Methanol is poisonous and water-soluble.

During periods of petrol shortages in the Second World War vehicles were converted to run on a mixture of carbon monoxide and hydrogen formed by gasification. Gasification results from burning wood and/or coal in a limited supply of air.

Bio-diesel

The bio-diesel industry is well established in countries such as Germany that have high subsidies and zero excise duty on the fuel. The most common crop used to produce bio-diesel is oil seed rape which is crushed to extract oil from the seeds. The oil then undergoes an esterification process. When raw oils and fats are used in diesel engines, of carbon builds up and blockages can occur. Also fats/oils degrade when stored. These problems are solved by combining the oils/fats with alcohol in the presence of a catalyst to form fatty esters. The process is called esterification or more correctly transesterification. Glycerol is a valuable byproduct, but the esters are expensive to manufacture.

Bio-oils

Bio-oils can be formed from heating biomass in an absence of air. Bio-oils, like crude oil are a complex mix of many chemicals but can be refined to obtain some useful products.

Bio-gas

Bio-gas is a mixture of methane, carbon dioxide and small amounts of hydrogen sulphide. Bacteria break down organic matter in the absence of air to form bio-gas. This process is called anaerobic digestion.

Bio-gas from sewage treatment plants and landfills is used to generate electricity and fire boilers. Bio-gas can be cleaned to remove carbon dioxide and hydrogen sulphide and then compressed to run vehicles. Bio-gas digesters work well on a small scale but labour costs often make them uneconomic to run. The residues left make a good fertiliser.

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Conversion devices

Electric vehicles

Electric cars are ideal for reducing city pollution. The big disadvantage is the limited driving range before recharging of batteries is required. Batteries add considerable weight to vehicles and require time to charge.

If all vehicles on the road were electric the national electricity generating requirements would multiply several times. Many new battery technologies are being developed but many still rely on toxic metals such as cadmium and lead. To date, none can compete with a tank full of petrol. Despite the disadvantages, electric vehicles have an important role to play in the future, especially where batteries are charged via renewable sources.

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If the electricity comes from coal or gas fired power stations are electric vehicles beneficial?


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Hybrid vehicles

Hybrid vehicles have already been described under the heading 'Will oil and other fossil fuels run out?' Another version of a hybrid vehicle is the Designline bus manufactured in Christchurch, which uses LPG to run a micro turbine coupled to a generator. The generator charges batteries that provide current for an electric motor. The micro turbine operates like a jet engine and is more efficient than conventional engines. Very low emissions are produced and vehicles are very quiet. This technology overcomes the short range and large weight of batteries inherent in conventional electric vehicles. It could use renewable sources of fuels, to substitute for LPG.

Fuel cells

Fuel cells are an alternative to batteries. They are very efficient energy conversion devices with minimal emissions. Fuel cells combine hydrogen and oxygen to produce water and an electric current. The most suitable type of fuel cell for vehicles is the proton exchange membrane because it can operate at low temperatures. The disadvantage is that these fuel cells require pure hydrogen or they clog up. Other fuel cells are not as fussy and can tolerate impurities but require high operating temperatures that are not suitable for vehicles.

Bibliography

I. E. A. 2001: World Energy Outlook.
Vaitheeswaran, V. 2001: Energy feature article. *Economist*, 10 Feb 2001, Vol.358 No.8208
Pearce, F. 2000: Gas from the past. *New Scientist*, 22 April 2000: Vol. 166 No.2235: 29–31.
Kicking the habit. *New Scientist*, 25 Nov 2000: Vol.168 No.2266: 35–42.
Rowland, F. 2001: Climate change. *Environment*, Vol.43 No.2: 29–34.
Kerr, R. 2001: Rising global temperature, rising uncertainty. *Science*, 13 April Vol. 292: 192–194.
Bunyard, P. 2000: Fiddling while the climate burns. *The Ecologist*, April Vol. 30 No.2: 48–49.
Climate debate heats up. *The Ecologist*, Vol.30 No.7: 48–50.
The Sustainable Energy Journal 1998: Kyoto analysis. Vol. 3 No.1: 2–5.
Sims, R. 2001: Latest IPPC Report identifies a major role for renewables. Renewable Energy World, Vol. 4 No.3: 30–45.
EECA Energy-wise Renewables. http://www.energywise.co.nz

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Acknowledgements

Written by Associate Professor Ralph Sims and John Adams, HOD Science, Palmerston North Boys High School (New Zealand Science, Technology and Mathematics Teacher Fellow 2001 hosted by the Centre for Energy Research, Massey University, Palmerston North.)
Reviewed by Murray Black, Mt Roskill Grammar School, Auckland; Chris Janes, Waiopehu College, Levin; and David Housden, St Bernard's College, Lower Hutt; Dr David Wratt, Principal Scientist, Climate Applications, National Institute of Water and Atmospheric Research Ltd; Barry Blackett, BP Oil Ltd.
Editors: Colin Walker and Ruth Munro
Diagram: Ian Hicks
Photographs: Cover/ RS – Ralph Sims, CW – Colin Walker
Typesetting: Robert Lomas

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ISSN 0111–1957
2002