A Clean Energy Future for Australia

A Study by
Energy Strategies for the
Clean Energy Future Group

Consisting of:

Australasian Energy Performance Contracting Association

Australian Business Council for Sustainable Energy

Australian Gas Association

Australian Wind Energy Association

Bioenergy Australia

Renewable Energy Generators of Australia

WWF Australia

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Clean Energy Future Group

AEPCA is the **Australasian Energy Performance Contracting Association**. Its members are formed from energy service companies, state government departments and private companies interested in the performance contracting process. Energy performance contracting is a smart, affordable and increasingly common way to make building improvements that save energy and money. Its mission is to act as the Peak Body to support the commercial growth of members and their market through education, industry promotion, self-regulation and industry standards. www.aepca.asn.au

The **Australian Business Council for Sustainable Energy (BCSE)** represents the interests of the broader sustainable energy industry including, renewables energy, cogeneration, gas-fired generation, waste-to-energy and energy efficiency industry. It has more than 250 organisations as members. It formed in September 2002 through the merger of the Australian EcoGeneration Association and the Sustainable Energy Industry Association. www.bcse.org.au

The Australian Wind Energy Association (AusWEA)'s vision is for a robust Australian Wind Community that makes a significant contribution to safe, reliable, economically and environmentally sustainable energy supply in Australia. AusWEA's mission is to represent the Australian Wind Energy Community and promote the sensitive and appropriate uptake of wind energy. www.auswea.com.au

Bioenergy Australia was established in 1997 as a government-industry forum to foster and facilitate the development of biomass for energy, liquid fuels, and other value added bio-based products. Bioenergy Australia is concerned with all aspects of biomass and bioenergy, from production through to utilisation, and its work embraces technical, commercial, economic, societal, environmental, policy and market issues. This report does not necessarily reflect the views of all individual Bioenergy Australia members. www.bioenergyaustralia.org

The **Renewable Energy Generators of Australia (REGA)** was formed in 1999 as an industry association with a common purpose of supporting the development of generation of electricity from truly renewable resources. REGA represents all sectors of the renewable energy industry; members represent 95% of the existing renewable energy generation capacity, and include equipment suppliers, developers and industry specialists. www.rega.com.au

WWF Australia is part of the WWF International Network - the world's largest independent conservation organisation. With the help of more than 50,000 supporters across Australia, we're helping to protect and conserve our most biologically outstanding land, freshwater and marine habitats and reduce the causes and impacts of climate change. www.wwf.org.au

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Copies of this study can be down loaded from each Clean Energy Future Group's web sites

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GLOSSARY

Absorption chiller	A chiller (*q.v.*) which is operated by heat rather than by mechanical energy as in the more common type of chiller using vapour compression refrigeration. It uses the cyclic separation (by heating) and absorption of a pair of fluids (termed refrigerant and absorbent) having a strong affinity for each other. Heat is absorbed, i.e. "coolth" is produced in the process of absorption.
Anaerobic digestion	A fermentation process for producing gas from biomass in a wet, oxygen-free environment.
Backcast	To develop a scenario by choosing a future state of society or a technology and then working out how to get from the present state to that future state.
Back pressure turbine	A turbine (usually a steam turbine) in which the steam exits the turbine chamber at significant positive pressure and thus with significant remaining energy available to be used in another process.
Bagasse	The fibrous residue of sugar milling that is used as a fuel to raise steam in the mills.
Base-load	Power stations that are designed to run 24 hours per day, 7 days per week. They usually have high capital cost and low running cost.
Biogas	Gas produced from biomass: e.g. from animal manure and garbage tips, by anaerobic digestion (*q.v.*).
Biomass	Material produced by photosynthesis or an organic by-product from a waste stream. It includes a wide variety of renewable organic materials, including forestry and agricultural wastes and residues, urban tree trimmings, food processing wastes, woody weeds, oil bearing plants, animal manures and sewage, energy crops and the organic fraction of municipal solid waste.
Boiler	A reactor where a fuel is burnt to heat water in order to produce steam or hot water.
Bottoming cycle	A type of cogeneration system in which hot exhaust gases from a kiln or similar high temperature process are used to produce steam which is then passed through a turbine to generate electricity. The steam exits from the turbine at close to atmospheric pressure and cannot be used to provide further useful energy.
Bottom up model (of greenhouse response)	A computer model of all or part of the energy sector that is based directly on data on the cost and performance of specific energy technologies and services.
Brown coal	Sometimes called lignite. The type of coal used to generate electricity in Victoria and South Australia. It has a very high water content and low carbon content and so has among the highest greenhouse intensities of all fossil fuels.
Capacity (of power station)	Rated or peak power, measured in megawatts or similar units.
Capacity credit	The effective capacity of an 'intermittent' or 'unreliable' power station to meet demand, divided by the capacity of a hypothetically totally reliable power station, often expressed as a percentage. All real power stations are unreliable to some degree and so have capacity credit less than 100%.
Capacity factor	The annual energy generated by a power plant divided by the energy that it would have generated if it had operated continuously at its rated or peak power, often expressed as a percentage.
Chiller	A device for producing "coolth" (as opposed to heat), which can be used to lower the internal temperature of a building.
Coal-bed methane	Methane gas that occurs naturally in black coal seams.
Cofiring	Burning two or more fuels together (e.g. coal and biomass) in the boiler of a power station.
Cogeneration	The production of electricity and useful heat together from the same power plant. Sometimes called 'combined heat and power'.
Combined cycle	A power station that generates electricity by means of one process (e.g. gas turbine) and then uses the waste heat from that process to generate more electricity from another process (e.g. waste heat boiler plus steam turbine). Combined cycle power stations have higher thermal efficiencies (*q.v.*) than ordinary 'single cycle' power stations.

Coppice	To cut off the above-ground branches of a tree so that they re-grow rapidly.
Dematerialisation	The process whereby advanced economies become relatively less dependent on the production of material commodities and their conversion into physical goods, and more dependent on the production and consumption of services, with the result that the consumption of raw materials per unit of GDP decreases.
Discount rate	An interest rate used to discount (i.e. reduce the value of) income or expenditure in the future (see Net Present Value) due in part to preference for consumption now rather than later. It is often expressed in 'real' terms, i.e. adjusted to exclude the effects of inflation..
Dispatchable power station	A power station that produces power upon demand. Usually refers to either a thermal or a hydro-electric power station based on a dam. Could also be used for an 'intermittent' power plant, such as solar or wind, which has dedicated storage. Concept is an idealisation, since 'dispatchable' power stations may fail to operate unexpectedly at some time or other
Distribution line	Power line for the local distribution of electricity. In Australia, it usually has voltage below 66 kV.
End-use energy	Final energy consumption (*q.v.*).
Energy intensity (of an economy)	Annual national energy consumption divided by GDP.
Energy service	A service that is provided by a combination of energy supply and a pattern of energy use: e.g. a warm home in winter; clean clothes; access to a school.
Fermentation	One of several methods for converting biomass into a gas or liquid, involving the use of micro-organisms (yeast or bacteria) which change the chemical composition of the biomass by means of enzymatic (biological) reactions that occur in a moist environment with little or no oxygen present.
Final energy consumption	Energy consumed in the 'final' or end-use sector. It equals primary energy consumption less energy consumed or lost in the conversion, transmission and distribution processes.
First Law of Thermodynamics	The conservation of energy, which states that energy cannot be created or destroyed, but only converted from one form to another.
Forecast	To develop a scenario by projecting from the present into the future, based on past trends. (Becomes increasingly unreliable as the future time increases.)
Fossil fuel	A primary fuel (*q.v.*) consisting of the fossilised organic material derived from plants and animals which lived in the remote geological past; the main fossil fuels are coal, petroleum and natural gas.
Fuel cell	An electrochemical system that converts hydrogen and oxygen into water, producing electricity and heat in the process, thereby providing a high efficiency means for converting the energy in a fuel(hydrogen) directly to electricity.
Fugitive emissions	Greenhouse gas emissions not resulting from the combustion of fossil fuels, but rather from mining, transmission, distribution and storage of fuels.
Gas turbine	An engine that burns a liquid or gaseous fuel to produce an expanding gas that drives a turbine. The turbine can be used to drive a generator (as in a power station), a piece of major mechanical equipment such as a pump or compressor (as in large industrial plants, gas pipelines etc.), or a propeller (as in aircraft engines).
GDP	Gross Domestic Product, a measure of economic activity, formally defined to be the total monetary value of 'final' goods and services produced in a country in a year. 'Final' excludes 'intermediate' goods and services which are used as inputs into the production of other goods and services.
Geosequestration	The capture of CO_2 gas from a large point source, such as a power station, and its storage deep underground.
Greenhouse (gas) intensity (of power station)	Megatonnes of CO_2 produced divided by electricity sent out in TWh, which is equivalent to kg of CO2 produced divided by electricity sent out in kWh.
Grid	Network of electricity powerlines.
Gross Calorific Value (GCV)	The quantity of heat energy released when a fuel is burned completely with oxygen, and the products of combustion are returned to ambient temperature and pressure. It is normally measured per unit mass or unit volume of a fuel.

	Sometimes termed Higher Heating Value (HHV). GCV is generally used in Australia and the USA, while Net Calorific Value (*q.v.*) is more often used in other countries.
Higher Heating Value (HHV)	See Gross Calorific Value.
Insolation	Solar energy input as sunshine.
Integrated gasification combined cycle (IGCC)	Combined cycle power station (*q.v.*) that gasifies solid fuel before burning it.
Intermediate load	A power station whose operation is between that of base-load and peak-load. Output can be varied more rapidly than base-load but more slowly than peak-load. Capital/fuel cost lower/higher than base-load but higher/lower than peak-load. Generally operates for several hours per day during medium to high demand periods.
Inverter	An electronic device that converts direct current (DC) electricity into alternating current (AC) with a specified frequency.
Least-cost planning	A method of planning the future development of an energy supply system that identifies the lowest cost means of meeting the final demand for energy services by assessing both supply-side options (new power stations, power lines etc.) and demand side options (increased energy use efficiency) on an equal basis.
Levelised cost / annuity	An amount of money which, if paid annually over the life of an asset, such as a power station, will fully repay the capital cost plus interest over the life. The term is sometimes used to include also the annual operating costs (fuel, operation and maintenance etc.), and thereby express the full cost of producing electricity from the power station.
Liquefied natural gas (LNG)	Natural gas which is kept in the liquid state at very low temperatures to facilitate storage and transport.
Loss-of-load probability	The average number of hours per year that electricity supply fails to meet demand.
Lower Heating Value (LHV)	See Net Calorific Value.
Mallee	A type of eucalypt which has multiple stems sprouting from a long-lived underground stem, termed a lignotuber (mallee root). Mallees have the ability to re-shoot repeatedly from the lignotuber and so are ideally suited to coppicing (*q.v.*).
Microturbine	A very small gas turbine that can be used to generate both useful heat and electricity at the point of use in commercial and (possibly in the near future) in residential buildings
MRET	Mandatory Renewable Energy Target
NEM	National Electricity Market
NEMMCO	National Electricity Market Management Company
Net Calorific Value (NCV)	This is equal to GCV (*q.v.*) minus the latent energy contained in the water vapour (in the exhaust gas) which is produced when hydrogen (from the fuel) is burned. Sometimes termed Lower Heating Value (LHV). Therefore, the difference between GCV and NCV increases as the hydrogen content of the fuel increases. As a result, the thermal efficiency of a coal-fired power station based on NHV is typically 2-3% higher than its thermal efficiency based on GCV; in the case burning natural gas, the NHV thermal efficiency may be 10-15% higher than the GCV thermal efficiency.
Net Present Value (NPV)	The value today of a future stream of revenue (income) and expenses, calculated by discounting future costs and revenues at a chosen discount rate and summing the discounted quantities. The effect of discounting is to make revenue and expenses in the more remote future relatively less important than those in the immediate future.
Off-grid	Not connected to the electricity network.
Peak-load	Power stations that are designed to run for only short periods to meet the peaks in demand. If they are thermal power stations (*q.v.*) (gas turbines), they have low capital cost and high running cost..
Peak watt	The rated or nameplate power capacity of an energy source, often applied to

	PV modules.
Photovoltaic (PV) cell and module	An electronic device that converts solar energy directly into electricity without any moving parts (apart from the electrons).
Primary energy	The chemical energy stored in a primary fuel (qv).
Primary fuel	Fuel that is extracted directly from the natural environment, such as coal, natural gas, crude oil, uranium, wood, bagasse, wind, solar energy.
Pyrolysis	One of several thermochemical methods for converting biomass or coal into a gas or liquid, involving heating the biomass or coal within a closed chamber in the almost complete absence of oxygen.
Reciprocating engine	An engine whose central elements are a cylinder and piston which moves up and down inside the cylinder, as in a standard car engine.
Remote area power supply	Power plant not connected to a large electricity grid. (However, it may be connected to a small local grid.)
Reformer (in chemistry)	A chemical method of converting alcohols and hydrocarbons into hydrogen, usually for use in a fuel cell.
Scenario	An evolutionary pathway between the present and a future state of society or technology.
Second Law of Thermodynamics	When energy is transformed from one form to another, it tends to flow from a higher grade or more ordered form -- such as mechanical, electrical energy, chemical or high-temperature heat -- to a lower-grade or more disordered form, ultimately low-temperature heat. So energy becomes degraded and less useful to humans. It is possible to reverse this natural flow, pushing low-grade energy 'uphill', but only by expending more high-grade energy at the input than is received at the output.
Secondary fuels	Fuels produced from primary (or other secondary) fuels by conversion processes to produce the fuels commonly consumed: e.g. thermal electricity, coke and refined petroleum products.
Sensitivity analysis	Repetition of a calculation a number of times to investigate the effect of changing an assumption or the data used.
STP	Standard temperature and pressure, comprising 0˚C and 1 atmosphere (101.3 kPa)..
Steam turbine	A turbine driven by steam that is produced by burning fuel to boil water.
Supercritical	New kind of boiler used in coal-fired power stations which operates under higher steam pressures and temperatures and so gains higher thermal efficiency. Two new power stations in Queensland are using supercritical boilers.
Thermal efficiency (of power station)	Electrical energy sent out divided by energy input, sometimes expressed as a percentage. In the case of thermal power stations, the energy input is the chemical energy stored in the fuel. There are two ways of calculating the latter, called Higher Heating Value (HHV), which is used in this report and generally in Australia, and Lower Heating Value (LHV), which is sometimes used overseas.
Topping cycle	A type of cogeneration system in which steam direct from the boiler, at high temperature and pressure, is passed through a steam turbine to generate electricity, from which it exits at a lower temperature and pressure to be used for thermal processes.
Transmission line	An electricity power line designed to carry a large quantity of electricity over a long distance. In Australia, a transmission line generally operates at a voltage of at least 132 kV, and most major lines operate at 330 or 500 kV.
Turbine	A motor whose central elements are a series of blades attached to a shaft, which rotates, usually within a chamber. Steam turbines, gas turbines, hydro turbines and wind turbines are used extensively in modern energy systems.
Wind farm	An array of wind turbines located in proximity to one another and generally using the same substation (transformer) and power line to connect to an electricity grid.

Units and Conversion Factors

Powers of 10

Prefix	Symbol	Value	Example
kilo	k	10^3	kilowatt kW
mega	M	10^6	megawatt MW
giga	G	10^9	gigajoule GJ
tera	T	10^{12}	terawatt-hour TWh
peta	P	10^{15}	petajoule PJ

SI units

Basic unit	Name	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
temperature	Kelvin	K

Derived unit	Name	Symbol
energy	joule	J
power	watt	W
potential difference	volt	V
pressure	pascal	Pa
temperature	degree Celsius	˚C
time	hour	h

Conversion factors

Type	Name	Symbol	Value
energy	kilowatt-hour	kWh	3.6×10^6 J = 3.6 MJ
energy	terawatt-hour	TWh	3.6×10^{15} J = 3.6 PJ
energy	litre of petrol	L	3.2×10^7 J
energy	m^3 of natural gas at STP		3.4×10^7 J
energy	tonne of NSW black coal	t	23 GJ
energy	tonne of Vic. brown coal	t	10 GJ
energy	tonne of green wood	t	10 GJ
energy	tonne of oven-dried wood	t	20 GJ
power	kWh per year	kWh/y	0.114 W
time	year	y	8760 h
pressure	atmosphere		101.325 kPa

1. Introduction

1.1. Why this study has been done

> *"Energy is vital to a modern economy. We need energy to heat and light our homes, to help us travel and to power our businesses. Our economy has also benefited hugely from our country's resources of fossil fuels – coal, oil and gas.*
>
> *"However, our energy system faces new challenges. Energy can no longer be thought of as a short-term domestic issue. Climate change – largely caused by burning fossil fuels – threatens major consequences in the UK and worldwide, most seriously for the poorest countries who are least able to cope … We need urgent global action to tackle climate change. We are showing leadership be putting the UK on a path to a 60% reduction in its carbon dioxide emissions by 2050…*
>
> *"Our analysis suggests that, by working with others, the costs of action will be acceptable and the costs of inaction are potentially much greater. And as we move to a new, low carbon economy, there are major opportunities for our businesses to become world leaders in the technologies we will need for the future…"*
>
> Tony Blair, Foreword to UK White Paper on Energy (DTI, 2003)

> *"The world is in the early stages of an inevitable transition to a sustainable energy system that will be largely dependent on renewable resources."*
>
> International Energy Agency (1999)

What this study does

This study explores the potential for deep cuts in emissions of the principal greenhouse gas, carbon dioxide (CO_2), in Australia. It focuses on stationary energy, that is energy that is used in the form of electricity, heat that is not produced from electricity, and mechanical energy. The study does not examine transport, which must be left for a separate study.

The principal goal of the present study is to investigate whether it is possible to achieve a 50% reduction in CO_2 emissions from stationary energy by 2040, by using a mix of existing technologies, with small improvements, in order to produce and use energy more efficiently and more cleanly. So, in our principal scenarios there are no dramatic breakthroughs in technologies: no cheap electricity from solar photovoltaic cells; no cheap capture and sequestration underground of CO_2 emitted by coal-fired power stations; and no cheap methods of producing hydrogen as a means of storing and transporting renewable energy. In practice, however, there will be innovation between now and 2040. In Chapter 11 we offer a glimpse of how, with innovation, we might achieve 80% or more reductions in CO_2 emissions beyond 2050 – but these are not the principal scenarios of this study. If we can reach our 2040 target with small improvements to existing technologies, then reductions beyond 2050 will be even easier with innovation.

Our method is to take existing technologies and develop a workable and credible stationary energy supply system for 2040 that meets our target and then to identify the key strategies that will allow us to get from the present to that 2040 state. In moving from the present to the future we take account of the main driving forces for increasing energy consumption: economic growth and population growth.

Our study is inspired by several earlier energy and greenhouse scenario studies performed overseas (RCEP, 2000; Interlaboratory Work Group, 1997, 2000; Marsh *et al*., 2003) and a pilot study published by the Australia Institute (Turton *et al*., 2002). These and other scenario studies are reviewed briefly in Chapter 13. However, the present study is different from earlier studies because of its focus on existing technologies and because it presents new scenarios on future energy use and greenhouse gas emissions in Australia.

The principal motivation for this study is similar to that expressed in the above quotation from the British Prime Minister: the need to bring human-induced climate change under control. By describing and analysing a feasible long-term future in which energy demand and supply mix are radically different from today's, decision-makers, professionals, environmentalists and the community at large can form a picture of how Australia and the world could have a much cleaner and more efficient energy system while still being prosperous. The present study is a contribution to this longer-term thinking about Australia's response to climate change.

Climate change[1]

The world's most authoritative body on climate change, the Intergovernmental Panel on Climate Change (IPCC), has warned that the nations of the world will need to shift to a low-carbon future in order to avoid dangerous changes to the global climate.

The IPCC has developed a number of climate change scenarios to evaluate future impacts. Even the most optimistic scenario, involving rapid change in economic structure and technology, shows CO_2 concentrations doubling by the end of the century, resulting in an increase in average global temperatures of around 2° C and a sea-level rise of 30 cm.[2] The IPCC notes that the climate system is subject to great inertia so that '[s]tabilization of CO_2 concentrations at any level requires eventual reduction of global CO_2 net emissions to a small fraction of the current emission level' (IPCC, 2001a, p. 16). There are advantages in beginning the task of reducing emissions sooner rather than later: 'The greater the reductions in emissions and the earlier they are introduced, the smaller and slower the projected warming and the rise in sea levels' (IPCC, 2001, p. 19).

Doubling of atmospheric concentrations of CO_2 is expected to be associated with global warming in the range 1.4-2.6°C by the end of the century (IPCC 2001a, Figure 22, p. 209). The United Nations Framework Convention of Climate Change

[1] This subsection reproduces several paragraphs from Turton *et al*. (2002) with permission from the Australia Institute.
[2] Scenario B1 in IPCC (2001), pp. 10-11.

(UNFCCC) commits nations (including Australia) to taking measures to prevent 'dangerous' levels of climate change. It is widely accepted that concentrations in excess of 550 ppm, or double the pre-industrial levels, would be dangerous, and that even a doubling is likely to be associated with major negative impacts (see IPCCa, 2001). According to the IPCC, stabilising concentrations at double pre-industrial levels will require deep cuts in annual global emissions, eventually by 60 per cent or more (see IPCCa, 2001, Figure 25).[3]

The need for deep cuts has been formally acknowledged by the Australian Government. The Foreign Minister, Alexander Downer, has stated:

> *"If we are going to achieve stability in global temperatures in the years ahead then CO_2 emissions will have to be reduced by between one half and two thirds".*[4]

Given the wide variation between nations in levels of emissions per capita and income per capita, it would be infeasible and unfair to require all nations to cut their emissions by 60 per cent of current levels. Developing countries might expect to reduce their emissions by less than this amount and wealthy countries with high per capita emissions, such as Australia, should expect to cut their emissions by more than 60 % in the longer term[5] , possibly by 80%.Table 1.1 shows Australia's greenhouse gas emissions in 1990, 1995 and 2001, as reported in the most recent National Greenhouse Gas Inventory (Australian Greenhouse Office, 2003). Emissions are expressed in units of carbon dioxide equivalent (CO_2-e). It can be seen that stationary energy combustion, the main focus of this study, contributed 259.5 Mt, or 47.8% of Australia's total emissions. Moreover, emissions from stationary combustion grew faster and by more than any other sector over the eleven year period. Australia's total net emissions remained effectively constant over the period, mainly because of a large reduction in emissions from Land Use Change and Forestry, which fell by 82 Mt CO_2-e. But growth in total emissions over the period more than offset the decline in Land Use Change and Forestry emissions. By 2001 emissions from Land Use Change had fallen to 37 Mt, partly offset by removals of 23 Mt from managed forestry. Hence, further reductions in emissions from Land Use Change, if achieved, could continue to offset growth in energy related emissions for a few more years. However, unless there is a decisive change in policy, within a few years growth in energy sector emission will start to drive Australia's greenhouse emissions inexorably upward.

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[3] IPCC 2001a, Figure 25(c) shows that to achieve stabilisation of atmospheric CO_2 concentrations at 550 ppm it is necessary to reduce emissions by 40-60 per cent by the end of the century and 65-85 per cent by 2150. Further reductions will be required beyond 2150.

[4] ABC Radio News, 28 June 2002.
http://www.abc.net.au/news/politics/2002/06/item20020627170339_1.htm

[5] This was reaffirmed in the decision adopted by the UNFCCC in Bonn in 2001 '[t]hat the Parties included in Annex I [industrialised countries] shall implement domestic action…with a view to reducing emissions in a manner conducive to narrowing per capita differences between developed and developing country Parties while working towards achievement of the ultimate objective of the Convention' (Decision 5/CP.6).

Table 1.1: Changes in Australia's greenhouse net gas emissions, 1990 to 2001

Sector	Net Emissions (Mt CO2-e)			Increase 1990 to 2001	
	1990	1995	2001	Mt CO2-e	Percent
Stationary energy	195.5	214.0	259.5	64.0	32.7%
Transport	62.0	69.0	77.2	15.2	24.5%
Fugitive energy	28.8	30.4	32.2	3.4	11.8%
Total energy	286.2	313.4	369.0	82.8	28.9%
Land use change and forestry	93.1	42.9	11.4	-81.7	-87.8%
All other sectors	136.5	131.1	147.7	11.3	8.2%
TOTAL NET EMISSIONS	515.8	487.4	528.1	12.3	2.4%

In order to set Australia on the necessary path towards a long-term 80% reduction in total CO_2 emissions, including those from land clearing, we choose in this study a substantial but achievable target for emissions from stationary energy: a 50% reduction compared with 2001.

Lessons for Australia from global responses

In 2000, the UK Royal Commission on Environmental Pollution brought down a report examining the feasibility of achieving a 60 per cent reduction in Britain's emissions by 2050 (RCEP, 2000). The report observed:

Human use of energy has grown enormously, based overwhelmingly on burning fossil fuels. This is causing a significant change in the composition of the atmosphere which, unless halted, is likely to have very serious consequences. ….

> *In addition to previously recognised risks from obtaining and using energy, the world is now faced with a radical challenge of a totally new kind, which requires an urgent response. The longer the response is deferred, the more painful the consequences will be.* (RCEP 2000, pp. 13, 16)

The Blair Government has responded with detailed study and discussion of how such a reduction might be achieved (DTI, 2003; Marsh *et al.*, 2003). Noting that the UK 'is likely to face increasingly demanding carbon reduction targets', the UK Government concludes:

> *Credible scenarios for 2050 can deliver a 60% cut in CO_2 emissions, but large changes would be needed both in the energy system and in society. …Given the strong chance that future, legally binding, international targets will become more stringent beyond 2012, a precautionary approach suggests that the UK should be setting about creating a range of future options by which low carbon futures could be delivered, as, and when, the time comes.* (Cabinet Office, 2002, p. 9)

To implement a process for achieving its substantial target for the reduction of CO_2 emissions, namely a 60% reduction by 2050; the UK Government has set a renewable energy obligation of 10.4% of electricity supply by 2010 from eligible technologies that exclude large hydro-electric plants commissioned before April 2002, and have recently extended the obligation to 15.4% by 2015-16. It is providing considerable financial support[6] for industry development; research, development and demonstration (where the latter is focused on offshore wind, energy crops and photovoltaics), and the development of scenarios where in some cases coal use is phased out within 20 years.

In 2002 Denmark obtained 18% of its electricity from wind power and a significant fraction of electricity and district heating from crop residues. Denmark plans to reduce its greenhouse gas emissions by 50% by around 2030.

The European Union has committed to introduce emissions trading by 1 January 2005. The scheme will work on a “cap and trade” basis with an emissions target allocated to each country. Coverage will initially be limited to combustion plants in excess of 20 MW capacities. It is estimated that 14,000 industrial as well as power generation facilities will fall under the scheme and be allocated emissions allowances. Each country is to establish its own target and develop a National Allocation Plan that needs to be submitted to the European Commission before the end of March 2004.

In the United States, although the Federal Government has not set a target, there is considerable action at State level (WWF USA, 2003).

- Five States have imposed mandatory limits on CO_2 emissions including three policies directed specifically at electricity sector emissions: In June 2003, Maine became the first US state to enact legislation requiring a statewide reduction in greenhouse gas emissions. In 2002 New Hampshire passed a law to regulate power plant emissions of CO_2 through a multiple pollution reduction program. The program requires a reduction of CO_2 emissions to 1990 levels by 2010 with a lower future cap to be recommended by 2004. In 2001 Massachusetts passed legislation requiring that six of its oldest, dirtiest power plants reduce their emissions of key air pollutants. The law requires the power plants to reduce their CO_2 emissions by 10% below a 1997 -1999 baseline by 2006.

- Thirteen States have passed legislation mandating that a specific portion of their electricity be generated by non-emitting renewable energy resources. These targets range from 2.2% by 2009 in Texas to 18% by 2012 in California.

In Asia there are some substantial actions.

- The Indian Government has strongly supported wind power, with the result that there is a thriving industry with 1700 MW installed by 2002.

- Although developing countries are not required to ratify the Kyoto Protocol, China has done so and has set in place programs to encourage the efficient use of energy and renewable energy. From 1996 to 1999, China reduced its CO_2 emissions[7], despite one of the highest rates of economic growth in the world (over 7% p.a.).

- Japan is subsidising the conversion of old coal-fired power stations to natural gas; and is funding new energy efficient industrial processes, photovoltaics and other

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[6] See www.dti.gov.uk.
[7] More recently, emissions have resumed an upward path.

renewable energy sources. It is also extending the application of its Law Concerning the Rational Use of Energy from large factories to large office buildings.

Compared with the responses of the other governments summarised here, the response by federal and state governments in Australia has not been strong. Funding for fossil fuels continues to be increased whilst research and development support for efficient energy use and renewable sources of energy has been substantially decreased. Specifically:

- Australia is one of only two countries that are signatories to the Kyoto Protocol, yet have said they will not ratify it. Nevertheless, the Government has stated that it intends to work to limit emissions to the level specified for Australia in the Kyoto Protocol[8].
- The only CRC devoted to renewable energy and efficient energy use has not had its funding renewed, yet there are three federally-funded Cooperative Research Centres devoted to fossil fuels.
- There are large subsidies to the production and use of fossil fuels (Riedy and Diesendorf, 2003; Riedy, 2003) and only small subsidies for renewables, most notably the temporary waiving of excise on ethanol and other bio-fuels produced from crop residues[9].
- The only industry and market development initiative for renewable energy is the Mandatory Renewable Energy Target (MRET). This has proven highly successful in driving investment but by 2010 it will have delivered less than a 1% increase is renewable energy use in Australia over 1997 levels. Compared with double figure targets in the EU and US states, this is insufficient to create internationally competitive renewable energy industries.

1.2. Structure of this report

Chapter 2 sets out the assumptions and method of this study. Chapter 3 reviews current energy demand and supply in Australia, drawing upon the latest published data (2000-01), and explains the basic concepts and terminology. Chapter 4 presents the economic model that is used to derive the energy demand in 2040. This generates the Baseline scenario which only has a weak implementation of efficient energy use. Its demand in 2040 is 57% above that of 2001. Then in Chapter 6 a medium-strength of efficient energy use is implemented, producing a new, lower level of energy demand for 2040, which we term the Medium Efficiency case. Even in this case, demand in 2040 is 25% higher than in 2001.

In Chapter 7 we turn to the supply side, considering the principal existing renewable energy technologies that could make contributions to our ‘clean’ energy scenarios. Chapter 8 summarises basic information on the fossil fuelled technologies. Chapter 9 brings this information to bear by specifying ways to increase the efficiency of energy supply and switch to fuels and technologies with lower greenhouse emissions.

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[8] An 8% increase compared with the 1990 level.

[9] The Government plans to commence phasing out the excise exemption from biofuels and LPG in 2008.

The supply and demand sides are integrated in Chapter 10, where a Baseline – Scenario 1 – is specified with CO_2 emissions 21% higher than in 2001 and contrasted with a Clean Energy – Scenario 2, in which CO_2 emissions are 50% lower than in 2001 and 59% lower than in Scenario 1. Two variants on Scenario 2, Scenarios 3 and 4, are also constructed. The low emission scenarios all have a very large reduction of emissions from electricity generation, and modest increases in emissions form all other stationary energy applications. One of the main problems in comparing the costs of various scenarios is the uncertainty in the prices of fossil fuels in 2040. So the costs of Scenario 2 are compared with those of four different fossil fuel scenarios, each with a large proportion of coal.

Chapter 11 removes the restriction limiting the analysis to small improvements to existing technologies. It finds that, starting from Scenario 2, there are several possible pathways for achieving 80-100% reductions in CO_2 emissions from stationary energy in the period beyond 2040. These pathways are all based on substantial improvement to existing technologies that are currently commercial but only in small markets.

Since the barriers to achieving Scenario 2 is not primarily technological, the proposed policies and strategies for facilitating the transition are set out in Chapter 12. These appear to be inexpensive and achievable, given appropriate policy settings. Finally, Chapter 13 reviews some earlier studies from Australia and overseas that investigated deep cuts in greenhouse gas emissions.