Sustainability and Really Cool Technologies (Energy, Water, Waste)

'Learning-by-Notes' Package for Year 10 Students

Lesson 1: Sustainable Development

The Opportunity of Our Lifetime

Teaching Sustainability in High Schools: Subject Supplement

Developed by:

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The Sustainable Living Challenge (www.sustainableliving.com.au)

The Sustainable Living Challenge is a leading Australian secondary schools program that encourages students and their teachers to explore sustainability issues as a part of the school experience. It aims to encourage young people to raise their awareness, engage their minds and develop their skills to be better able to respond to the challenge of sustainability in their future personal and professional lives. The annual program is available to all Australian schools (Grade 7 – 12) and is free to enter. The Queensland Node of the Sustainable Living Challenge is hosted by Griffith University.

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The Port of Brisbane Corporation is a Government Owned Corporation responsible for the operation and management of Australia's third busiest container port. Its vision is, '*To be Australia's leading port: here for the future*'. Sustainability for the Port of Brisbane Corporation means making economic progress, protecting the environment and being socially responsible. In response to the recent drought, and the wider global debate on climate change, the Port is committed to working with the port community to showcase the Port of Brisbane as a sustainable business precinct. Initiatives aimed at reducing the Port of Brisbane's ecological footprint include energy efficiency, a green corporate fleet and constructing green buildings.

The Natural Edge Project (www.naturaledgeproject.net)

The Natural Edge Project (TNEP) is an independent non-profit Sustainability Think-Tank based in Australia, administratively hosted by Griffith University and the Australian National University. TNEP operates as a partnership for education, research and policy development on innovation for sustainable development. Driven by a team of early career Australians, the Project receives mentoring and support from a range of experts and leading organisations in Australia and internationally, through a generational exchange model. TNEP's initiatives are not-for-profit. All support and revenue raised is invested directly into existing initiatives and development of future initiatives.

Lesson 1: Sustainable Development

The Opportunity of Our Lifetime

Our biggest challenge in this new century is to take an idea that seems abstract - sustainable development - and turn it into a reality for all the world's people.

Kofi Annan, Former United Nations Secretary General

Our choices at all levels – individual, community, corporate and government – affect nature. And they affect us.

Dr David Suzuki, Geneticist, Academic and Broadcaster

Educational Aims

This lecture provides a general introduction to the following three lessons on energy, water and waste. Additional Readings are provided to introduce students to key topics, in case they do not have prior learning in these areas.

This introductory package provides the context to sustainable development through identifying a number of key challenges for the 21st Century. We consider the definition of sustainable development to be where technologies, processes and practices can reduce our environmental impact while still meeting the needs of the world's growing population. We highlight the specific role technology plays in addressing climate change and sustainable development.

Resources: Learning-By-Notes Text

-	Key Learning Points	2 pages
-	Background Reader 1.1: Learning from the Past – Easter Island Story	1 page
-	Background Reader 1.2: Understanding Climate Change	10 pages
-	Background Reader 1.3: The Role of Technology in Sustainable Development	2 pages
-	Background Reader 1.4: Looking at the Waves of Innovation	3 pages

Resources: Key Websites

-	An Inconvenient Truth:	www.climatecrisis.net
-	Millennium Development Goals:	www.un.org/millenniumgoals/
-	Ecological Footprint Network:	www.footprintnetwork.org/
-	The Sustainable Living Challenge:	www.sustainableliving.com.au/

Key Learning Points

1. Our generation lives in exciting times, the significant challenges we face could not have even been imagined by our parents and grandparents. As we learn and discover more about the planet, we are becoming aware of how much we don't know about the complex interactions we have with the natural environment.

2. The planet is essentially a 'closed system' where sunlight enters and heat leaves. What we do within this 'system' can have effects on how it behaves. Research by the United Nations[1] and more recently the Intergovernmental Panel on Climate Change[2] and the *Stern Review*[3] show that our human behaviours are significantly affecting this closed system.

3. 21st Century challenges include:[4]
   a) A rapid growth in population that is seeking food, water, shelter and quality of life.
   b) A rapid decline in many of the Earth's natural systems and their ability to regenerate.
   c) Increasing consumption of goods and services that require lots of energy and resources.
   d) Increasing disturbances to the atmosphere and oceans, affecting weather and climate.

4. The most used definition of 'Sustainable development' comes from the report of the World Commission on Environment and Development, called *Our Common Future.*[5] This is also referred to as the 'Brundtland Report', named after the Commission Chair, Dr Gro Brundtland. Released more than 20 years ago in 1987, this report defined that sustainable development is '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.* Essentially this means living our lives in a way that won't stop our children and grandchildren having a similar or even better quality of life. We might think of this as 'thinking forever', where decisions today will affect the planet long into the future.

5. In 2006, Al Gore's movie, *An Inconvenient Truth,* pointed out that since the release of the Brundtland Report, the world's behaviours have changed little. It is now up to this generation to make a difference - the way we choose to deal with these challenges will play a big part in deciding the future for humans – and indeed other species – around the planet. Al Gore asks us to move past 'despair' about this situation, to 'hope' for a rapid shift to sustainable development that addresses these issues. We have an opportunity to be creative and innovative in finding solutions that benefit us and future generations.

6. The 'Ecological Footprint' is a concept that can help us to understand how our activities affect the planet, and how we might make them more sustainable. Every product we buy and every service that we use has an impact on the planet, otherwise known as an 'environmental load', for which we can estimate an 'ecological footprint'. An example of a product could be a bottle of water, a pair of jeans, an MP3 player, or a car. A service could be for example the provision of broadband internet, electricity or water to the house. The size of a product's or a service's ecological footprint depends on the amount of energy and materials needed to make, transport, package, market, consume and dispose of it. By

[1] The UN Millennium Ecosystem Assessment is a big research initiative, undertaken to determine: the changes in our ecosystems; the effect of these changes on human well-being now and in the future; and ways to respond to these challenges to prevent any future harm to both humans and the environment . See www.millenniumassessment.org.
[2] IPCC (2007) *Fourth Assessment Report WG2: Climate Change 2007: Impacts, Adaptation & Vulnerability*, International Panel on Climate Change.
[3] Stern, N. (2006) *The Stern Review: The Economics of Climate Change*, Cambridge, Cambridge University Press.
[4] These challenges are part of a set of key issues that countries around the world are trying to address together, through the UN Millennium Development Goals, see http://www.un.org/millenniumgoals/.
[5] Brundtland, G. (ed.) (1987) Our Common Future: The World Commission on Environment and Development, Oxford University Press, Oxford.

considering the collective footprint of such products and services, we can get an idea of the size of the ecological footprint for our personal lifestyles, and organisations such as our school and workplace.

7. We need to be careful about how we do the ecological footprint estimations, understanding that we are making a lot of assumptions. Even so, the exercise can be very useful to help us understand the complex relationships between our lifestyles and the environment. When we consider the 'ecological footprint' of a product or a service, we can uncover what would otherwise be 'hidden' energy and resource costs that most of us never consider.

8. Estimations by organisations such as the Ecological Footprint Network are showing that when we include such hidden environmental loads, it is clear that our current development path is unsustainable. With the current ecological footprint of our western lifestyles (like in Australia and the US) it will be physically impossible for all developing nations to achieve Western material living standards. Indeed, the current global 'ecological footprint' is already greater than the carrying capacity of our planet.

9. When we discuss the Ecological Footprint, the unit of measure is called a 'global hectare' (gha), which refers to one hectare (approximately soccer field size) of biologically productive space with world-average productivity.[6] Using this unit of measure, the planet can regenerate about 1.8 global hectares per person per year. In 2004, Australia's Ecological Footprint was 7.7 global hectares (gha) per person, which is more than three times what can be regenerated, and more than three times the average global Footprint of 2.2 gha![7]

10. An '<u>innovation</u>' is a new idea or invention that is transformed into a useful product or service. There is significant evidence that sustainable development will drive innovation in the 21st Century.[8] Sustainable development technologies include many of those that are currently in use, such as energy and water efficient appliances and resource saving fittings, renewable energy such as solar and wind power, and other green technologies that are efficient, non-toxic, low or no waste, and are reusable and recyclable. There are also opportunities to innovate solutions that do much more with much less, significantly reducing our ecological footprint. This is known as 'resource productivity improvement'.

11. Significant innovations that are helping to make a shift to sustainable development include:

    a) Hybrid-electric vehicles: In the automotive industry vehicles are now being redesigned to run on fuels other than petrol. New hybrid vehicles combine electric motors, long-lasting batteries, a light car body and fuel switching technology.

    b) Laptop computers: In moving from desktops to more portable computing technologies, the 'laptop' needed to become 80-90 percent more efficient than original models to enable them to run on batteries.[9] This was successfully achieved through innovating better computer chips, cooling devices and monitors.

    c) Electricity Supply – 'Distributed Generation': Innovation in energy efficiency technologies such as new/renewable fuels, solar cells, and wind turbines is leading to a situation where homes and buildings no longer require the traditional electricity grid for their power needs (i.e. 'off-the-grid').

[6] Ecological Footprint calculations for Australia are available at: www.epa.vic.gov.au/ecologicalfootprint/default.asp. Accessed 15 May 2008
[7] Loh1, J., and Wackernage, M. (2004) Living Planet Report 2004. World Wildlife Fund, UNEP, Global Footprint Network.
[8] For a further summary see Hargroves, K. and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London, Chap 1, p 17.
[9] See the Australian Greenhouse Office – *Office Equipment* at www.greenhouse.gov.au/challenge/publications/factsheets/fs3.html. Accessed 9 August 2007.

Background Reader 1.1: Learning from the Past – Easter Island Story

The following information is a brief overview of the Easter Island story, adapted from Jarrod Diamond's publication, 'Collapse – How Societies Choose to Fail or Survive'.[10]

Easter Island, with an area of only 64 square miles, is the world's most isolated piece of habitable land. It lies in the Pacific Ocean more than 3,200 kilometres west of the nearest continent (South America), and 2,200 kilometres from even the nearest habitable island (Pitcairn). In just a few centuries, the people of Easter Island wiped out their forest, drove their plants and animals to extinction, and saw their complex society spiral into chaos and cannibalism.

Pollen records show that destruction of Easter's forests was well under way by the year 800, just a few centuries after the start of human settlement. Then charcoal from wood fires came to fill the sediment cores, while the pollen of palms, other trees and woody shrubs decreased or disappeared, and the pollen of the grasses that replaced the forest became more abundant. Not long after the year 1400 the palm finally became extinct, not only as a result of being chopped down but also because the now ever-present rats prevented its regeneration (of the dozens of preserved palm nuts discovered in caves on Easter, all had been chewed by rats and could no longer germinate). While the Hauhau tree did not become extinct in Polynesian times, its numbers declined drastically until there weren't enough left to make ropes from. By the time European explorers visited Easter Island, only a single, nearly dead Toromiro tree remained on the island, and even that lone survivor has now disappeared.

Every day newspapers report details of famished countries - Afghanistan, Liberia, Rwanda, Sierra Leone, Somalia, the former Yugoslavia, Zaire - where soldiers have appropriated the wealth or where central government is yielding to local gangs of thugs. As the risk of nuclear war lessens, we are no longer concerned about ending our existence with a big bang, and so there is nothing obvious to make us stop and think about our current course of development. With the gradual and incremental nature of climate change, the risk is now that we will just wind down, slowly, and end in a whimper. Corrective action is blocked by vested interests, by well-intentioned political and business leaders, and by their electorates, all of whom are perfectly correct in not noticing big changes from year to year. Instead, each year there are just more people and fewer resources on Earth.

If mere thousands of Easter Islanders with only stone tools and their own muscle power sufficed to destroy their environment and society, how can billions of people with metal tools and machine power fail to do worse?

But there is one crucial difference. The Easter Islanders had no books and no histories of other doomed societies. Unlike the Easter Islanders, we have past-information that can save us. Our main hope for our children's generation is that we may now choose to learn from the fates of societies like Easter's.

[10] Diamond, J. (2006) *Collapse: How Societies Choose to Fail or Survive*, Penguin Books, UK.

Background Reader 1.2: Understanding Climate Change

The following information provides a brief overview of the related background material, adapted from 'The Natural Advantage of Nations', Chapter 2: Risks of inaction on Sustainable Development.[11]

> *Stabilising concentrations at double the pre-industrial levels will require deep cuts in annual global emissions, eventually by 60 percent or more. To achieve stabilisation of atmospheric CO_2 concentrations at 550 parts per million (double the 'natural' levels of CO_2) it is necessary to reduce emissions by 40-60 percent by the end of the century, and 65-85 per cent by 2150. Further reductions will be required beyond 2150.*
>
> **International Panel on Climate Change, 2001**[12]

Understanding the language of Greenhouse Gas Emissions

According to the International Panel on Climate Change (IPCC), effects on climate due to pollution, land clearing and the industrial economy are now very apparent. Up until the Industrial Revolution, carbon dioxide (CO_2) was the most significant greenhouse gas contributor to global warming. Since the Industrial Revolution, industrial processes have created and emitted new forms of potent greenhouse gases, such as Nitrous Oxide, Hydrofluorocarbons, Perfluorocarbons and Sulfur Hexafluoride. So, when we consider the impact of 'greenhouse gases' in the atmosphere, we are not just talking about CO_2. Different gases have different abilities to trap heat, and remain in the atmosphere for different lengths of time. 'Global warming potential' (GWP) is a measure of how much a particular greenhouse gas is estimated to contribute to global warming. The GWP value will depend on the time-span over which the potential is calculated (for example 10 years, or 100 years), because a gas which is quickly removed from the atmosphere may initially have a large effect but over longer time periods becomes less important. So, 'greenhouse gas' includes a wide variety of gases that have short to long time-spans, and many with very high global warming potentials compared to CO_2.

'Greenhouse gas concentration' refers to many different gases with different characteristics. We therefore use the unit of measure called 'carbon dioxide equivalent' (shown as 'CO_2e'), which is measured in parts per million, to include the impacts of all of the greenhouse gases.

It is very important to know whether we are talking about CO_2 or CO_2e when we talk about gas concentrations, because the numbers can be very different. For example, the research indicates that in 2006 CO_2 was at 380 parts per million. When combined with the other greenhouse gases being emitted, the equivalent level of CO_2 (shown as CO_2e) is 430 parts per million and is rising at more than 2 parts per million each year.[13]

Figure 1 and Figure 2 below show carbon dioxide and methane concentrations, based on air extracted from ice cores drilled in the Antarctic ice-cap. From the data, we appear to be experiencing a peaking of the *natural cycle* of greenhouse gas concentrations in the atmosphere and temperatures, to which we are adding more greenhouse gases from human activities. Table 1 shows the global warming potential of a variety of greenhouse gases.

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[11] Hargroves, K. and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London, Chap 2, pp 34-41.

[12] Intergovernmental Panel on Climate Change (IPCC) (2001) *Climate Change 2001: Synthesis Report, Synthesis of the Third Assessment Report*, Intergovernmental Panel on Climate Change, United Nations Environment Program/World Meteorological Organisation, Cambridge University Press.

[13] Stern, Sir N. (2006) *Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge.

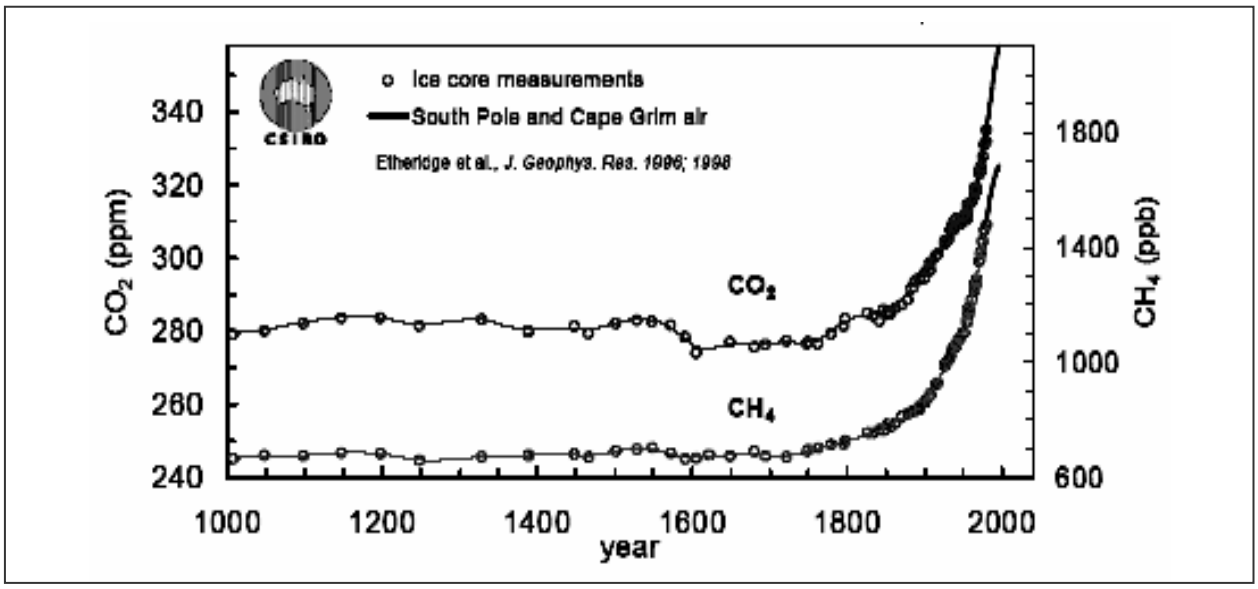

Figure 1. Changes in atmospheric carbon dioxide (parts per million) and methane concentrations (parts per billion) in the atmosphere, in the last millennium

Source: Etheridge *et al* (1996), pp 4115 - 4128[14]

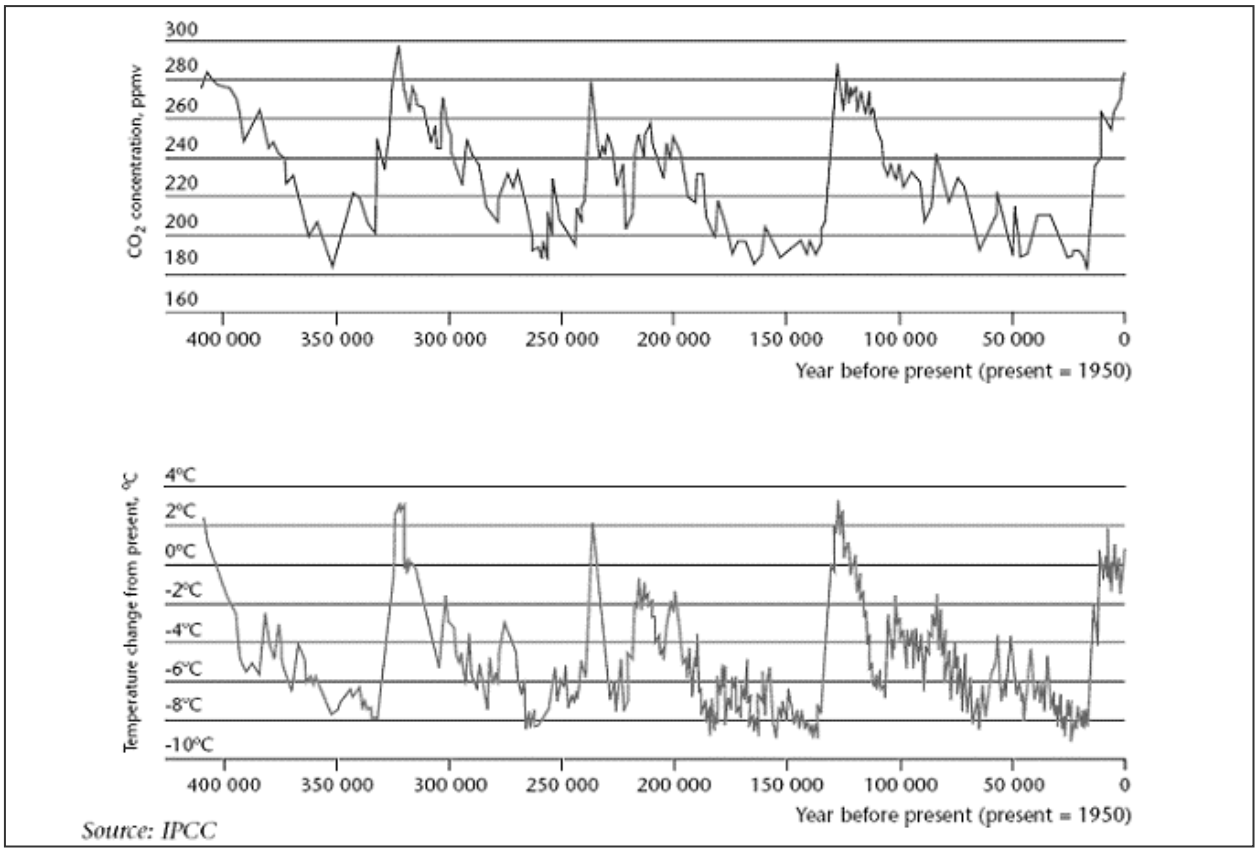

Figure 2. Plot of Carbon Dioxide (CO_2) Concentrations (parts per million by volume) and Temperature from 400,000 years ago to 1950

Source: Petit, J. *et al* (1999), pp 429 - 436[15]

[14] Etheridge, D.M. *et al* (1996) 'Natural and anthropogenic changes in atmospheric CO_2 over the last 1000 years from air in Antarctic ice and firn', *Journal of Geophysical Research*, vol 101, no D2, pp 4115-4128.

[15] Petit, J. (1999) 'Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica', *Nature*, vol 399, pp 429-436.

Table 1: Different types of greenhouse gases and their relative impact on global warming

Symbol	Name	Common Sources	Atmospheric Lifetime (years)*	Global Warming Potential	percent of USA Emissions
CO_2	Carbon Dioxide	Fossil fuel combustion, forest clearing, cement production, etc.	50-200	1	79.9
CH_4	Methane	Landfills, production and distribution of natural gas and petroleum, fermentation from the digestive system of livestock, rice cultivation, fossil fuel combustion, etc.	12	21X	9.5
N_2O	Nitrous Oxide	Fossil fuel combustion, fertilizers, nylon production, manure, etc.	150	310X	5.8
HFC's	Hydrofluorocarbons	Refrigeration gases, aluminium smelting, semiconductor manufacturing, etc.	264	Up to 11,700X	1.8
PFC's	Perfluorocarbons	Aluminium production, semiconductor industry, etc.	10,000	Up to 9200X	
SF_6	Sulphur Hexafluoride	Electrical transmission and distribution systems, circuit breakers, magnesium production, etc.	3,200	Up to 23,900X	
*Standard Industry Classification					

Source: Energy Information Administration (1998) & IPCC (2001)[16]

[16] Energy Information Administration (1998) Form EIA-846, 'Manufacturing Energy Consumption Survey', and Form EIA-810, 'Monthly Refinery Report' (1998); Intergovernmental Panel on Climate Change (2001) *Climate Change 2001: The Scientific Basis*, Cambridge University Press.

Let's now take a moment to consider the following points in relation to Figure 1 and Figure 2:

1. Research published in *Science* in 2005 indicates that for 650,000 years CO_2 levels have been at, or less than, 260 parts per million (ppm).[17] Further, data based on isotope ratios in marine micro fossils suggests strongly that the concentration of CO_2 has not, in fact, been much above 300 ppm for around 23 million years.
2. In 2006, carbon dioxide (CO_2) levels in the atmosphere were at 380 parts per million (ppm). Although this number is a very small fraction of the atmosphere, even a tiny amount of CO_2 (and indeed other greenhouse gases) has a powerful ability to trap heat in the atmosphere.
3. CO_2 pumped into the atmosphere will remain there for 80 to 100 years and so will influence temperature and contribute to the greenhouse effect long after its release. This means that even if new emissions of carbon dioxide are reduced, the overall concentration of CO_2 will continue to increase as the continuing emissions combine with background levels.

The International Panel on Climate Change (IPCC) concluded in their 2001 report that at whatever level global warming is stopped, it will require a 70 percent cut in global greenhouse gas emissions (i.e. CO_2e) to do so. According to Dr Pearman, former chief of the CSIRO's Atmospheric Physics Division and Australia's representative on the Intergovernmental Panel on Climate Change (IPCC), '*we don't have that much longer*'. These conclusions may seem extreme but they come from a detailed understanding of atmospheric science and the future global trends in development, material and energy flow.

Considering Climate Change Scenarios

Some students may have seen fictional dramas like the movie *The Day After Tomorrow* directed by Roland Emmerich.[18] Although climate change in these types of fictional movies is often highly dramatised for viewer entertainment, the possible consequences of planetary climate change are increasingly popular topics of discussion and the IPCC has developed a number of climate change scenarios to evaluate future impacts. These scenarios show that even if it is assumed that rapid changes in economic structure and technology are adopted, CO_2 concentrations will double by the end of the century, resulting in an increase in average global temperatures of around 2 degrees Celcius and a sea-level rise of 30 centimetres.

It is easy to think that these numbers are small and the impacts will be minor. However as Table 2 below shows, small increases in global temperature are expected to have major impacts across a range of ecological and social areas in Australia.[19]

[17] Siegenthaler, U. *et al* (2005) 'Stable Carbon Cycle–Climate Relationship During the Late Pleistocene', *Science*, 25 November, vol. 310. no. 5752, pp 1313-1317.
[18] The website for *The Day After Tomorrow* is at www.thedayaftertomorrowmovie.com which includes interesting interactive data on extreme weather events from around the world.
[19] Stern. Sir N. (2006) *Stern Review: The Economics of Climate Change,* Cambridge University Press, Cambridge, Chapter 13: Towards a Goal for a Climate, p 294. Available at http://www.hm-treasury.gov.uk/media/8A7/C6/Chapter_13_Towards_a_goal_for_climate.pdf. Accessed 3 January 2007.

Table 2.1: Summary of temperature impacts on Australia across Tourism, Water and Primary Industries, and Infrastructure and Insurance

Temp rise	Tourism	Water and Primary Industries	Infrastructure and Insurance
<1°C	- Snow-covered alpine areas shrink by 10 to 40% - Vertebrates in the World Heritage Wet Tropics lose half their habitat	- 14% of Victoria's marine invertebrates lose habitat - Droughts in NSW 70% more frequent and more widespread - Wheat production increases with temperature rises up to 3 to 4˚C, if precipitation also increases; but export value declines - Melbourne's water supply falls 3 to 11%	- 18% more days above 35°C in SA - Extreme rainfall 10 to 20% more intense in NSW - Electricity infrastructure suffers 3% decrease in transmission efficiency - Demand for natural gas heating in Melbourne falls - Peak electricity demand in Melbourne and Sydney falls by up to 1%, and rises in Adelaide and Brisbane by 2 to 5%
>1°C	- 81% of the Great Barrier Reef bleached - Vertebrates in the World Heritage Wet Tropics lose 90% of their core habitat.	- Melbourne's water supply falls 7 to 35% - Murray-Darling flows fall 12 to 25% - Queensland fruit fly spreads south - 40% loss of Eucalyptus core habitat	- Height of '100-year' storm surge at Cairns rises 22%, doubling the flooded area - Storm surge rises 25% along Victoria's east coast - Double the people exposed to flooding in Australia
>2°C	- 97% of the Great Barrier Reef bleached - 80% of Kakadu freshwater wetlands lost	- Pasture growth slows by 31% - Macquarie River Basin (NSW) flows fall by 5 to 35% - Livestock carrying capacity in native pasture systems falls by 40%	- Temperature-related deaths of people over 65 rises by 89 to 123% - Road maintenance costs in Australia rise by 17%, despite a decline in South Australia - '100-year' storm tides along Victoria's east coast 15% more frequent - Tropical cyclone rainfall increases 20 to 30%, as wind speed increases 5 to 10% - Forest fire danger rises 10% across Australia
>3°C	- Distribution of Great Barrier Reef species shrinks by 95% - 65% of Reef species lost in Cairns region - Snow-covered alpine area shrinks by 20 to 85% - '60 day' snow cover declines by 40 to 95%	- 55% loss of Eucalyptus core habitat - Timber yields in southern Australia rise by 25 to 50%, but fall by same margin in North Qld and the Top End - Australian net primary production falls by 6% - Flow in the Murray-Darling falls by 16 to 48%	- Dengue fever transmission zone reaches Brisbane and possibly Sydney - Temperature-related deaths of people over 65 rise by 144 to 200% - Oceania experiences a net loss of GDP
>4°C	- Most Australian vertebrates lose 90 to 100% of their core habitat	- Extreme rainfall in Victoria increases by 25%	- Peak electricity demand in Adelaide, Brisbane and Melbourne increases by 9-25% - 180 days a year above 35°C in SA and NT - '100-year' storm tides along Victoria's east coast 30% more frequent

Source: Preston, B.L. and Jones, R.N. (2006)[20]

[20] Preston, B.L. and Jones, R.N. (2006) *Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions*, CSIRO, Australia.

The 2006 Stern Review states, 'Carbon emissions have already pushed up global temperatures by half a degree Celsius. If no action is taken on emissions, there is more than a 75 percent chance of global temperatures rising between two and three degrees Celsius over the next 50 years. There is a 50 percent chance that average global temperatures could rise by five degrees Celsius.' The following Figure 3 from the Stern Review correlates to the levels of greenhouse gases in the atmosphere with the expected impacts across a range of factors such as food, water and ecosystems.

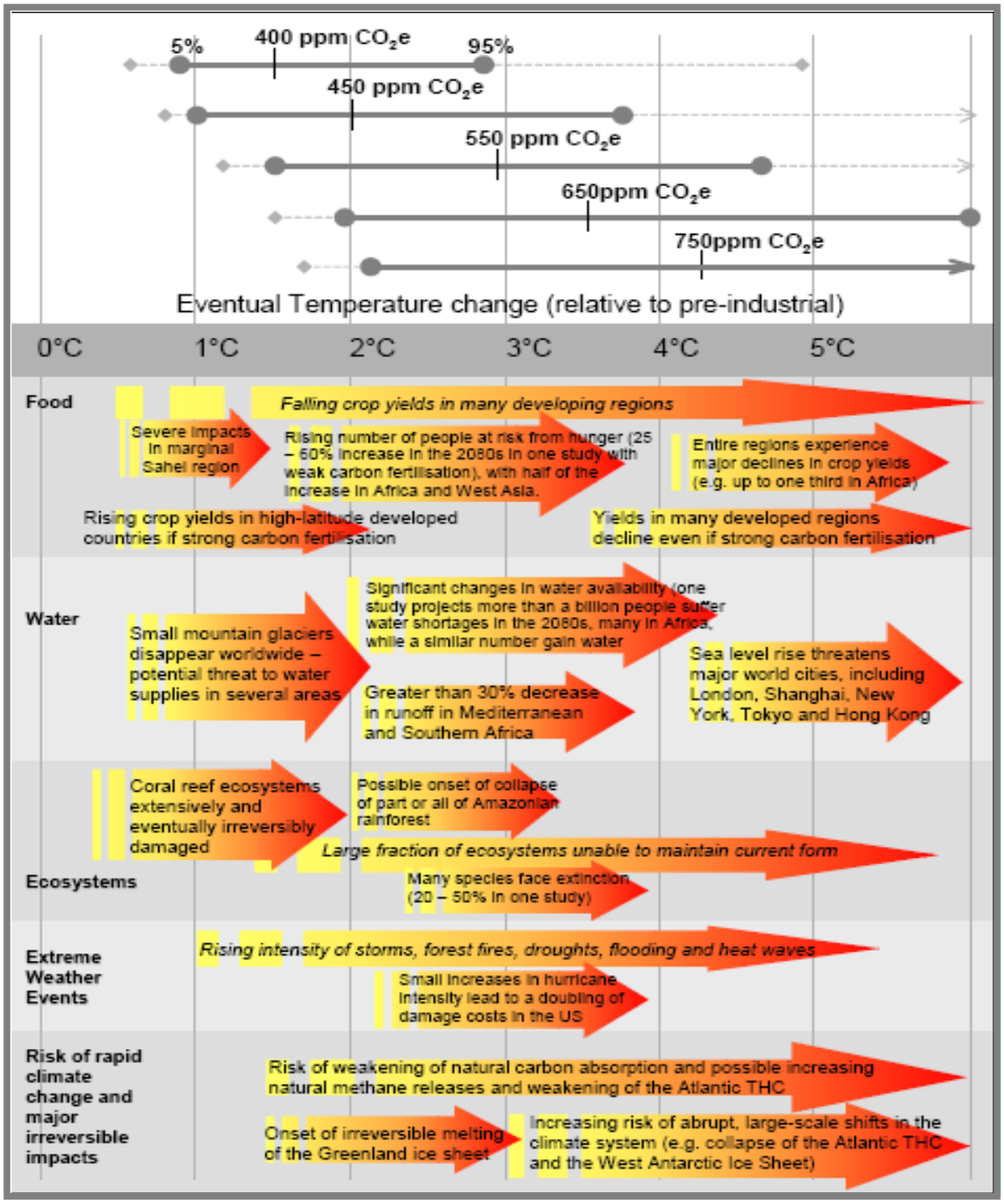

Figure 3. Stabilisation levels and probability ranges for temperature increases
Source: Stern, Sir N. (2006)[21]

[21] Stern. Sir N. (2006) *Stern Review: The Economics of Climate Change,* Cambridge University Press, Cambridge, Chapter 13: Towards a Goal for a Climate, p 294, Figure 13.4. Available at www.hm-treasury.gov.uk/media/8A7/C6/Chapter_13_Towards_a_goal_for_climate.pdf. Accessed 3 January 2007.

The Need for Both Climate Change 'Mitigation' and 'Adaptation'

It is clear that society will need to adapt to a new climate pattern as a result of a rapid increase in greenhouse emissions since the industrial revolution. Within the context of this challenge, there are two important considerations for moving forward:

1. We need to focus on *reducing emissions* of greenhouse gases and therefore stabilising the corresponding increases in global temperature (i.e. '*Climate Change Mitigation'*).
2. We need to focus on *preparing for a certain level of adaptation* by society and the environment to an altered climate regime, assuming appropriate stabilisation is achieved (i.e. '*Climate Change Adaptation*').

Climate change *adaptation* is often more politically popular to consider, it doesn't necessarily need to address why the change is happening (i.e. our behaviour). However, interest in finding climate change *mitigation* solutions as well as dealing with climate change adaptation is growing, as governments, companies and institutions in Australia and around the world realise the urgency of action to curb emissions.[22] Targets to reduce emissions in the order of 60 percent by 2050 provide many opportunities to innovate.

George Monbiot, in his 2006 book, *Heat: How to Stop the Planet from Boiling,*[23] argues that '*to avert catastrophic effects on both humans and ecosystems, we should seek to prevent global temperatures from rising by more than two degrees above pre-industrial levels, as two degrees is the point at which some of the most dangerous processes catalysed by climate change could become irreversible*'. Monbiot suggests that these impacts include the drying out of many parts of Africa, and the inundation of salt water into the aquifers used by cities such as Shanghai, Manila, Jakarta, Bangkok, Kolkata, Mumbai, Karachi, Lagos, Buenos Aires and Lima. Researchers at the Potsdam Institute for Climate Impact (Germany) have estimated that holding global temperature change to below two degrees means stabilising concentrations of greenhouse gases in the atmosphere at or below 440 ppm equivalent CO_2 ('CO_2e'). Therefore if the *Stern Review* estimate of 430ppm of CO_2e is accurate then greenhouse gas concentrations cannot increase much more than they are today if we are to avoid serious damage to the world's ecosystems.

But how likely is this to happen based on current trends? Monbiot points out that '*according to a paper published by scientists at the Met Office we currently produce around 7 billion tonnes per year of carbon dioxide*',[24] let alone the other five types of greenhouse gas. The Meteorological Office paper suggests that, *'the current total capacity of the biosphere to absorb this CO_2 is 4 billion tonnes a year'*.[25] Therefore we need to at least reduce our emissions from seven billion tons to four billion tons (i.e. by 43 percent) to stay within the current biosphere's capacity. One of the many complicating factors when considering climate science is that the capacity of the biosphere will reduce 'non-linearly' as the impacts of global warming affect the planet's ecosystems. The Met Office paper goes on to suggest that '*by 2030 the capacity of the biosphere will reduce to 2.7 billion tonnes'*. Therefore we need to reduce the current seven billion tons produced per year down to 2.7 billion tons a year (i.e. by 62 percent) by 2030.

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[22] Smith, M. and Hargroves, K. (2007) 'Action on climate change can help business competitiveness and economic growth', Submitted as a call for leadership from participants to the 8th National Business Leaders Forum on Sustainable Development, Brisbane, TNEP.
[23] Monbiot, G. (2006) *Heat: How to stop the planet burning*, Allen Lane, Penguin Press, New York.
[24] Ibid.
[25] United Kingdom Meteorological Office (2005) *International Symposium on the Stabilisation of Greenhouse Gases*, Hadley Centre, Met Office, Exeter, UK. Available at http://www.stabilisation2005.com/impacts/impacts_earth_system.pdf. Accessed 3 January 2007.

The *Stern Review* states that most climate models show a sobering reality: that we will actually increase rather than decrease levels and reach *approximately 560 ppm CO_2e* sometime between 2030 and 2060 - effectively a doubling of the pre-industrial levels. This is expected to result in a warming of at least 5°C.

> *On a global scale* [this] *would be far outside the experience of human civilisation … such impacts as the Greenland or West Antarctic Ice Sheets melting* [would commit] *the world to a sea level rise of between 5 and 12 metres*.
>
> ***Sir Nicholas Stern, 2006***[26]

As 2007 Nobel Laurette and former US Vice President Al Gore points out in *An Inconvenient Truth*, information such as climate change statistics and forecasts tends to have two effects on people, either denial or despair, both resulting in little or no action. The main risk is that people will shift quickly from denial to despair and miss the opportunity space in between. As Gore proposes, what will help is every person in a position to influence, doing all they can as fast as they can in the hope that what survives our development experiment is capable of maintaining life as we know it.

If we are to achieve our environmental goals, they must be pursued in a holistic context, blending advancements in social, environmental and economic areas. As former Australian Senator, Robert Hill, stated,

> *We need to develop decision-making processes which take into account not only the financial costs and benefits of our actions, but also the social and environmental consequences. Those processes will need to shift the focus away from short-term economic gain toward long term economic, social and environmental impacts: the triple bottom line.*
>
> ***Robert Hill, former Australian Senator, 2000***[27]

Society therefore needs to pursue its environmental, social and economic goals simultaneously. In order to achieve sustainable development across such a triple bottom line spectrum we have to ask, in relation to each domain (environmental, social and economic), *what do we want to sustain/maintain and why?* Society is interested not only in maintaining environmental, social and economic values (i.e. sustaining things or attributes that it values), but also in improving on past conditions (i.e. achieving genuine progress).

As Phillip Sutton, Director of *Green Innovations*, writes,[28]

> *The term 'sustainability' alone is not about the integration of ecological, social and economic issues, nor is it about improving quality of life. It's about maintaining or sustaining something, literally the 'ability to sustain'. Many environmentalists mean 'ecological sustainability' when they say 'sustainability' and many business people mean 'economic sustainability'. But when we use the term 'sustainability' the inferred meaning is 'ecological, social and economic sustainable development' (a combination of the three plus the dynamic aspect of improvement encapsulated in the word 'development'). What we need to bear in mind, is that over the long term, financial and economic outcomes are not sustainable unless genuine progress is made to develop*

[26] Stern. Sir N. (2006) *Stern Review: The Economics of Climate Change*, Cambridge University Press, Cambridge.
[27] Hill, R. (2000) 'An address to The International Society of Ecological Economists by the Federal Minister for the Environment and Heritage', Australian National University, Canberra, July 6, 2000. Available at www.ea.gov.au/minister/env/2000/sp6jul00.html. Accessed 3 January 2007.
[28] Green Innovations (2000) *Sustainability: What does it mean?,* Green Innovations. Available at www.green-innovations.asn.au/sustblty.htm#what-is. Accessed 7 June 2006.

and restore nature and social capital. And that it is not possible to achieve a desired level of ecological, social or economic sustainability (separately) without achieving at least a basic level of all three aspects of life and society, simultaneously.

Addressing Global Warming: Climate Change Mitigation[29]

Hunter Lovins, President of a US non-profit organisation called *Natural Capitalism Solutions*, dedicates her life to demonstrating that a wide array of opportunities exists to reduce emissions of greenhouse gases (greenhouse gas) and save energy in ways that reduce cost and confer substantial competitive advantage to companies that embrace them. However, she has found that too few corporate executives are aware of such opportunities, let alone how to capture them. Working with The Natural Edge Project on strategies to reduce greenhouse gas emissions for the Chicago and European Climate Exchanges, Hunter Lovins has concluded that the struggle to understand the science of complex carbon cycles has afforded business leaders and politicians the luxury of waiting. Now, for better or for worse, that time has passed.

In the report to the two climate exchanges in March of 2005 Hunter Lovins and The Natural Edge Project highlighted the following points:

1. Science has revealed deeper trouble and shorter timelines for solving global warming problems than had previously been thought. In January, 2005, Dr. Rajendra Pachauri, the chairman of the Intergovernmental Panel on Climate Change (IPCC), told an international conference in Mauritius attended by 114 governments that global warming had already hit the danger point, and that international attempts designed to avoid it had failed. Pachauri stated that he personally believes the world has '*already reached the level of dangerous concentrations of carbon dioxide in the atmosphere*,' and called for immediate and *'very deep'* cuts in emissions.
2. Pachauri cited a multi-year study by 300 scientists which showed that the Arctic was warming twice as fast as the rest of the world, and that its ice cap has shrunk by up to 20 percent in the past three decades. Remaining ice is 40 percent thinner than it was in the 1970s and is expected to disappear altogether by 2070. The levels of carbon dioxide have leapt abruptly over the past two years, suggesting that climate change may be accelerating out of control. Pachauri stated that because of inertia built into the Earth's natural systems, the world is now only experiencing the result of pollution emitted in the 1960s, and much greater effects will occur as the increased pollution of later decades work their way through. Carbon released into the atmosphere today will still be insulating the earth for decades. Pachauri concluded: '*we are risking the ability of the human race to survive.*'
3. To adopt an aggressive climate strategy is equally important for business, as competent greenhouse gas management is becoming a proxy for competent corporate governance. Leaders already capturing the sustainability advantage often start because they realise that acting now is actually a 'no regrets' strategy - if climate change turns out to be real, they will already be in a leadership position in dealing responsibly with it, but even if the scientists are wrong and there is no threat to the climate, these are actions they want to take anyway, because doing so is profitable. In a world that overwhelmingly recognises climate change as a serious threat, behaviour that ignores it is becoming seen as irresponsible.

[29] The background information for this part is an edited extract from Hargroves, K., Smith, M. and Lovins, H. (2005) *Prospering in a Carbon Constrained World: Profitable Opportunities for Greenhouse Gas Emissions Reduction*, Chicago Climate Exchange and European Climate Exchange Member Report. Available at http://www.naturaledgeproject.net/Documents/ProsperinginaCarbonConstrainedWorld.pdf. Accessed 2 December 2007.

Far from being a burden, recent studies in the United Kingdom and Australia show that deep cuts in carbon emissions are achievable and affordable. Organisations in the US have also undertaken studies on how to reduce greenhouse emissions significantly over the next 30-50 years,[30] while in the UK the Blair Government has released a detailed plan for how a 60 percent reduction in emissions might be achieved. There are now over 13 major studies showing how nations could achieve deep cuts in greenhouse emissions cost-effectively and even profitably.[31]

In a landmark speech, Tony Blair remarked that,

> [The Scientists have] *said that by using known technologies, or those very close to market, the world could reduce emissions by over 60 percent. This would not involve huge shifts in the economy, or enormous changes in lifestyles. It would allow developing countries to increase emissions, in the medium term, on a conventional development path. And it could be achieved gradually, over a period of years by 2050. There is huge potential from wind, wave and other renewable technologies. Improving the efficiency with which we operate our energy processes also offers enormous savings - up to half our energy use could be saved by the use of known efficiency techniques*.
>
> ***Tony Blair, PM Great Britain, 2003***[32]

Even a cautious study by the UK's Department of Trade and Industry concluded that the economic costs of reducing emissions in the UK would be small; costing approximately six months of GDP between now and 2050.[33] And these calculations made no effort to tabulate the benefits of climate action. The study found that, if phased in over 50 years, the economic impacts do not impose significant costs on the economy but rather, it can create more energy-efficient businesses, less congested traffic in cities, and new export opportunities for firms and nations that lead the charge. European nations such as the UK, Sweden, France, Denmark, and The Netherlands have already made significant reduction commitments of approximately 60 percent by 2050.

Sweden, for example, has called for a European-wide target of 60 percent by 2050. France has also taken a very aggressive position regarding its longer-term commitment, promising to reduce emissions by 75 percent by 2050. Denmark, meanwhile, has renewed its commitment to a 21 percent reductions target by 2010, with wind already generating 20 percent of its electricity needs.

Globally, numerous companies and communities are achieving their greenhouse gas reduction targets ahead of schedule, and are achieving higher than expected returns on investment. In the UK, a range of companies, many from the heaviest industrial sectors, have committed to 12 percent reductions by 2010. The UK Government signed 10-year Climate Certification Agreements (CCA) in 2000 with 44 industry sectors, representing more than 5,000 companies.

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[30] Interlaboratory Working Group (1997) *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond,* Oak Ridge, TN and Berkeley, Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory; Mintzer I., Leonard, J.A. and Schwartz, P. (2003) *US Energy Scenarios for the 21st Century*, Pew Center on Global Climate Change.

[31] References to reports that show that deep cuts in greenhouse emissions are possible: Turton, H., Ma, J., Saddler, H. and Hamilton, C. (2002) *Long-Term Greenhouse Gas Scenarios*, Discussion Paper No. 48, The Australia Institute, Canberra; Department of Trade and Industry (2003) *Our Energy Future – Creating a Low Carbon Economy*, Energy White Paper, UK Department of Trade and Industry, version 11. Available at www.dti.gov.uk/energy/whitepaper. Accessed 3 January 2007; Denniss, R., Diesendorf, M. and Saddler, H. (2004) *A Clean Energy Future for Australia*, a report by the Clean Energy Group of Australia.

[32] Tony Blair (2003) Speech on Sustainable Development. Available at http://www.number-10.gov.uk/output/Page3073.asp. Accessed 1 February 2007.

[33] Department of Trade and Industry (2003) *Our Energy Future – Creating a Low Carbon Economy*, Energy White Paper, UK Department of Trade and Industry, version 11.

They include the UK's most energy-intensive industries: steel, aluminium, cement, chemicals, paper, and food and beverages. Of 12,000 individual sites covered by CCAs, 88 percent met their targets and have had their certification agreements renewed.

So, far from being a burden, strategically addressing greenhouse gases can lead to dramatic improvements for business performance, facilities management, and brand enhancement. In effect, a strategy to identify opportunities to reduce emissions can lead to discovering opportunities to achieve many more benefits throughout the organisation.

Background Reader 1.3: The Role of Design in Meeting the Challenge of Climate Change

Sustainable design is the practice of designing physical objects and the built environment in alignment with sustainability principles. Students may have also previously heard and/or used the terms 'eco-design', 'green design', and 'design for environment'. The aim of sustainable design is to create built environment solutions that contribute positively to an environmentally, economically, socially, and culturally sustainable future. In practical terms, sustainable design is essentially about using nature as a model for how we design our environments, systems, and human products. Through sustainable design we may reduce or eliminate negative environmental and social impacts using assessment and innovative design to substitute less harmful products and processes for conventional ones.

Sustainable designs aim to 'fit' within the natural environment. As an example, a design team using a sustainable design philosophy might design a building that acts like a tree. The building might be designed to draw its energy from the sun (i.e. solar power) and behave differently over the different seasons of the year. The building might be a repository for water, it might create a pleasant microclimate, and might be able to absorb and treat 'waste' silently and safely. Like a tree the building might also fit within its environment by being culturally appropriate, providing amenities needed by the community, and it might also be constructed of locally available and sustainable materials.

According to the American Society of Interior Designers (ASID), sustainable design is the fastest growing segment of the interior design industry.[34] As the field grows, there is increasing awareness of the need for such designers to work collaboratively due to the high level of innovation that is required. This includes working with colleagues within the same discipline, and also working with professionals in other disciplines to achieve sustainable design solutions in each and every project.

Sustainable design principles and methodologies have been communicated through popular publications such as Schumacher's 1973 book entitled *Small is Beautiful,*[35],Janine Benyus' 1998 publication *Biomimicry,*[36] McDonough and Braungart's 2002 book, *Cradle to Cradle,*[37] and Ken Yeang's 2006 book, *Eco-Design.*[38] *Small is Beautiful* looks at the benefits of *Whole System Design* to achieve significant outcomes. *Biomimicry* is a design methodology developed by Janine Benyus, focusing on 'design inspired by nature'. *Cradle to Cradle* is about ensuring that nutrients are continuously cycled as valuable resources, rather than being used and then disposed (also referred to as 'waste equals food'). *Eco-Design* looks at opportunities for greening the built environment.

The practice of sustainable design has also been advanced by prominent design firms such as the global architectural firm HOK, who created the *HOK Guidebook to Sustainable Design.*[39] This book showcases a number of design methods, checklists and examples for practitioners in the workplace.

[34] See American Society of Interior Designers (ASID) – *Sustainable Design* at http://www.asid.org/knowledge/Sustainable+Design.htm. Accessed 2 December 2007.
[35] Schumacher, E.F. (1973) *Small is Beautiful: Economics as if People Mattered*, Harper & Row, New York.
[36] Benyus, J. (1997) *Biomimicry: Innovations Inspired by Nature*, William Morrow, New York.
[37] McDonough, W. and Braungart, M. (2002) *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press, New York, Chapter 4: Waste Equals Food.
[38] Yeang, K. (1995) *Designing With Nature: The Ecological Basis for Architectural Design*, McGraw-Hill, New York.
[39] Mendler, F. and Odell, W. (2000) *The HOK Guidebook to Sustainable Design*, John Wiley & Sons, Inc Indianapolis.

There are a number of key sustainable design principles/strategies available to the design profession to address issues around sustainable development. Four key sustainable design strategies are grouped under a business model called 'Natural Capitalism',[40] which is about rewarding energy and material efficiency:

1) *Radical Resource Productivity:* doing much more with much less
2) *Biomimicry:* innovation inspired by Nature
3) *Service and Flow:* providing services rather than selling goods
4) *Reinvest in Natural and Human Capital:* ensuring that the design promotes reinvestment in natural (i.e. environment) and human (social) capital

In concluding, we provide a cautionary note to the opportunities presented, in relation to the importance of learning the language of sustainable design. We need to be careful with regard to what we call 'sustainable' practices, versus practices that are progressively improving their position along the 'sustainability journey'. Many solutions claiming to be 'sustainable' may not be fully sustainable but rather transitioning *towards* sustainability with the goal of becoming sustainable in the future.

[40] Hawken, P., Lovins, A.B. and Lovins, L.H. (1999) *Natural Capitalism: Creating the Next Industrial Revolution,* Earthscan, London.

Background Reader 1.4: Looking at the Waves of Innovation

The following information provides a brief overview of the related background material, adapted from 'The Natural Advantage of Nations', Chapter 1: A Critical Mass of Enabling Technologies, Chapter 6: What will be the major driver of innovation in the 21st century?, and Chapter 13: National Systems of Innovation.[41]

Nations and firms are increasingly becoming aware of how they need to be ahead of the next so-called 'wave' of innovation in order to increase prosperity and maintain economic growth. Recent developments and studies in economics now place innovation and better technical design at the heart of sustained economic growth over long periods. Many people, from business leaders to policy makers, to politicians, to academics, are now asking, '*what will give rise to the sustainable areas of innovation?*' In the past, major breakthroughs in innovation have occurred when there have been enough effective technologies complementing each other, and providing more efficient ways to meet people's needs. In order for a wave of innovation to occur there needs to be a significant range forming a critical mass of relatively new and emerging technologies and a recognised genuine need in the market that will lead to a market expansion.

As discussed in *Natural Capitalism,*[42] the first industrial revolution began with the steam engine and the new machines made to increase the labour productivity of cotton spinning and the production of steel. This was followed by further industrial shifts with the engineering that evolved out of advances in the understanding of, for instance, electro-magnetism.

A focus on mass production of the automobile and the electrification of cities ensued, a wave that lasted until the 1940s. The rise of semiconductors and electronics provided just some of the 'enabling technologies' that helped create new business opportunities throughout the 1950s and 1960s. In the case of the Information and Communications Technology (ICT) wave of innovation, it is easy to identify the technologies that were driving the growth of capacity in the industry. Innovations in computer processing power, network bandwidth and data storage have all helped achieve the predictions of Gordon Moore in the 1970s, that *'computing power will continue to double every 18 months, while costs hold constant'*. This last wave of industrial activity was largely based on semiconductors, fibre optics, networks and software.

Many of the applications in the ICT wave of innovation were based on the idea of reducing transaction costs.[43] In the book, *Unleashing the Killer App*, Downes and Mui[44] suggest that the market for the many internet applications was in the reduction of transaction costs. For instance, e-mail is a cheap and fast means of communication, finding information in general is now much faster and cheaper online with internet booking, purchasing and banking, significantly reducing the costs of customer transactions.

The ICT revolution is just one in a series of long waves of industrial innovation first noted in the 1940s by Joseph Schumpeter, an Austrian-born economist. In his work, Schumpeter tracked the rise and flow of economies with respect to technology. There is now a critical mass of enabling eco-innovations making integrated approaches to sustainable development economically viable. If the last wave of innovation, ICT, was driven by market needs such as reducing transaction costs, many believe there is significant evidence that the next waves of innovation will be driven by the need to simultaneously improve resource productivity while lightening our environmental

[41] Hargroves, K. and Smith, M. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London, Chap 2, pp 16-22, 83-84, 244-271.
[42] Hawken, P., Lovins, A.B. and Lovins, L.H. (1999) *Natural Capitalism: creating the next industrial revolution*, Earthscan, London.
[43] Transaction costs are the costs of undertaking transactions between purchaser and seller, supplier and distributor.
[44] Downes, L. and Mui, C. (1998) *Unleashing the Killer App*, Harvard Business School Press, Boston.

load on the planet. Figure 4 below summarises these 'waves of innovation' into a 'Waves of Innovation Model', as described in *The Natural Advantage of Nations*.

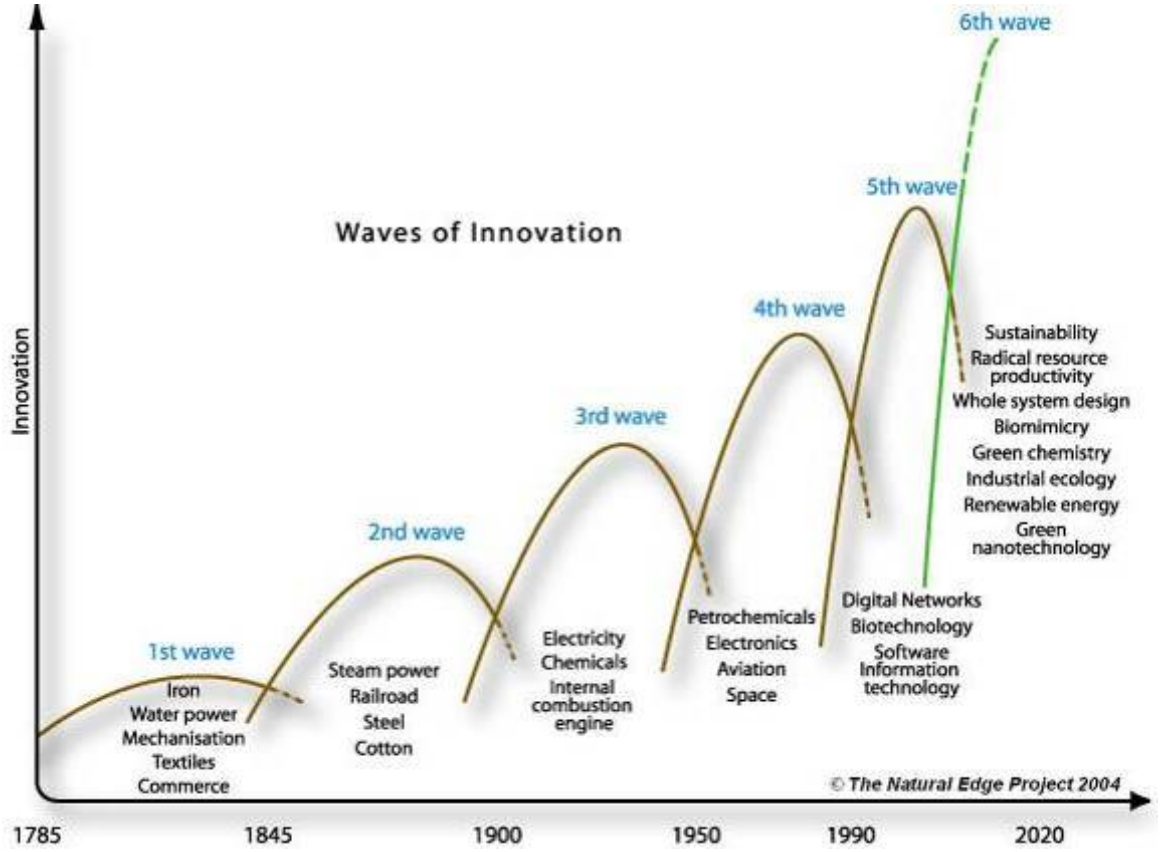

Figure 4. Waves of Innovation Model

Source: Hargroves, K. and Smith, M. (2005), p 17[45]

Emerging Enabling Technologies

Five examples of emerging enabling technologies include:

1. *Optoelectronics*: Significant moves are being made to design the optoelectronic computer, which is designed to run on particles of light (photons) as opposed to the traditional electronics. About the size of a Frisbee, the optoelectronic computer concept is extremely fast (comparable to today's fastest supercomputers), generates much less waste heat, and is more compact than the current electronic version.[46]
2. *Fuel Cell Technology*: KDDI, in cooperation with Hitachi and Toshiba, are developing fuel cell batteries for mobile phones. They have identified the increasing need for energy supply longevity, as people use their phones more often, in addition to providing a more sustainable solution.[47]
3. *Materials Science*: Two engineers from University College London have devised a method of customising the properties of a material to dramatically improve its efficiency and usage –

[45] Hargroves, K. and Smith, M.H. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London.
[46] Crosby, K. (2000) 'Introducing the Computer of 2010', *Forbes.com e-article,* 21 August 2000. Available at www.forbes.com/asap/00/0821/087.htm. Accessed 2 August 2007.
[47] Fuel Cell Works (2004) 'KDDI Corp plans to build fuel cells in cooperation with Hitachi & Toshiba', *FuelCellWorks.com e-article* 11 July 2004. Available at www.fuelcellsworks.com/Supppage896.html. Accessed 2 August 2007.

making, for example, aircraft wings that are dense and strong close to the fuselage while making the tip of the wing light and flexible. This method uses the culmination of existing technologies including finite element analysis, genetic algorithms and rapid prototyping technologies.[48]

4. *Nanotechnology*: Scientists at the Institute of Bioengineering and Nanotechnology in Singapore have developed a method to make a contact lens that allows drugs to be successfully delivered through the eye. Making small nano-channels in the contact lens for storing drugs, medication can be delivered far more efficiently and in steady controlled doses (as opposed to eye drops, in which 95 percent of the solution is washed away by tears).[49]
5. *Biomimicry*: Design based on nature. Japan's bullet train, or Shinkansen, is one of the fastest forms of public transportation in the world. It transports commuters at 300 km/h and is surprisingly quiet, thanks to lessons learned from studying the physiology of the Owl and the King Fisher. Engineers managed to reduce the noise and aerodynamic drag created by the current collectors from the overhead wires by inscribing 'serrations' based on the design of the owl's feathers.

The examples that will be featured throughout this material provide evidence and add weight to what many have already sensed; namely, that the problems are serious but there are exciting efforts and solutions being developed around the world through various industry sectors.[50] Not only do we now have solutions to many problems, but we are also gaining insight as to which solutions are the most cost-effective and profitable. If we can work together to address sustainable development, we can position ourselves to be at the forefront of the next waves of innovation.

[48] Author unknown (2005) 'Material benefits', *Economist.com e-article*, 10 March 2005. Available at www.economist.com/displaystory.cfm?story_id=3714003. Accessed 9 August 2007.
[49] Author unknown (2005) 'Better than a poke in the eye', *Economist.com e-article,* 10 March 2005. Available at www.economist.com/displaystory.cfm?story_id=3713983. Accessed 9 August 2007.
[50] United Nations Environment Program (2002) *Industry as a partner for sustainable development - 10 years after Rio: the UNEP assessment*, UNEP, United Kingdom. This UNEP report documents sector-specific progress in implementing Agenda 21, building on the 22 industry-driven sector reports of the 'Industry as a partner for sustainable development' series.