The Allen Consulting Group

Deep Cuts in Greenhouse Gas Emissions

Economic, Social and Environmental Impacts for Australia

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Report to the Business Roundtable on Climate Change

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Abbreviations

ABARE	Australian Bureau of Resource Economics
ACF	Australian Conservation Foundation
ACG	The Allen Consulting Group
AEEI	Autonomous Energy Efficiency Improvement
CCS	Carbon Capture and Storage
CGE	Computable General Equilibrium
CO_2	Carbon Dioxide
CO_2–e	Carbon Dioxide Equivalent
COAG	Council of Australian Governments
COPS	Centre of Policy Studies at Monash University
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GJ	Gigajoule
GSP	Gross State Product
GST	Goods and Services Tax
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LNG	Liquefied Natural Gas
MIT	Massachusetts Institute of Technology
MMRF	Monash Multi–Regional Forecasting
MRET	Mandatory Renewable Energy Target
Mt	Million tonnes
mtpa	Million tonnes per annum
MWh	Megawatt hour
NCP	National Competition Policy
NEMMCO	National Electricity Market Management Company
OECD	Organisation for Economic Cooperation and Development
PJ	Petajoules
ppmv	Parts per million by volume
PRT	Payroll Tax
R&D	Research and Development
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development

Executive summary and conclusions[1]

This report by the Allen Consulting Group was commissioned by the Business Roundtable on Climate Change. Its focus is on climate change and what might be done to prevent the conditions occurring that could bring about catastrophic shifts in the earth's climate in the future. Within that global context, the report examines the likely impact on the Australian economy and community of taking significant policy action to bring about deep cuts in greenhouse gas emissions by the middle of this century.

The third report of the United Nations' Intergovernmental Panel on Climate Change (IPCC) was published in 2001. After examining the extent of global warming to date, majority expert opinion contained in the report agreed that this rise in temperatures was caused mainly by human actions. The report went on to suggest that if average global temperatures increase further by more than 2° Celsius there would be a risk of 'catastrophic' climate change.

The science of climate change is still uncertain in some respects. The precise nature of the link between global warming and climate change is not yet fully understood. The extent of the rise in global temperatures required to bring about 'catastrophic' shifts is also relatively uncertain. Nevertheless, since the IPCC report was published four years ago further research has done nothing to invalidate the report's findings. Indeed, a number of more recent studies as well as observed phenomena, such as the increase in the incidence of extreme weather events and the retreat of the polar ice caps, suggest the situation is more urgent than was understood in 2001.

Overall, even on the basis of the precautionary principle alone, there is a clear case for taking action directed towards stabilising carbon concentrations in the earth's atmosphere. A number of pathways have been proposed for achieving stabilisation of carbon concentrations, with estimates of the required reductions in emissions ranging between 30 and 60 per cent from current levels by the middle of the century. A 'deep cuts' approach has been endorsed in principle by a number of countries.

The analysis contained in this report estimates the effects on the Australian economy of reducing greenhouse gas emissions by 60 per cent from year 2000 levels by 2050. To put this in context, Australia's GHG emissions from the stationary energy sector alone have already increased by nearly 40 per cent since 1990. Clearly, a 60 per cent reduction in emissions over a period when the Australian economy is otherwise projected to grow by around 130 per cent under business–as–usual assumptions represents a very substantial task. Major advances in technology will be required if we are to achieve this target while continuing to improve living standards.

While it is virtually impossible to forecast technological breakthroughs, the analysis in this report is based on feasible changes in existing technologies as estimated mainly by CSIRO, but we have also drawn on other sources. Under these assumptions, in 2050 electricity will be generated almost entirely by renewables

[1] This is an independent report to the Business Roundtable by the Allen Consulting Group. The views expressed in this report are those of the Allen Consulting Group and are not necessarily representative of those of the Roundtable as a whole or the individual companies.

plus fossil fuel with carbon capture and storage (CCS) technologies.[2] Transport will be based on hydrogen fuel cells and hybrid motors. Forestry will thrive, while households, government and industry will all use energy more efficiently. Our economy will change in many ways, with production of coal being significantly reduced but exports of uranium and LNG increasing substantially.

Two emission trajectories were specified as alternative pathways to meeting the 60 per cent target:

- In the 'early action' scenario, a straight–line trajectory of emissions reductions between 2013 and 2050 was determined.
- The 'delayed action' scenario incorporated an assumption that action would be delayed until 2022, after which emissions would be reduced more rapidly to reach the same overall emissions reduction by 2050 as under the 'early action' scenario. All other inputs were the same as in the 'early action' scenario.[3]

The results are presented relative to a base case, or business–as–usual, projection for the Australian economy. The base case does not incorporate any new measures to abate greenhouse gases beyond those that are already in place.

In reporting the economic impacts in summary form, we focus here just on Australia's GDP. Comprehensive results are provided in chapter 4 of the report. Over the entire forecast period to 2050, real GDP is projected to increase at an average annual rate of 2.2 per cent under the business–as–usual projection. In the 'early action' scenario, real GDP grows at 2.1 per cent a year to reach an estimated $2.0 trillion in 2050, or around 6 per cent less than in the base case. Under the business–as–usual projection, this value of GDP would be attained around 2.5 years earlier (in 2047), with GDP in 2050 equal to an estimated $2.1 trillion at 2002 prices.

In absolute terms this loss of national income to 2050 seems high. However, the cost burden will be shared with future generations that will also reap benefits in terms of reduced climate change. In relative terms, therefore, a reduction in the rate of economic growth from 2.2 to 2.1 per cent may be seen as a reasonable price to pay if, in consequence, climate change were to be arrested.

Under the 'delayed action' scenario, real GDP increases between 2002 and 2050 at an average annual rate of 1.9 per cent — this compares to an average annual growth rate of 2.2 per cent under the base case, and 2.1 per cent in the 'early action' scenario. In the 'delayed action' scenario, real GDP reaches an estimated $1.84 trillion in 2050, 13 per cent lower than under the business–as–usual projection. Under the base case, this value of GDP would be attained six years earlier in 2044, with GDP in 2050 reaching $2.11 trillion.

The first important conclusion is that the negative impact on Australia's economy of very substantial emissions reductions over half a century can be seen to be less than many observers might have expected. While the absolute loss of GDP foregone is significant, the costs appear more reasonable when evaluated in terms of the overall loss of economic growth over the period, with the average annual rate

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[2] Nuclear energy was excluded from the analysis on the advice of the client. Other technologies, such as geothermal, were excluded because of a lack of available cost data.

[3] We assume that the pace of energy efficiency improvements is influenced to some extent by action to address climate change. Autonomous energy efficiency improvement factors for electricity generation technologies were therefore delayed in the 'delayed action' scenario relative to the 'early action' scenario.

of growth reduced by only ten basis points from 2.2 to 2.1 per cent. This represents a significantly lower 'hit' on the economy, for example, than the effects of an ageing population over the same period.[4]

The second strong conclusion is that the economic costs of meeting a 'stretch' emissions target would be much greater if action were delayed. The GDP cost under the 'delayed action' scenario would be substantially greater than under the 'early action' scenario and would be concentrated over a much shorter period. The economic benefits from delayed action in the early part of the period would be more than outweighed by the substantially greater costs in the period from 2022 on. Under the 'delayed action' scenario, GDP in 2050 would be 13 per cent lower than under the business–as–usual projection, compared with six per cent lower under the 'early action' scenario. This represents a very substantial additional cost.

It should be noted that the results of this analysis are heavily dependent on a number of assumptions. The most important of these refer to the necessary assumption of global action, the rate of feasible technological progress and the possibility of increased energy conservation. Significant policy advances will be required if substantial progress is to be achieved in these areas.

4 See Table 3.1 in Chapter 3 of this report.

Chapter 1

Background to the project

This project was commissioned by the Business Roundtable on Climate Change.[5] The main objective was to examine the likely cost to the Australian community of participating in a global program to deliver deep cuts in emissions of greenhouse gases by the middle of this century. A secondary aim was to evaluate whether or not these costs would be reduced as a result of 'early action' to place our economy on a lower emissions trajectory.

Three groups participated in this project:

- the Allen Consulting Group contributed economic and policy advice and is responsible for producing this report;
- the Centre of Policy Studies (COPS) at Monash University was responsible for the economic modelling presented in this report; and
- the Commonwealth Scientific and Industrial Research Organisation (CSIRO) contributed projections of climate change.

This report is one of three pieces of work associated with the broader project, and presents the results of economic modelling of the impacts on Australia of participating in action to effect a significant reduction in global greenhouse gas emissions by 2050. Apart from the accompanying CSIRO study, a synthesis report — bringing together the scientific and economic evidence to present the broader argument for action — has been developed by the Business Roundtable.

1.1 Policy making under risk and uncertainty

As is discussed in the next chapter of this report, a consensus among the Inter–governmental Panel on Climate Change (IPCC) scientists emerged in their third report to suggest that if average global temperatures were to increase by more than 2° Celsius there would be a risk of catastrophic climate change. Notwithstanding the uncertainty that still exists around the precise links between CO_2 emissions and resulting increases in global temperature, one pathway to avoiding temperature increases of this magnitude could be to reduce future emissions along the lines discussed in this report, that is to aim for a reduction in industrialised countries' greenhouse output (60 percent below 2000 levels by 2050), and supporting abatement by developing countries (allowing for more modest levels of emission constraint in the lead up to 2050).

Despite the existence of a substantial expert consensus on the main propositions surrounding climate change, it would be idle to pretend that the science is yet precise or that there are not areas of significant uncertainty. Some of these are:

- the extent to which global warming is anthropogenic. While it is widely accepted that human actions have played a part in causing warming, and the climate models suggest that their role is significant, the division of

[5] Companies represented on the Roundtable, which is convened by the Australian Conservation Foundation (ACF), include BP, IAG, Origin Energy, Swiss Re, Visy and Westpac.

responsibility between human actions and natural phenomena is not absolutely clear;

- whether or not an increase in global temperatures above 2°Celsius would indeed be catastrophic. Some observers, for example, believe that adjustment to such a temperature increase would be feasible, while others consider that highly damaging changes would occur with a lesser increase in temperature;
- whether or not an increase in carbon concentrations to 550 ppmv is consistent with an increase in the average global temperature of around 2° Celsius. The third IPCC report could only provide a wide range of projected global temperature increases this century; and
- because of these uncertainties, whether cutting global greenhouse gas emissions so as to stabilise carbon concentrations by 2050 would be successful in arresting climate change.

While some observers cite these uncertainties as a reason for taking no action, such an argument is difficult to sustain. The overwhelming weight of expert opinion, expressed not just through the IPCC but also, in the context of the Gleneagles G8 summit in July 2005, by the academies of science of the leading nations of the world (including the US and China), suggests that, left unchecked, global warming could lead to catastrophic climate change. On the basis of the precautionary principle alone, policy makers need to design actions to counter such an outcome.

The desirability of adopting a long–term global emissions target is one issue that will be on the Table in any international discussion of future options to address climate change. To understand whether or not such a policy is desirable, it is critically important to estimate the costs and benefits involved in taking such action. Clearly the policy should be introduced if the costs of doing so are less than the costs of not taking action. While this sounds simple, in reality, of course, it is not. On the one hand, the costs of taking action are more readily calculated. While there are many uncertainties, including the speed of future technological advance and the price of greenhouse–friendly energy, we can estimate the cost of taking action within reasonable bounds. The House of Lords in Britain recently concluded that the global costs of controlling emissions so as to achieve a long run goal of atmospheric concentrations of 550 ppmv ranges, in present value terms, between US$2 trillion to US$17 trillion.[6] To put this in context, annual expenditures to meet a 550 ppmv target would be around 0.2 to 3.2 per cent of annual current income.

On the other hand, it is much more difficult to estimate the costs of *not* taking action. What would the costs be if the scientists are correct and catastrophic climate change occurred? Nobody really knows, but the human cost of flooding in low–lying areas such as Bangladesh and even, if the thermohaline circulation of the oceans breaks down, of a new ice age in certain regions of the world would be immense. This makes it difficult to argue that, on the basis of the precautionary principle alone, the world should not take action to avert excessive climate change in the future. Nevertheless, this argument would be considerably strengthened if the scientists could work with economists to produce credible estimates of the costs of *not* taking action.

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[6] UK House of Lords Select Committee on Economic Affairs 2005, *The economics of climate change*, Authority of the House of Lords.

1.2 Objectives of this report

This study represents the first attempt in Australia to contribute to one side of the cost–benefit analysis of the need for deep cuts in greenhouse gas emissions. While the analysis is important and highly complex, we should acknowledge that it represents only a first step. The analysis could usefully be further developed in a number of ways including, for example:

- The use of a global economic model that would provide much better projections of global demand and changes in commodity prices as a consequence of international action on climate change. Clearly the economic impact of deep cuts in emissions globally would have a profound impact on Australia's economy, both in a macro sense and in terms of changes in demand for our exports. The approach used here of imposing exogenously determined negative and positive growth factors to selected commodities clearly provides only an approximation of those impacts.
- The integration of an energy sector engineering model with the economic model would provide a better representation of the stationary energy sector. For example, this would allow us to specify that individual generators would work until the end of their economic lives when they would be replaced by the most cost–effective technologies projected to be available at that time. This may well reduce the costs of taking action.
- The inclusion of all fuel types, including solar thermal, nuclear power (excluded from this study on the advice of the client) and geothermal (excluded because of a lack of information on feasible sites). It is widely acknowledged that utilising a broad range of technologies will assist in reducing the cost of abatement. If both geothermal and nuclear energy were included, for example, available cost information suggests that electricity prices would increase by less than they do in the modelling presented in this report. The price of permits and the negative impact on the economy from meeting the target would then be commensurately lower.

Despite these reservations, and while its findings should be regarded as being indicative to some degree, this study offers some important insights into the costs of taking significant action in Australia.

This report is set out as follows:

- *Chapter 2* — develops the case for adopting a target of reducing emissions by 60 per cent relative to their 2000 levels by 2050;
- *Chapter 3* — outlines the assumptions underlying the economic modelling of the impacts of achieving a long–term abatement target in Australia;
- *Chapter 4* — presents the modelling results; and
- *Chapter 5* — contains the conclusions of the study and draws out some implications of the analysis.

Chapter 2

Setting a long–term emissions target

2.1 Introduction

The potential for changes in the composition of the earth's atmosphere — in particular with respect to the so–called 'greenhouse gases' (GHGs) that strongly absorb infrared radiation — has been known for more than a century. It was not until observations commenced in the 1950s, however, that scientists demonstrated that the concentration of carbon dioxide (CO_2), a key greenhouse gas, was increasing. This led to growing research activities aimed at understanding both the cause of that increase, and its potential to impact on the earth's climate. In 1985, the global research community prepared a statement that was intended to announce to the wider population that this research, although still quite incomplete, was sufficiently compelling to warrant that the issue of climate change should be considered as a critical issue to the global community.[7]

The scientific understanding of the climate system has advanced substantially since that statement was made, particularly within the last decade. Simultaneously, the level of concern over the issue of climate change has intensified. Periodic assessments of climate change and its impact on human and natural ecosystems published by the Intergovernmental Panel on Climate Change (IPCC) in 1990, 1996 and 2001 all highlight the potential for the increase of greenhouse gases in the atmosphere to shift the climate of the world.[8] The latest IPCC report, the Third Assessment Report, made the following underlying points:

- the planet has warmed;
- the composition of the atmosphere is continuing to change;
- models of the climate system have greatly improved;
- much of the observed warming of the last century was due to greenhouse gases;
- greenhouse gases will continue to rise through the 21st century; and
- climate change will continue through the 21st century.

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7 Villach 1986, *The Role of Carbon Dioxide and Other Greenhouse Gases in Climate Variation and Associated Impacts,* Conference Statement for the Second UNEP/WMO/ICSU Assessment Meeting, Villach, WMO Bull: Austria 35, pp. 130–134.

8 See: IPCC (J. Houghton, Y. Ding, D. Griggs, M. Noguer, P. van der Linden, and D. Xiaosu (eds)) 2001a, *Climate Change 2001: The Scientific Basis,* Contribution of the Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, World Meteorological Organisation and United Nations Environment Programme, Intergovernmental Panel on Climate Change, Cambridge University Press: Cambridge, p 944; IPCC (J. McCarthy, O. Canziani, N. Leary, D. Dokken and K. White (eds)) 2001b, *Climate Change 2001: Impacts, Adaptation and Vulnerability,* Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, World Meteorological Organisation and United Nations Environment Programme, Cambridge University Press: Cambridge, p 1032; IPCC (B. Metz, O. Davidson, R. Swart and J. Pan (eds)) 2001c, *Climate Change 2001: Mitigation,* Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, World Meteorological Organisation and United Nations Environment Programme, Cambridge University Press: Cambridge, p. 700; IPCC 2001d, *Climate Change 2001: The Scientific Basis. Summary for Policymakers,* A report of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, World Meteorological Organisation, Geneva: United Nations Environment Programme, IPPC: Nairobi, p. 98; and IPCC 2002e, *Climate Change 2001. Synthesis Report,* Contributions of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, World Meteorological Organisation and United Nations Environment Programme, Cambridge University Press: Cambridge, p. 397.

In this chapter, taking into account this scientific evidence and risk, we posit an appropriate long–term target for global emission reductions for the purposes of this study.

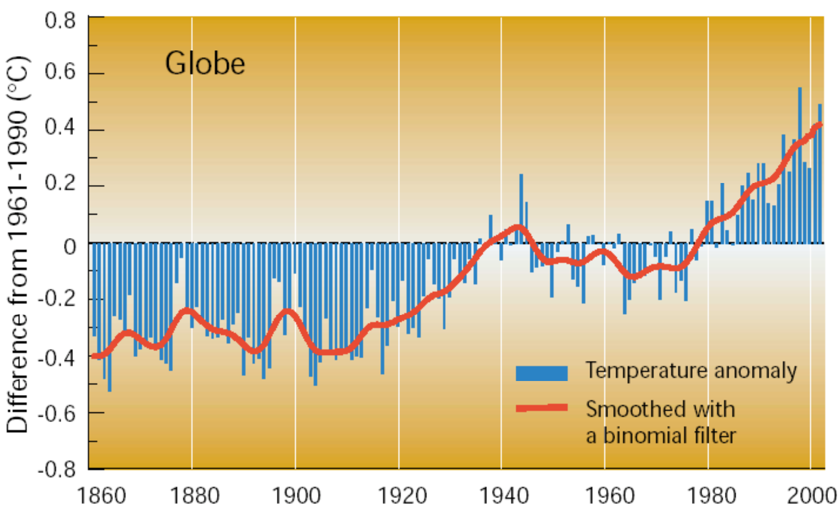
2.2 The evidence on climate change

The earth has warmed

Recent developments in scientific measurement techniques allow changes in the climate to be accurately charted through time. The accumulation of this body of evidence over the last three decades now allows scientists to state with certainty that the earth has entered into a period of significant warming, and that this is largely correlated with increasing concentrations of CO_2. The Third Assessment Report of the IPCC suggests that 'an increasing body of observations give a collective picture of a warming world and other changes to the climate system'. These observations show, for example, that the lowest 8 km of the atmosphere has become warmer while the extent of snow and ice has decreased. The ocean heat content has increased, leading to a rise in sea level and a reduction in the speed of circulation of the ocean currents.

Figure 2.1

GLOBAL TEMPERATURES, 1860 – 2000



Source: Hadley Centre for Climate Prediction and Research.

The data contained in Figure 2.1 show clearly the extent of warming over the last century — the average global surface temperature has increased by about 0.6°C over this time. Associated with this general warming, scientists have observed:

- an increase in global extreme maximum temperatures;
- an increase in global extreme minimum temperatures;
- a decrease in the number of extreme low temperature days; and

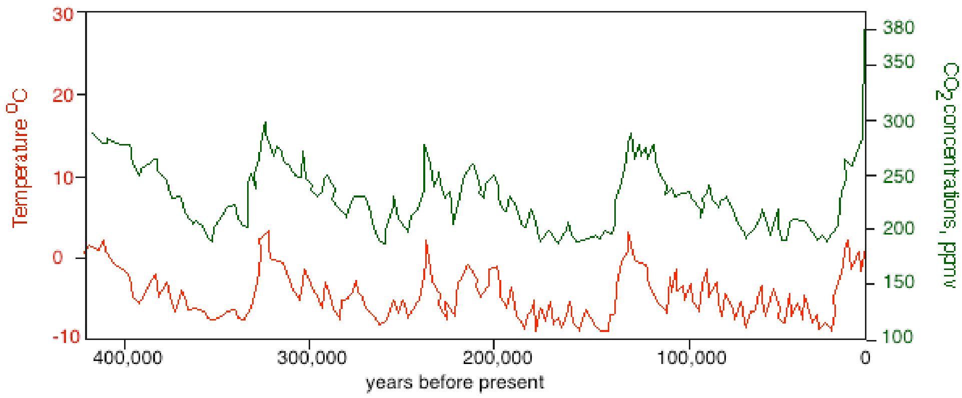
- an increase in extreme precipitation.[9]

Human activity has caused the increase in temperature

The evidence from scientific research suggests that there has always been a clear correlation between the level of CO_2 concentrations in the atmosphere and the earth's temperature. This is shown in Figure 2.2 where data from the last 420,000 years, mainly derived from polar region ice core analysis, show a regular cycle of increases in CO_2 concentrations and average temperatures. How then can we be sure that we are not in another similar natural cycle and perhaps even approaching a turning point where the two trend lines will turn downwards again? This has always been a key point put forward by those who are sceptical about the existence of an anthropogenic greenhouse effect.

Figure 2.2

GLOBAL CO_2 CONCENTRATIONS AND TEMPERATURE: THE LAST 420,000 YEARS



Source: Petit, J.R. et al, *Nature* 399, 1999.

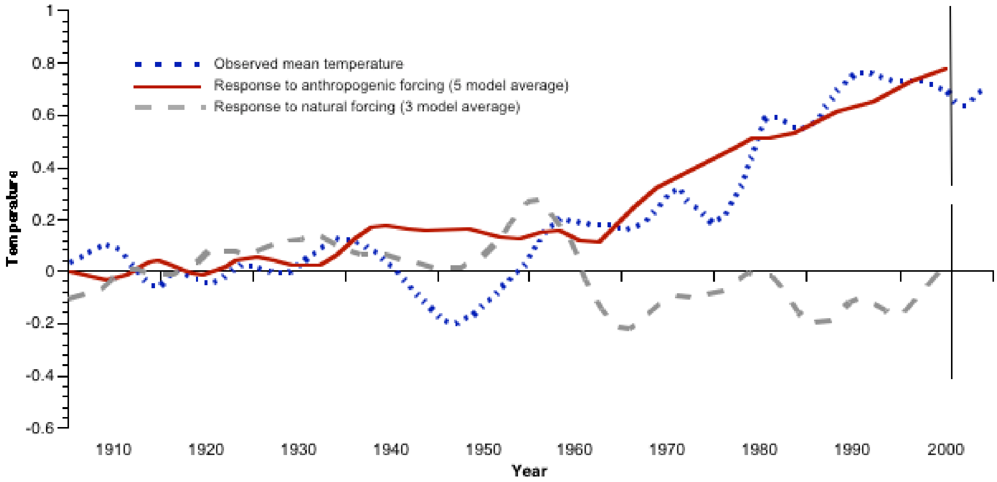
One response to this is that the level of CO_2 concentrations has entered new territory and that this is clearly correlated with the increase of GHG emissions that are attributable to human activities. As may be seen from the historical trends in Figure 2.2, the level of CO_2 concentrations in the atmosphere has moved in a regular cycle between about 180 and 280 parts per million by volume (ppmv). The current upturn in CO_2 concentrations, which may indeed have begun as a natural phenomenon, has not peaked at the 280 ppmv mark as in previous cycles. Instead it has spiked very rapidly up to nearly 380 ppmv and shows no sign of slowing down.

While acknowledging the role played by natural phenomena such as variations in solar emissions, the Third Report of the IPCC concludes that 'most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations' and that 'greenhouse gases continue to increase due to human activities'. In support of this finding, recent modelling suggests that simulations based on anthropogenic factors provide superior tracking of recent temperatures in Australia than models based on natural phenomena (Figure 2.3).

[9] P. Frich, L. V. Alexander, P. Della–Marta, B. Gleason, M. Haylock, A. M. G. Klein Tank and T. Peterson 2002, *Observed coherent changes in climatic extremes during the second half of the twentieth century,* Climate Res. 19, pp .193–212.

Figure 2.3

VARIATIONS OF AUSTRALIAN MEAN TEMPERATURES, 1910 – 2000



Source: Karoly and Braganza 2004, *Journal of Climate.*

Temperatures will continue to rise

Forecasts of energy use suggest that carbon dioxide concentrations will continue to rise, and may even accelerate, in coming decades.

In its reference scenario, the International Energy Agency (IEA) projects that to meet global demand for electricity the world's generating capacity will need to double between 1999 and 2030.[10] The scenario further assumes that around 40 per cent of this capacity will come from coal, and 60 per cent from gas, implying an almost doubling of emissions from the power sector over this period. These projections are driven largely by the following factors:

- about two billion people in developing countries currently do not have access to sufficient levels of energy to enjoy a high quality of life. In order to reduce poverty and improve living standards in the developing world, energy use will have to increase. The World Business Council for Sustainable Development estimates that primary energy use could more than triple by 2050 in line with efforts to alleviate poverty at rates targeted by the United Nations[11];
- in the first half of the 21st century, the world's population is expected to increase by perhaps a further two billion;
- parts of the developed world are still failing to decouple growth in energy usage from economic growth; and.
- the developed world has already invested huge amounts of capital in existing fossil fuel–based energy systems. Any transition to new energy systems will require leadership and the community–wide weighing of investments lost against costs avoided.

Complicating this forecast increase in GHG emissions is the 'life' of greenhouse gases — the effective lifetime of carbon dioxide in the atmosphere is around 80

[10] IEA 2002, *World Energy Outlook.*

[11] World Business Council for Sustainable Development 2005, *Facts and trends to 2050: Energy and climate change.*

years. This means that a very long lead time is required to arrest further increases in global temperatures. Because of this lag, it would require a massive turnaround in emissions to reduce concentrations, and thereby reverse the growth in global temperatures. Indeed even to stabilise concentrations of carbon dioxide gas in the atmosphere, quite massive reductions in emissions are required.

These factors are reflected in IPCC scenarios developed to project the range of possible climate change outcomes over the next century.[12] The scenarios all forecast increases in global temperatures with warming at sea level projected to be in the range of 1.4 to 5.8°C between 1990 and 2100.

In public policy terms, the issue is not global warming *per se*, but rather the implications of this warming for the earth's climate, and in turn, for human welfare. *Prima facie*, changes to planetary mean temperature of a few degrees may appear to be of little consequence — since daily and seasonal variations of temperature are in the order of 10°C, the warming of the past century (0.6°C) or even anticipated for this coming century (between roughly 1°C to 6°C) seems relatively modest to the untutored eye.

However the year–to–year variation of the planetary mean temperature is around a few tenths of a degree, and is of a similar magnitude even on a decadal timescale. According to many scientists, the planet has only warmed around 5°C between the last glacial maximum (around 20,000 years ago) to the current interglacial temperatures. This increase has brought about a major redistribution of ecosystems, as well as extinctions and the emergence of new species. In this context, forecast increases in temperature of between 1°C and 6°C over the next century are unprecedented, and could have very serious consequences for mankind.

2.3 A longer–term target for emissions reductions

Uncertainty and the rationale for a target

The central challenge in climate change is dealing with uncertainty. This uncertainty exists across three dimensions:

- *science* — while the IPCC has determined that we can be virtually certain that the earth has warmed and that this warming has been caused by anthropogenic activity, what is less certain is:
  - climate sensitivity to given greenhouse gas concentrations in the atmosphere; and
  - the effect of any specified level of temperature/climate change on natural and human systems;
- *economics* — uncertainty exists around the baseline 'business as usual' greenhouse gas emissions trajectories; the net costs of possible climate change impacts; the effectiveness of different policy responses and the risks to the global economy of these; and
- *strategy* — individual national decision makers face uncertainties in predicting the behaviour of other nations in negotiating and implementing a global

[12] These scenarios attempt to represent possible alternative futures that reflect population growth, technological innovations, the bridging of inequities in energy supply across the world, economic development and other factors. They cannot be regarded as predictions, nor can probabilities be ascribed to the likelihood of any one scenario being more likely to represent the future.

approach — making the wrong strategic decision will potentially be highly costly.

The decision on how to respond to the problem of global warming therefore involves balancing a highly uncertain but potentially catastrophic outcome against the imposition of potentially huge and inequitable mitigation costs. Australia is at risk of significant negative impacts should global warming and subsequent climatic changes occur. However reducing carbon dioxide emissions to avoid global warming will involve economic costs which — depending on technological developments and emission reduction timetables — could be substantial. Moreover, these costs will be borne today, while the benefits derived from them will mostly only be bestowed upon future generations.

Complicating this further, delaying action until some of the uncertainty is resolved will make the problem harder to deal with and, because of the lag between emissions and their impact, may result in the effects of climate change being far worse.

An argument could be made that if there is a risk of serious and irreversible climate change then lack of certainty should not be a reason to fail to initiate appropriate mitigation (and adaptation) policies. However, this viewpoint does not provide any practical guidance on how much mitigation or adaptation is sensible at any particular point in time.

Inevitably then, deciding on a response to climate change requires a value judgement about the extent of the risks posed, the extent of the economic burden justified in addressing them, and the timeframe over which these costs should be borne. In this context, there is a need for an approach that will achieve significant medium–term reductions in emissions while minimising economic costs and maximising flexibility in the face of uncertainty. In particular, looking for policy options that have regard to the rate at which capital assets can be economically replaced, the rate at which learning — about the science, economics and technology — can be expected to take place, as well as progress in international negotiations and which provide long run but constantly adjustable incentives to the private sector is critical.

Such an approach would involve:

- establishing a substantial global emissions reduction target — any reduction in emissions will need to be drastic if the trend in global temperatures is to be slowed, arrested and finally reversed. Kyoto–type interim targets may be seen as a stepping stone along this pathway. A stringent medium–term target is required to avoid further increases in global warming, and eventually to achieve reductions in average global temperature;
- ‘early action’ — to begin reducing emissions and stimulate learning by doing, but not necessarily at a level that will require premature retirement of long–lived industrial assets;
- measures to stimulate new abatement technologies in order that the costs of stringent emission reductions in the medium to long term are manageable; and
- adaptation measures such as changes to agricultural practices and improvements in infrastructure in order to minimise the impact of impending climate change that cannot be avoided.

Setting an appropriate medium–term target for emissions reductions requires us to form a view about:

- the likely impact of given level of CO_2 concentrations on global temperature; and
- the likely climatic impact of this increase in global temperature.

These two issues are considered below.

How will CO_2 emissions impact on global temperature?

The IPCC determined in their Third Assessment Report that a doubling in the level of CO_2 from pre–industrial levels — corresponding to a CO_2 concentration of 550ppmv — would result in an increase in global mean temperature of between 1.5°C and 4.5°C. Since the IPCC report was published in 2001, however, there have been two large scale attempts to set "probabilistic" bounds around likely climate responses to radiative forcing from the greenhouse effect:

- a Massachusetts Institute of Technology (MIT) study —which includes variability in emission rates;[13] and
- a British Meteorology Office study — which assumes a doubling in atmospheric concentrations and then uses a huge number of computer simulations with varied parameter inputs to develop a probability distribution.[14]

It would be fair to characterise both of these approaches as suggesting a median temperature increase at around 2.3°C to 3.4°C but with the distribution significantly skewed toward higher temperatures. The MIT simulations suggest a one in twenty probability of temperature increases in excess of 5.3°C and a one in two probability of increases in excess of 2.3°C. In the UK Met Office simulations, more than 4.2 per cent of runs showed temperature increases in excess of 8°C.

More recently, research undertaken by Oxford University, also using distributed computing methodology, showed a substantial temperature response to even a relatively low stabilisation level, and greater than 11°C for a doubling of CO_2.[15]

Criticisms of the IPCC's scenarios

The IPCC's projections of increased temperature in coming decades have been criticised on the basis that they are based on projections of GDP in developing countries that are implausibly high.[16] The argument follows that the IPCC's projection of temperature increases in the range of 1.4 to 5.8°C to 2100 are overstated.

First, it must be acknowledged that any type of scenario analysis necessarily embodies considerable uncertainty — particularly when projecting outcomes fifty

[13] MIT 2001, MIT Joint Program on the Science and Policy of Global Change, published on the web [web.mit.edu/globalchange/www/MITJPSPGC_Rpt73.pdf] as *Report No 73 – Uncertainty Analysis of Global Climate Change Projections*.

[14] British Met Office 2005, 'Uncertainty in Predictions of the Climate Response to Rising Levels of Greenhouse Gases', *Nature*, Vol 433, 27 January 2005.

[15] D. Stainforth, M. Allen , D. Frame and C. Piani. 2005, 'Risks Associated with Stabilisation Scenarios and Uncertainty in Regional and Global Climate Change Impacts,' Presentation to the 'Avoiding Dangerous Climate Change Conference,' Exeter, Feb 1–3 2005.

[16] See I. Castles and D. Henderson 2003, 'The IPCC Emissions Scenarios: An Economic–Statistical Critique', *Energy and Environment,* vol. 14, no. 2, pp. 159–185 Multi–Science, United Kingdom; and *The Economist*, 'The Intergovernmental Panel on Climate Change had better check its calculations', Feb 13 2003.

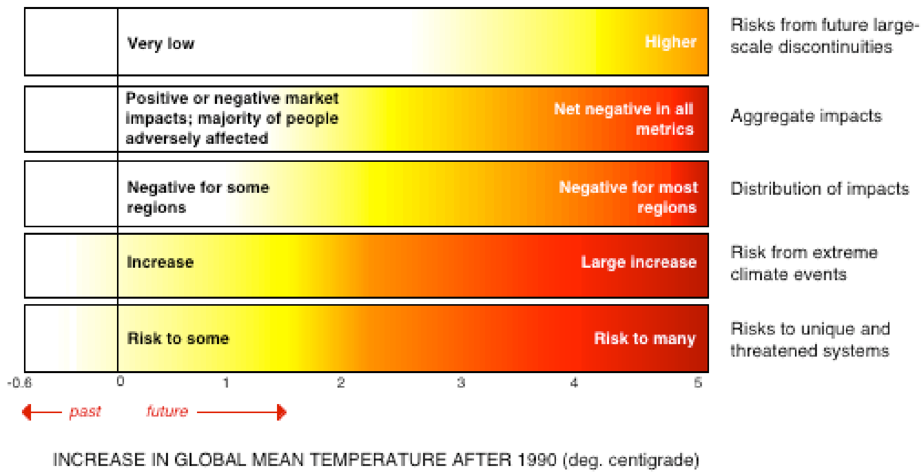
years into the future. Secondly, the more recent work on the temperature outcomes associated with given CO_2 stabilisation levels suggests that the range of climate sensitivities may actually be significantly *higher* than that found by the IPCC. To some extent, this may balance any upward bias in the IPCC's temperature projections. It should be noted, however, that the tendency of these distributions to exhibit a strong skewness to the right reflects the risk of non–linearity in the climate response to increased radiative forcing. There appears to be a small, but not insignificant, risk of very severe climate events resulting from emissions growth that is within the foreseeable range.

How will increases in temperature impact on the earth's climate?

As well as uncertainty about the temperature impact of a given level of CO_2 concentrations, there is also uncertainty about the effect this temperature rise will have on the climate.

Figure 2.4

IMPACTS OF OR RISKS FROM CLIMATE CHANGE, BY REASON FOR CONCERN



Source: IPCC 2001, *Third Assessment Report*, TS12. Note: Each row corresponds to a reason for concern, and shades correspond to severity of impact or risk. White means no or virtually neutral impact or risk, yellow means somewhat negative impacts or low risks, and red means more negative impacts or higher risks. Global–averaged temperatures in the 20^{th} century increased by 0.6°C and led to some impacts. Impacts are plotted against increases in global mean temperature after 1990. This figure addresses only how impacts or risks change as thresholds of increases in global mean temperature are crossed, not how impacts or risks change at different rates of change in climate. These temperatures should be taken as approximate indications of impacts, not as absolute thresholds.

Science is not yet able to tell us where all the critical thresholds lie. Making judgements about when we will cross over into the realm of 'dangerous' climate effects must necessarily involve social, economic and political as well as scientific considerations. How much temperature change might bring about a material change in climate patterns that communities of the world would regard as 'dangerous'? The definition of what is 'dangerous' is dependent on the factors driving changes in climate as well as what humans are prepared and not prepared to accept as options for the future. The IPCC provides a preliminary indication of how the risk of certain adverse climate effects is likely to increase with rising mean global temperature levels (Figure 2.4). According to this scale, the risks to unique and threatened systems and from extreme climate events begin to increase even at very low levels of global temperature increases.

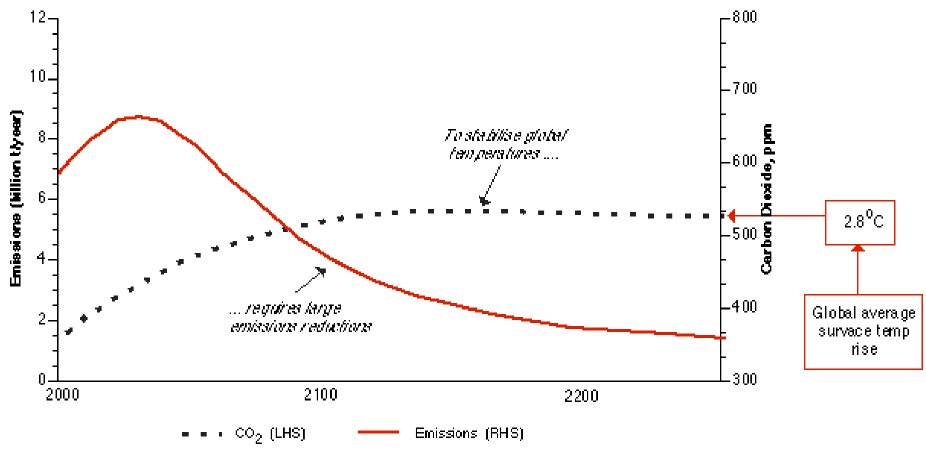
Setting an emissions target

Despite the uncertainty about the level of global warming and subsequent climate impacts that will eventuate from a given level of CO_2–e stabilisation, by taking a decision with respect to appropriate levels of risk, the acceptable peaking and stabilisation levels of greenhouse gases in the atmosphere could be inferred. Several possible emissions reduction targets have been canvassed:

- the European Union (EU) has set an indicative target for long–term global temperature rise of not more than 2°C above pre–industrial levels.[17] Some evidence[18] suggests that the level of CO_2–e concentrations required in order that this temperature outcome is "likely" is 400 ppmv CO_2–e (current levels are around 380 ppmv);
- an objective currently being widely canvassed overseas is to reduce global emissions by around 50 per cent below business as usual projections by 2050. According to work by the CSIRO, this would put the world on a path to stabilising atmospheric greenhouse gas concentrations at around 550 ppmv and restricting further global warming to about 2.8°C (Figure 2.5). This is broadly consistent with work done by researchers at Princeton University who have concluded that limiting carbon emissions to present–day levels for 50 years (which is roughly equivalent to halving emissions in 2050 relative to current projections) would put the world on a track to stabilise the concentration of carbon dioxide in the atmosphere at about 500 ppmv.[19]

Figure 2.5

STABILISING CO_2 CONCENTRATIONS AND GLOBAL TEMPERATURES



Source: CSIRO

The United Nations Framework Convention on Climate Change (UNFCCC) — to which most of the world's nations have agreed — sets out a legal framework for

[17] European Environmental Agency (http://org.eea.eu.int/documents/newsreleases/climate_report–en).

[18] M. Meinshausen 2005, 'On the risk of overshooting 2°C', Presentation to the 'Avoiding Dangerous Climate Change Conference,' Exeter, Feb 1–3 2005.

[19] S. Pacala and R. Socolow 2004, 'Stabilisation wedges: Solving the climate problem for the next 50 years with current technologies', *Science,* 305, pp. 968–972.

controlling emissions of greenhouse gases. In article 2 the contracting parties pledge themselves to:

> "achieve stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner."

Article 3.3 states that:

> "Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing [precautionary] measures, taking into account that policies and measures to deal with climate change should be cost effective so as to ensure global benefits at the lowest possible cost."

The optimal strategy in this context is to establish long–term objectives while maintaining the flexibility to be able to respond if circumstances change. This implies seeking policy options that have regard to the rate at which capital assets can be economically replaced; the rate at which learning — about the science, economics and technology — can be expected to occur; as well as progress in international negotiations. Associated with these considerations is the need to maintain some policy flexibility while providing the private sector with as much long–term investment certainty as possible.

Weighing up all of these legitimate considerations suggests a target of reducing emissions by around 60 per cent below 2000 levels by 2050 may be appropriate. Emissions reductions greater, or more quickly, than this would probably require a sharp downturn in emissions before 2020, which as well as being highly unlikely in the current context is also likely to impose substantial costs. Most of these costs are generated when mitigation policies force the retirement of energy–producing assets before the end of their useful life. The World Business Council for Sustainable Development (WBCSD)[20] makes the following observations about how — assuming we allow current assets to live out their useful life — the long–lived nature of energy–related infrastructure impacts on our ability to affect emission levels:

- in transport — even assuming relatively high uptake of 'no emission' vehicles to replace current stock, it would not be until 2040 that the total number of traditional vehicles in use — and the emissions they produce — begin to decline; and
- in stationary energy — even if all new coal–fired generators utilised carbon capture and storage (CCS) and/or nuclear/renewable capacity was built instead, CO_2 emissions from electricity would not start to decline before 2030.

Given this inertia in the world's energy–producing infrastructure, even moderate requirements to replace the current stock of energy infrastructure are likely to impose substantial economic shocks. This means there is a case for moderating both the timing and the size of reductions in emissions required by our chosen target. This case is strengthened when we consider that substantial time will be needed to develop new low–emission energy–related infrastructure, and to reduce uncertainties around the science, economics and global negotiations.

[20] World Business Council for Sustainable Development 2004, *Facts and Trends for 2050: Energy and Climate Change.*

This argument must of course be balanced with the clear view that setting a relatively high level as a target risks generating little, if any, action in the near–term. Changing the world's reliance on fossil fuels will be a long–term process that needs to start now. Stabilisation in the mid–range provides an incentive for this necessary action but also gives more time for replacement of long–lived assets and for further development of new technologies and scientific evidence to support the case for change.

The target for this project

For the purposes of this project, we have analysed a 60 per cent reduction in industrial country emissions by 2050 relative to 2000 levels – supported by abatement action in developing countries that follows this lead after a period of further emissions growth. This is consistent with widely disseminated and well–known long–term target analysis work done by the Royal Commission on Environmental Pollution in the United Kingdom.[21]

Two pathways to the achievement of this target are analysed:

- 'early action': abatement action to reach the target commences in 2013. Emissions are reduced annually in a linear fashion from that year to reach the target in 2050; and
- delayed action: abatement action to reach the target commences in 2022. Emissions are reduced annually in a linear fashion from that year to result in the same quantum of emissions reductions (in terms of tonnes of CO_2–e) by 2050 as that achieved under the 'early action' scenario.

It should be emphasised that an assumption of *global* action is fundamental to this analysis. Any large–scale unilateral action by Australia would constitute bad policy in that it would impose significant costs on the community while having a negligible impact on climate change.

[21] UK Department of Environment, Food and Rural Affairs 2003, *The scientific case for setting a long–term emissions reduction target*, sourced from defra.gov.uk on 31 August 2005.

Chapter 3

Modelling framework

Modelling the economic impact of long–term cuts in global greenhouse gas emissions inherently involves a high degree of uncertainty. Specifying the modelling exercise therefore requires us to make a series of assumptions about future global policy settings, technological progress and economic outcomes. The modelling approach requires first the estimate of a base case, or business–as–usual scenario that does not incorporate additional greenhouse gas abatement measures. Simulations of the 'policy shocks' can then be compared with this base case. Clearly, projecting economic outcomes over 45 years to 2050 is highly problematic even under business–as–usual assumptions and these uncertainties are magnified when a very substantial policy shock is imposed on the model.

Therefore, while every effort is made to ensure that the modelling is as soundly based as possible, it is important to note at the outset that because of the many assumptions inherent therein, the modelling represents just one possible view of the future. The modelling assumptions presented below should be viewed in this context — both the modelling inputs and results they generate are intended to be illustrative rather than definitive.

3.1 The model: MMRF–Green

The analysis in this report is based on modelling using the MMRF–Green model, developed and operated by the Centre of Policy Studies (COPS) at Monash University. MMRF–Green is a version of the Monash Multi–Regional Forecasting (MMRF) model specifically designed to evaluate the impact of greenhouse policy shocks. The current version of MMRF–Green, which is a very detailed dynamic, multi–sectoral, multi–regional model of Australia, distinguishes 49 industries, 54 products, eight States/Territories and 56 sub–State regions.

For electricity generation — which will be the key driver of results in this modelling exercise — MMRF–Green distinguishes nine separate sectors:

- *black* and *brown* coal;
- *gas* and *oil/liquids*; and
- renewables — *hydro*, *biomass*, *biogas*, *solar* and *wind*.

Appendix A to this report provides a full description of the structure and capabilities of MMRF–Green. Appendix A also contains more detail on the nature of each of the 49 industry sectors modelled as part of this analysis.

3.2 Global assumptions

The achievement of deep cuts in global CO_2 emissions by 2050 necessarily requires abatement action by all of the world's major GHG emitters, including developing countries. As noted, MMRF–Green is a detail–rich model of Australia's domestic economy but it lacks an international dimension. The following international settings were adopted to reflect the external economic operating environment for Australia as it moves to achieve significant long–term emission reductions against the backdrop of similar action overseas. Importantly, the analysis focuses on Australia achieving a long–term emissions target in parallel with other countries, and in the absence of an international emissions trading system. The implications of international emissions trading are briefly discussed in chapter 5.

In relation to the impact of changes in supply and demand for Australia's traded commodities the following assumptions are relevant:

- *Participation*: developed countries — including the United States — will reduce emissions to 60 per cent below 2000 levels by 2050. Abatement action by these countries is assumed to commence in 2013. Developing countries will also reduce emissions at the same rate as developed countries, but will not commence abatement action until later in the projection period. This assumption is based on work by the Royal Commission for Environmental Pollution in the United Kingdom.[22]
- *Terms of trade*: demand for exports and imports will change as relative prices are impacted by the requirement to reduce emission levels. Based on some earlier work, it is assumed that at a carbon price of $100 per tonne of CO_2–e, world demand schedules for Australian produced commodity exports will shift down as follows:
  - 50 per cent black coal
  - 50 per cent oil
  - 10 per cent iron ore
  - 20 per cent aluminium and alumina
  - 20 per cent iron and steel
  - 20 per cent basic chemicals

  The model also assumes that world demand schedules for Australian produced commodity exports will shift up as follows:
  - 100 per cent uranium
  - 50 per cent gas

  Lastly, MMRF–Green assumes that the supply price of oil (an important import) will fall by 50 per cent (— that is suppliers absorb a significant portion of the cost increase induced by the carbon price).

These assumptions were developed with reference to earlier global modelling work undertaken for COPS by ABARE, and by projections of global primary energy supply shares produced by the IEA, Shell and the World Energy Council.[23] It needs

[22] UK Department of Environment, Food and Rural Affairs 2003, op. cit. The Royal Commission on Environmental Pollution in the UK developed an emissions projection for global emissions where CO_2 concentrations in the atmosphere stabilised at a level of 550ppmv. Assuming high emissions growth and low natural rates of carbon uptake, to reach this target, Annex 1 emission reductions of 60 per cent of 2000 levels by 2050 (then declining at a slower rate out to 2150 where they reach a level which is consistent with the carbon uptake of the natural system) were required. Similarly, non–Annex 1 emission reductions were required to follow a similar pattern, starting from around 2030, reducing to 2100, and followed by a slower reduction to 2150.

[23] International Energy Association 2003, *Energy to 2050: Scenarios for a Sustainable Future*; Shell 2005*, Shell Global Scenarios to 2025* sourced at http://www.shell.com/home on 31 August 2005; World Energy Council

to be acknowledged, however, that these estimates are speculative and that the use of a detailed global economic model would be required to test the implications of alternative international outcomes and settings.

3.3 Economic assumptions

GDP

Base case GDP growth is that which is projected to prevail over the next fifty years given economic, demographic and social factors, and assuming no change in current greenhouse policies.

Real GDP growth in the long term is driven by three major components: population growth, productivity growth and workforce participation levels.[24] Over the past four decades, Australia's real GDP has grown by an average of 3.75 per cent per year.[25] However, due largely to demographic factors, future trends show real GDP growth slowing relative to the outcomes experienced over the past forty years. The Commonwealth Government's 'Intergenerational Report' (IGR) projects real GDP growth to fall steadily to around 2 per cent in the 2030s.

Table 3.1

MODELLING ASSUMPTIONS: AVERAGE ANNUAL GROWTH IN EMPLOYMENT, LABOUR PRODUCTIVITY AND REAL GDP (AUSTRALIA)

Decades	Labour productivity growth	Employment growth	Real GDP
2000s	1.6	1.5	3.2
2010s	1.5	1.1	2.6
2020s	1.5	0.8	2.2
2030s	1.5	0.7	2.1
2040s	1.5	0.7	2.1
Average 2003–2050	1.5	0.9	2.4

Note: All parameters are in real terms ($1999–00).

In line with the IGR, we will assume that the combination of employment growth slowing and productivity growth remaining around its long run average will mean that real GDP is projected to decline to an average of 3.1 per cent per year in the current decade, and to around 2 per cent per year by the 2040s (Table 3.1).

Gas costs

The MMRF–Green base case makes the following assumptions in relation to gas prices and supply:

2005, *Global Energy Scenarios to 2050 and Beyond* sourced at http://www.worldenergy.org/wec–geis/edc/scenario.asp **o**n 31 August 2005.

[24] K. Henry 2002, 'The Demographic Challenge to Our Economic Potential', *Chris Higgins Memorial Lecture,* 13 November 2002, available at http://www.treasury.gov.au

[25] Commonwealth of Australia 2002, *Intergenerational Report 2002–03*, Budget Paper No.5.

- Wholesale gas prices will rise slowly in real terms throughout the outlook period in most States.
- The proven, probable and undiscovered gas reserves which currently meet the majority of natural gas demands within South Eastern Australia — namely the Cooper, Gippsland, and Bass Strait/Otway basins — will start to decline significantly from around 2037 on.
- As these key basins run down, it is assumed the growth in consumption demand would be met primarily by discoveries in more removed basins such as Browse and Papua New Guinea, as well as from coal seam methane.

As a result, gas prices remain relatively steady, in general showing only a mild upward trend in Eastern Australian markets and a general downward trend in Queensland as coal seam methane supplies come on stream in that State:

- In Victoria prices are expected to start rising from the current $3.20 per gigajoule (GJ) from around 2013 on, reaching $4.00 per GJ in 2030 and then rising by another $1.40 over the next 15 years.
- Prices in NSW are expected to rise to $4.00 per GJ at the same time as Victoria (2030), but then increase at a slower rate over the next 25 years, rising to $5.10 per GJ by 2050.
- Prices in Western Australia and the Northern Territory are projected to hold constant for the entire outlook period.
- The highest prices are expected in Tasmania, where gas prices are expected to edge up to nearly six dollars per GJ by 2050, while the lowest prices are expected in parts of Queensland, especially the north east and central areas where prices are expected to dip to $2.60 by 2050.

Other macroeconomic assumptions

In generating the base case forecasts, COPS use:

- State/Territory macroeconomic forecasts from Access Economics and State treasury departments for the years to 2010;
- national–level assumptions for changes in industry production technologies and in household preferences from COPS; and
- forecasts through to 2008 for the quantities of agricultural and mineral exports, and estimates of capital expenditure on major minerals and energy projects from various sources, such as state government agencies, the Australian Bureau of Agricultural and Resource Economics (ABARE), and the National Electricity Market Management Company (NEMMCO).

For the later years of the forecast period COPS use, in the main, extrapolations of earlier–year trends.

3.4 Emissions target and carbon price: the 'early action' scenario

The 'early action' scenario: Australia acts to meet a target of reducing greenhouse gas emissions by 60 per cent relative to 2000 levels by the year 2050 as part of global abatement efforts. This target is achieved on a linear trajectory commencing in 2013.

Emissions target

The MMRF–Green base case is a business–as–usual scenario in which Australia and the world continue to debate the merits of major action to curb greenhouse gas emissions, but nothing is implemented. Accordingly, the base case does not include any of the potential future policy action to address climate change canvassed in current government policy documents such as the Commonwealth Government's White Paper on Energy.[26] In this scenario, greenhouse emissions in Australia grow at just below 1.0 per cent per annum on average between now and 2050.

In the 'early action' scenario, it was assumed that the emissions target of a 60 per cent reduction in emissions relative to 2000 by 2050 would be reached in a linear fashion. The first year of abatement action was specified to be 2013 to coincide with the expiration of the first commitment period under the Kyoto Protocol. On this basis, the overall target and the target emissions reduction in each year is as follows:

- According to the MMRF–Green base case, total emissions of CO_2–e in Australia in the year 2000 were 499.1Mt (includes forestry sequestration, but excludes emissions from other forms of land use change). Our target for 2050 is therefore 0.4*499.1 = 199.7Mt of CO_2–e.
- Again according to the MMRF–Green base case, total emissions in Australia in 2012 are projected to be 561.4Mt of CO_2–e (includes forestry sequestration, but excludes emissions from other forms of land use change). To reach the 2050 target in a linear way we therefore need to have annual reductions in emissions of around 9.5Mt of CO_2–e.

Carbon price signal

In 2013, we impose a price on all CO_2–e emissions (in each year, uniform across all emitters without exception) which is endogenously calibrated in each year to achieve the year–to–year reduction target. (We are not making a major policy choice here: in the model, an emissions trading scheme is modelled in the same way as the imposition of a carbon price penalty.)

In the first year (2013) the carbon price is at the level required to reduce emissions by 9.5Mt of CO_2–e relative to their level in 2012. Note that in our base case, emissions in 2013 increase by around 4Mt of CO_2–e relative to their level in 2012. So the carbon price must achieve a reduction in emissions (relative to baseline levels) in 2013 of around 13.5Mt of CO_2–e. In the second year (2014) emissions will again have to fall by 9.5Mt of CO_2–e relative to their level in 2013. In our base case, emissions in 2014 increase by around 4Mt of CO_2–e relative to their level in 2013. So the carbon price must achieve a reduction in emissions in 2014 (relative to

[26] Commonwealth Government 2004, *Securing Australia's Energy Future*, available at www.pmc.gov.au/energy_future

baseline levels) of around 26Mt of CO_2–e. This will require a higher carbon price than that which was needed in 2013. Clearly, we will see the carbon price steadily rising through time. As the task becomes more difficult (i.e. when most electricity is produced by relatively costly renewables, when available efficiencies have been exhausted in most sectors etc) the annual increases in carbon price will get steadily larger even though the annual reductions in emissions (year–to–year) are the same.

Revenue recycling

The carbon price introduced in both modelling scenarios will generate a revenue stream for government over the forecast period. The most straightforward options for utilising this revenue from a modelling perspective involve using the revenue from the carbon price to reduce or eliminate other forms of taxation. The optimal revenue recycling strategy in this regard is one that will enhance living standards and maximise economic efficiency. There are a number of alternatives:

- Income tax
  - Personal income tax

    A reduction in personal income tax is likely to boost disposable income and, in turn, consumption and savings (relative to what would have otherwise been the case following the introduction of the carbon price). Depending on the level of the reduction, employment may also be boosted as the incentives to work increase, particularly for low–income workers and 'second earners' in two income families.

  - Corporate tax

    A reduction in corporate income tax has only modest impacts on economic efficiency, due to dividend imputation (which effectively neutralises the effect of the tax on domestic shareholders) and the taxation of repatriated dividends by home jurisdictions. Nevertheless, a reduction in company income tax tends to increase returns to investment and encourage economic activity (relative to what would have otherwise been the case following the introduction of the carbon tax). There will be some redistribution of wealth away from emitting towards non–emitting industries.

- Goods and services tax (GST)

  Using carbon price receipts to reduce GST returns the collected revenue directly to consumers and therefore boosts consumption levels and reduces savings. However, although the GST is a Commonwealth tax, it is intended to represent a growing source of revenue for the States/Territories. Therefore, reducing GST is not favoured because it would exacerbate fiscal imbalances within the Australian federation by reducing an important source of revenue for State and Territory governments.

- Payroll tax (PRT)

  A reduction in PRT generally has the effect of increasing employment in the model, at least in the short term. However, again for reasons of practicality, because PRT is administered individually by the States/Territories, imposing a uniform change to PRT in the modelling is not likely to represent a realistic outcome.

- Return to owners of emitting firms

  The economic burden associated with a carbon price is shared between the shareholders of emitting firms (through reduced profits and share values) and downstream customers (through increased prices). Analysis of the US energy markets suggests around 75 per cent of the economic costs would be passed through to consumers, with shareholders bearing the remainder.

  Returning greenhouse revenues to the owners of emitting firms (that paid them in the first instance) effectively hands the tax proceeds back to Australian and international shareholders in those firms (around 80 per cent and 20 per cent for shareholders of Australian firms as a whole). This has a similar impact to reducing company income tax, but more effectively targets firms that are adversely impacted by the introduction of the carbon price.

We opted to divide the recycled revenue evenly between cuts in corporate and personal income taxes. The alternatives were rejected on the following basis:

- GST and payroll tax reductions can be fairly criticised on practicality grounds; and
- returning revenue to emitting firms in perpetuity assists with adjustment issues but overcompensates shareholders, is a narrowly–based recycling alternative, and raises issues around the allocation of compensation.

Specifically, the revenue raised by the carbon price is recycled via the following mechanisms:

- In the 'early action' scenario, the initial economic impacts of emission reductions were reduced by grandfathering 50 per cent of the emissions permits in 2013, reducing to zero (no grandfathering) over a ten year period. In the 'delayed action' scenario, 50 per cent of emissions permits were grandfathered in 2022 reducing to zero over a ten year period from that year.
- In both scenarios, the net revenue raised from greenhouse policy measures was used to reduce personal and corporate income taxes in proportion to the approximate size of these taxes (i.e. 70 per cent used to reduce personal tax and 30 per cent used to reduce corporate tax).

The impact of this assumption is that there is no change to government revenue (or expenditure) arising from the decision to adopt a long term greenhouse target.

3.5 Emissions target and carbon price: the 'delayed action' scenario

The 'delayed action' scenario: Australia meets a target of reducing greenhouse gas emissions by the same aggregate amount as under the 'early action' scenario between now and 2050, although action does not commence until 2022. This takes place against a backdrop of international abatement effort.

The total quantum of emissions reduced over the forecast period relative to the base case in the 'early action' scenario is 12,925Mt of CO_2–e. The 'delayed action' scenario commences in 2022 when we put in place a price on all CO_2–e emissions — endogenously calibrated in each year to achieve the required year–to–year reduction target — to achieve this same quantum of emission reductions in a linear reduction over the 28 years until 2050. The year 2022 was selected as the year for commencement of delayed action — it represents a delay of nearly a decade on action following the expiration of the first commitment period under the Kyoto Protocol.

As in the ‘early action’ scenario, we will see the carbon price steadily rising through time. As the task becomes more difficult the annual increases in carbon price will get steadily larger even though the annual reductions in emissions (year–to–year) are the same.

3.6 Emissions reductions in the energy sector

In response to the imposition of the 2050 target and the accompanying carbon price, emissions of GHGs from the energy sector will fall for two key reasons:

- producers will switch fuel types in electricity generation (against relatively emissions–intensive generation types such as coal, and towards lower emissions generation such as gas and renewables); and
- producers will switch away from energy altogether (as it becomes more expensive) in favour of other production inputs (i.e. capital and labour).

The extent of these two effects will depend largely on the rate of technological progress over the forecast period, both in relation to electricity generation itself and to the end–use processes that use electricity as a key input.

Technological change: autonomous energy efficiency improvement factors

Autonomous energy efficiency improvement (AEEI) is technological change that reduces the use of energy per unit of industry output, essentially by substituting capital for energy in the production process. AEEI is generally used in general equilibrium models to account for the historically observed pattern of reduced energy intensity in the economy, over and above any structural trends such as, for example, more rapid growth of low intensity sectors such as services. This AEEI effect can encapsulate:

- better use of vintaged technologies (i.e. improved production practices);
- replacement of vintaged with new technologies (i.e. improved production practices); and
- improvement in new technology (i.e. improved production possibilities).

There is commonly variation across models with respect to the factor and product substitution opportunities reflected (this is a major element of what differentiates models). Because AEEI enters as a ‘balancing’ term that calibrates the model to past observation, AEEI can take on a different value for different models, all of which seek to explain the same observed outcome, or shed light on what outcome might be expected as we make marginal changes to the observed pattern of production, resource availability and policy settings.

In MMRF–Green, AEEI is assumed to take place in the base case at a fixed rate per cent per year reflecting past trends in energy efficiency improvements. Different rates apply in different industry sectors. For example, in every year, the quantity of energy inputs required to generate a unit of output in the coal–generated electricity sector is assumed to fall by 0.5 per cent. The base case further assumes that this

AEEI is costless and by itself, therefore, it is a technological improvement that shifts out the industry supply curve and increases real GDP (by the cost reduction associated with reduced input usage).

In both the ‘early action’ and ‘delayed action’ scenarios we assume that the adoption of a long–term greenhouse target results in an acceleration in AEEI within the economy. This occurs because greater emission scarcity drives economic agents to take up opportunities for improved energy usage that would not otherwise have been utilised. Emission scarcity also acts to induce technological change focused on reducing the call on emissions in the production of goods and services. The dynamics of this process can be complex, but are vitally important to achieving an efficient and low cost greenhouse response. This is the process whereby emission constraints make the development and adoption of new technologies profitable, and is proxied in this set of simulations by an increase in the AEEIs for different industries.

Generation technologies

The value of AEEI assumed in the ‘early action’ and ‘delayed action’ scenarios was determined with reference to the level of remaining technological potential available for each of the relevant technologies. CSIRO was consulted on technological opportunities for fossil and renewable technologies. CSIRO’s advice reflects consideration of technology change modelling undertaken as part of IPCC deliberations, and the AEEIs for various sectors assumed by COPS. Learning by doing relationships have also been incorporated for renewable energy technologies. Further, we assume that Australia is a technology taker and the availability of new technology is driven by action in the international market place. Of course, the uptake of these technologies in Australia will be a function of domestic energy prices, and is captured in the model through choices between input combinations with different energy (and cost) implications.

Due to lack of data, a number of technologies in the early stages of development and/or deployment were not included in the analysis — these include hydrogen, waste–to–energy, solar thermal and geothermal generation technologies. Similarly, nuclear generation — currently supplying around 18 per cent of the world’s electricity — may also play an important part in facilitating domestic reductions in emissions, but was not explicitly included in the analysis – reflecting the preferences of the Business Roundtable. Some of these technologies may have the potential to contribute significantly to Australia’s energy system over the next 40–50 years. Where these omitted technologies help to reduce the cost of meeting emission reduction targets, the costs of action indicated in this analysis are likely to be overestimated.

Tables 3.2, 3.3 and 3.4 below show that AEEI factors that were applied in each electricity sector in the base case and in the ‘early action’ and ‘delayed action’ scenarios. Annual AEEI factors in each case were adjusted to reflect assumed rates of technological progress under each scenario.

Table 3.2

BASE CASE: AEEI FACTORS FOR GENERATION TECHNOLOGIES

	2013–2019 (%)	2020–2050 (%)
Coal – Black	0.6	0.5
Coal – Brown	0.6	0.5
Gas	0.6	0.5
Oil	0.6	0.5
Hydro	0.6	0.5
Biomass	1.75	1.5
Wind	1.75	1.5
Biogas	1.75	1.5
Solar	1.75	1.5

Source: MMRF–Green and CSIRO

Table 3.3

EARLY ACTION SCENARIO: AEEI FACTORS FOR GENERATION TECHNOLOGIES

	2013–2019 (%)	2020–2050 (%)
Coal – Black	0.9	0.8
Coal – Brown	0.9	0.8
Gas	0.9	0.8
Oil	0.9	0.8
Hydro	1.5	0.75
Biomass	3.5	2.5
Wind	3.75	3.00
Biogas	3.75	3.00
Solar	3.5	2.5

Source: MMRF–Green and CSIRO

Table 3.4

DELAYED ACTION SCENARIO: AEEI FACTORS FOR GENERATION TECHNOLOGIES

	2017–2036 (%)	2037–2050 (%)
Coal – Black	0.9	0.8
Coal – Brown	0.9	0.8
Gas	0.9	0.8
Oil	0.9	0.8
Hydro	1.5	0.75
Biomass	3.5	2.5
Wind	3.75	3.00
Biogas	3.75	3.00
Solar	3.5	2.5

Source: MMRF–Green and CSIRO

AEEIs for end–use technologies and non–energy sectors

For sectors (and energy using technologies) beyond electricity generation, the effect of induced technical change and improved energy use (e.g. 'no regrets' energy efficiency improvements) is reflected in an AEEI of 1.2 per cent per annum over the forecast period.

Carbon capture and storage

In addition to the energy efficiency and fuel switching activity that will be induced by an impost on greenhouse gas emissions, incentives will also be generated for technologies that reduce or prevent the post–production discharge of greenhouse gases.

Carbon capture and storage (CCS) technologies — involving underground disposal of gases in appropriate storage facilities e.g. depleted gas reservoirs — is a high profile example, which offers the potential for emission reduction on a large scale. Given the significant investment costs for 'capture and compression' facilities this technology is most likely to be relevant to fossil fuel electricity generators and natural gas producers.

McLennan Magasanik Associates provided a range of CCS cost estimates that reflect indicative costs for CCS for Australian States and territories.[27] These cost estimates range from $43 to $57 per tonne of CO_2–e in 2010 falling to $14 to $22 per tonne of CO_2–e in 2050.[28] In addition, it was assumed that:

- CCS for power stations is only about 85 per cent effective in capturing CO_2 from the waste stream;
- CCS for power stations is an energy intensive process — about 0.35 GJ of energy per tonne of CO_2 is required for compression and this is factored into the modelling;
- storage costs only will apply to CCS opportunities in the upstream gas industry; and
- CCS cannot be applied to more than 25 per cent of total national emissions in any given year, to account for transport restrictions.

Information on the indicative energy requirements associated with pipeline transport of CO_2 to disposal sites was not obtained for this project. This may well be small compared to the energy requirement of compression, and will also be highly dependent on pressure, pipeline design and distance.

Limits to fuel switching

An upper limit on the proportion of all energy that can come from renewable sources (other than biomass) was imposed in the modelling to reflect intermittency — the share of these renewables (mainly wind and solar) in total generation gradually increases up to a limit of around 50 per cent by 2050. This limit is broadly consistent with the future world energy scenarios developed by the IEA, Shell and the World Energy Council.[29] In reality, it is likely that these limits will not apply by 2050, as grid management techniques are evolving for both peak load and intermittent generation.

[27] McLennan Magasanik Associates 2005, unpublished.

[28] By means of comparison, the IPCC determined that the application of CCS to electricity production, under 2002 conditions, is estimated to increase electricity generation costs by about 0.01 – 0.05 US dollars per kilowatt hour (US$/kWh), depending on the fuel, the specific technology, the location, and the national circumstances. Most modelling as assessed in the IPCC's report suggests that CCS systems begin to deploy at a significant level when CO2 prices begin to reach approximately 25 – 30 US$/tCO2. (Sourced from http://www.ipcc.ch/activity/ccsspm.pdf)

[29] IEA 2003, Shell 2005 and World Energy Council 2005, *op–cit*.

Electricity from biomass was not subject to a resource constraint, reflecting the fact that, unlike most other renewable energy sources, biomass is suitable for generating baseload electricity.

No water constraints were placed on any of the renewable generation technologies.

3.7 Emissions reductions in sectors other than energy

There are several sources of emissions that are not related to fuel combustion. For these sources COPS have collated available information on abatement potential in these sectors (e.g. anti–methanogen vaccine for ruminant animals in the agriculture sector; emission reduction processes in the waste sector) that suggests for a carbon price of $100 per tonne of CO_2–e, technologies become economically–viable that will reduce emissions per unit of output in the following sectors by the following amounts:

- 60 per cent (agriculture);
- 70 per cent (fugitive emissions from mining black coal);
- 40 per cent (fugitive emissions from mining oil);
- 10 per cent (fugitive emissions from mining gas);
- 10 per cent (fugitive emissions from mining brown coal);
- 10 per cent (chemical industrial processes);
- 10 per cent (cement industrial processes);
- 25 per cent (aluminium industrial processes); and
- 10 per cent (waste).

We use these point estimates to put in place linear relationships between the price of CO_2–e and the percentage reductions in emissions per unit of activity. For example, the relationship for agriculture asserts that for a carbon price of $10 per tonne CO_2–e , emissions per unit of output would fall by 6 per cent. The cost to the industry associated with putting in place the abatement technology is assumed to just equal the value of the carbon penalty saved.

Transport

In addition to the mechanism noted above we model technological change that leads to a reduction in the use of petroleum products per unit of transport activity. We assume that a carbon price of $100 per tonne of CO_2–e confers economic viability on technologies (e.g. fuel cells, hybrids) that reduce fuel per unit of transport activity by 40 per cent. As for activity emissions, we use this point estimate to put in place a linear relationship between the price of CO_2–e and the percentage reduction in petrol use per unit of activity.

Further, we also exogenously assumed a shift in consumer preferences away from passenger cars and towards public transport.

Forestry

Sequestration from forestry activities is also built into the model. Forestry will expand in line with growing demand for carbon credits as the carbon price increases, however this growth is limited by constraints on the availability of land for forestry activity. The primary mechanism through which expansions of forestry affect markets in the MMRF–Green model is through changes in the value of timber growing.

Chapter 4

Modelling results: economic impact

The quantitative modelling results for the two scenarios developed in Chapter 3 are presented in this chapter.

Unless otherwise stated, most results are presented relative to a ‘base case’ scenario — this represents the MMRF–Green model’s best estimate of future economic activity assuming that current policy settings and economic conditions remain largely unchanged going forward.

It is important to note at the outset that the modelling results represent only a partial picture of the overall economic costs and benefits of the scenario outcomes. In particular, the modelling does not incorporate the economic benefits of cutting GHG emissions in terms of reducing the rate of climate change. As such it is a *cost effectiveness* assessment, indicating the economic costs of reducing a quantity of emissions, rather than a cost benefit analysis, which would seek to value the benefit of the foregone emissions.

RESULTS SUMMARY

The ‘early action’ scenario

- Under ‘early action’, Australia acts with the rest of world to meet a target of reducing its greenhouse gas emissions by 60 per cent relative to 2000 levels by the year 2050. This target is reached in a linear fashion commencing in 2013.
- In line with the specification for the scenario, Australia’s GHG emissions are nearly 80 per cent (or 714Mt) lower in 2050 than they would have been without the imposition of the greenhouse target. This is equivalent to achieving a 60 per cent cut in emissions relative to 2000 levels.
- The economy expands by 120 per cent between 2013 and 2050 while primary energy consumption stays about the same. This compares to the base case where the economy increases by about 130 per cent over the time period while primary energy consumption increases by about a half. This indicates that the policy settings in place under the ‘early action’ scenario induce the economy to become substantially more energy efficient.
- Under the ‘early action’ scenario, GDP is less than would otherwise have been the case, however the economy eventually ‘catches up’ and we reach GDP of $2 trillion around 2.5 years later than would otherwise have been the case.
- Results for most indicators flatten out temporarily in 2022 because this is when CCS in relation to coal and gas electricity generation becomes economic: the abatement task from there on becomes easier as a result and this causes the carbon price, electricity prices etc to stop increasing at such a fast rate.

The 'delayed action' scenario

- Under 'delayed action', Australia acts with the rest of world to meet a target of reducing its greenhouse gas emissions by the same aggregate amount as under the 'early action' scenario between now and 2050, although action does not commence until 2022.
- Australia's GHG emissions are around 97 per cent (or 888Mt) lower in 2050 than they would have been without the imposition of the greenhouse target. This is a higher annual reduction than was the case under the 'early action' scenario (714Mt) because in order to obtain the same quantum of emission reductions over the forecast period in the 'delayed action' scenario, annual reductions are necessarily higher.
- The economy expands by 100 per cent between 2013 and 2050 under the 'delayed action' scenario while primary energy consumption falls by around 20 per cent. This compares to the 'early action' scenario where the economy increases by about 120 per cent while primary energy consumption stays about the same.
- Under the 'delayed action' scenario, GDP is substantially less than would otherwise have been the case — in 2050, GDP is 13 per cent lower than otherwise, and the economy reaches GDP of around $1.8 trillion six years earlier in the base case than under 'delayed action'.

4.1 Key drivers of results

As outlined in Chapter 3, to reach the emissions reduction target, a carbon price is introduced — in 2013 under the 'early action' scenario, and in 2022 under the 'delayed action' scenario. The carbon price is the policy shock that induces economic changes in the model and is the driver for the key modelling results presented in this chapter. In particular, in response to the carbon price:

- *producers (emitters)* either:
  - pay the carbon penalty; or
  - abate their emissions — normally at a cost — in order to avoid the carbon penalty. This will involve making changes to the production input mix and/or production technologies to make the overall production process less GHG–intensive; and
- *consumers* shift their preferences away from relatively GHG–intensive goods. This occurs in response to the increased prices producers now charge for these in order to compensate them for the costs of the carbon penalty or the costs of abating their emissions.

Most of the economy–wide changes in response to the carbon penalty are driven by changes in the energy sector. There are three major impacts in this sector:

- *the fuel mix changes* — in favour of relatively lower GHG–intensive energy sources — as these become relatively more cost competitive following the imposition of the carbon price;
- *electricity prices increase* because:
  - GHG–intensive fuel sources — such as coal — are made more expensive by the imposition of the carbon price; and

  - relatively more expensive electricity sources — such as renewables and CCS technologies — make up a greater proportion of the overall fuel mix; and

- *energy use falls* relative to output as alternative inputs to production (in particular capital) become relatively more cost competitive, and as production processes are adapted to use less energy.

Actions by producers and consumers in response to the carbon price cause economic growth — and associated measures such as consumption — to fall over time relative to what they would have been in the absence of the carbon price. This decline in economic activity is ameliorated by the existence of abatement opportunities in those industries sectors that generate GHG emissions. For example, abatement opportunities include CCS in relation to emissions from electricity generation, the replacement of traditional engines with hybrids or fuel cells in the transport sector, and the introduction of anti–methanogen vaccines in agriculture. Where abatement opportunities are cost effective relative to the carbon penalty, they will be taken up by emitters and will reduce the overall economic impact of the policy shock.

As noted earlier, this description of the impacts of the carbon price on economic variables — and indeed the entire quantitative analysis contained in this report — does not incorporate the potential economic costs of failure to act to prevent climate change. The analysis represents only the cost side of the full cost/benefit equation associated with abatement action to reduce the impacts of global warming.

4.2 Key results: 'early' and 'delayed' action scenarios

Carbon price

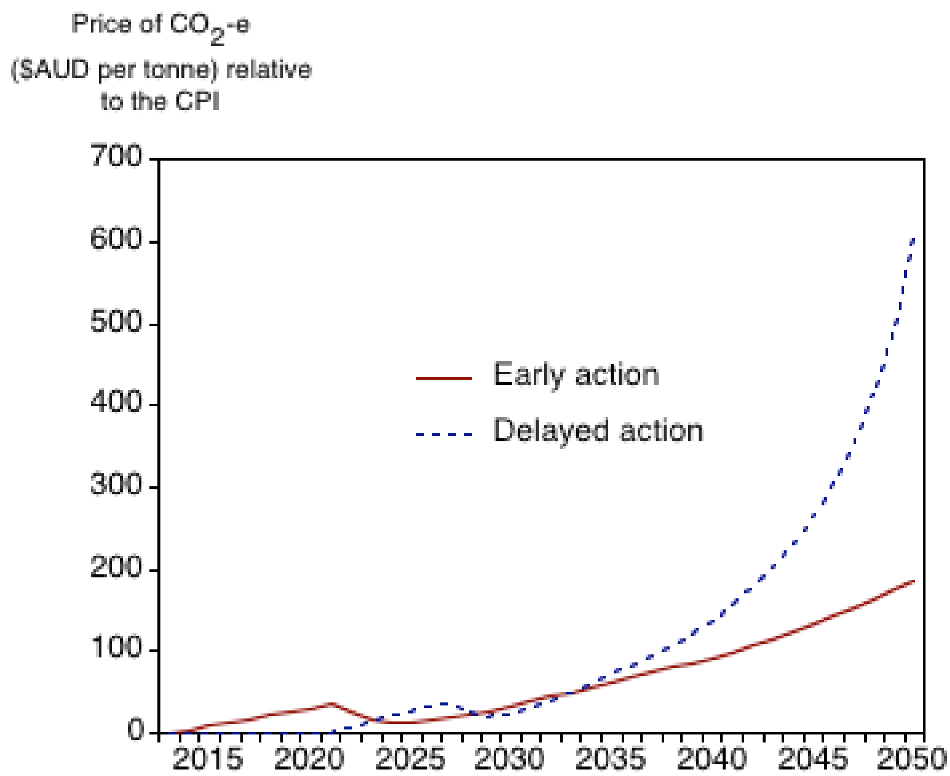
The primary policy mechanism used to achieve the emissions reduction target in the 'early action' scenario is a carbon price, introduced in 2013. This price rises steadily from \$0.70 per tonne of CO_2–e in 2013 to \$186 per tonne of CO_2–e in 2050.

In the 'delayed action' scenario, the carbon price is introduced in 2022. This price rises steadily from \$6.70 per tonne of CO_2–e in 2022 to \$614 per tonne of CO_2–e in 2050.

Figure 4.1 below shows carbon price movements under the early and delayed action scenarios.

Figure 4.1

CARBON PRICE FORECAST: EARLY AND DELAYED ACTION



Source: MMRF–Green

GDP

Early action scenario

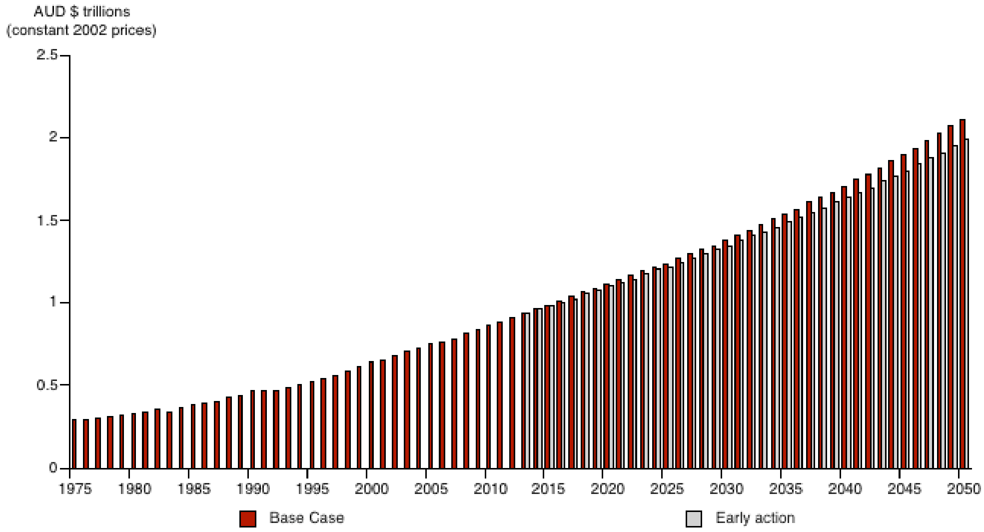
Over the entire forecast period (between 2002 and 2050) real GDP[30] increases under both the base case and 'early action' — at an average annual rate of 2.2 per cent under the base case and 2.1 per cent under the 'early action' scenario (Figure 4.2). In the 'early action' scenario, real GDP reaches an estimated $2.0 trillion in 2050. Under the base case, this value of GDP would be attained around 2.5 years earlier in 2047, with GDP in 2050 equal to an estimated $2.1 trillion. In 2050 under the early action scenario, GDP is about 6 per cent lower than it otherwise would have been under base case assumptions.

In 2020, GDP is around $1.110 trillion in the base case, and under the 'early action' scenario is around $15 billion lower at $1.095 trillion.

[30] All real estimates are measured in 2002 constant prices.

Figure 4.2

EARLY ACTION SCENARIO, ACTUAL AND PROJECTED REAL GROSS DOMESTIC PRODUCT



Source: MMRF–Green

The annual rate of growth declines over time in both the base case and early action scenarios, due to the effects of an ageing population, which in turn leads to lower employment growth. This effect is offset to some extent by productivity growth. In per capita terms, average annual growth in real GDP per capita is 1.5 per cent under the base case and 1.3 per cent under the 'early action' scenario target. Population growth is estimated at 0.9 per cent per annum on average between 2002 and 2050, and declines over time. As shown in Figure 4.2, real GDP per capita also grows but at a declining rate between 2002 and 2050.

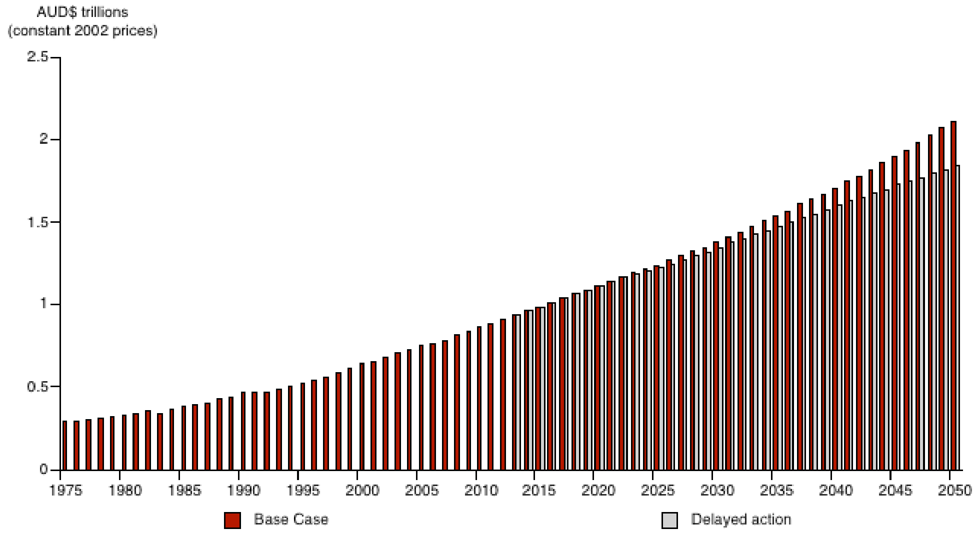
Figure 4.1 puts the GDP changes under the 'early action' scenario into an historical context. Under the base case, average GDP growth over the period 1975 to 2050 is 2.7 per cent while under the 'early action' scenario it is 2.6 per cent. Under 'early action', GDP still grows to nearly six times its 1975 level despite the economic costs associated with meeting the emissions target.

Delayed action scenario

Real GDP increases between 2002 and 2050 at an average annual rate of 1.9 per cent under the 'delayed action' scenario (Figure 4.3). In this scenario, real GDP reaches an estimated $1.84 trillion in 2050. Under the base case, this value of GDP would be attained six years earlier in 2044, with GDP in 2050 reaching $2.11 trillion. Under the delayed action scenario, therefore, GDP would be around 13 per cent lower in 2050 than under the base case.

Figure 4.3

DELAYED ACTION SCENARIO, ACTUAL AND PROJECTED REAL GROSS DOMESTIC PRODUCT

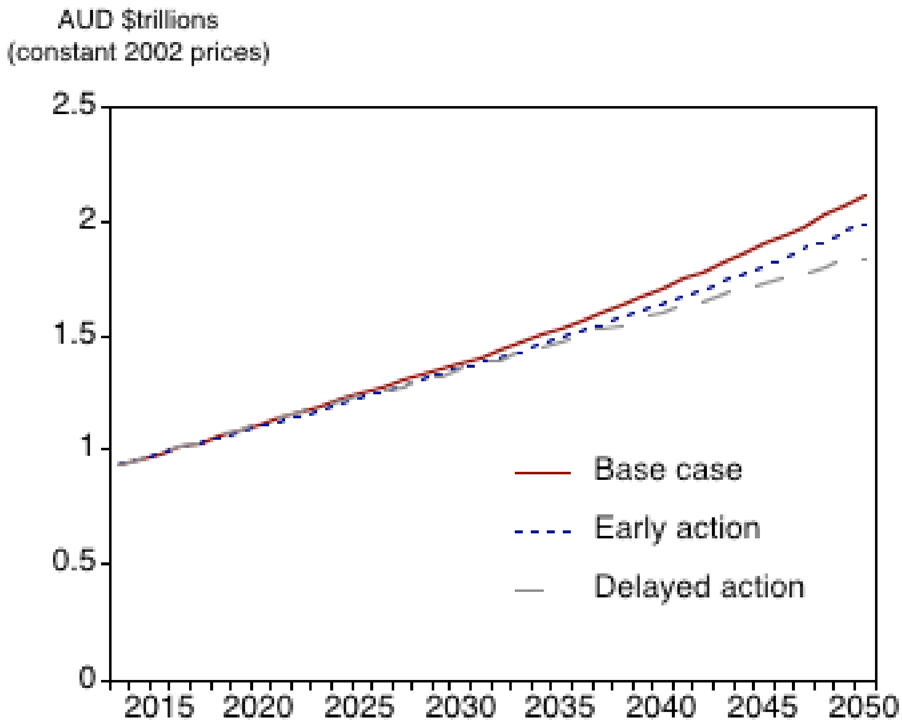


Source: MMRF–Green

Figure 4.4 below shows GDP changes under all three scenarios — the base case, early action and delayed action.

Figure 4.4

GDP FORECAST: EARLY ACTION, DELAYED ACTION AND BASE CASE



Source: MMRF–Green

Consumption

In line with the nature of relationships in the economy, the impact of the carbon price policy shock on consumption will largely mirror the impacts of the shock on GDP. However for a variety of reasons, the *net* impacts on consumption of the change in policy may differ from the net impact of the shock on GDP. Specifically, in both scenarios and for all years, the size of the impact on real consumption in absolute terms is smaller than the size of the impact on real GDP. This can be rationalised by noting that:

(i) the change in real GDP is approximately the change in real income generated in the economy;

(ii) the change in real income available for consumption is less than the change in real income generated because some of the generated income accrues to foreigners and of the income available to residents around 20 per cent is removed as income tax; and

(iii) the revenue raised via the carbon price is added to income available for consumption from GDP to yield total income available for consumption by residents.

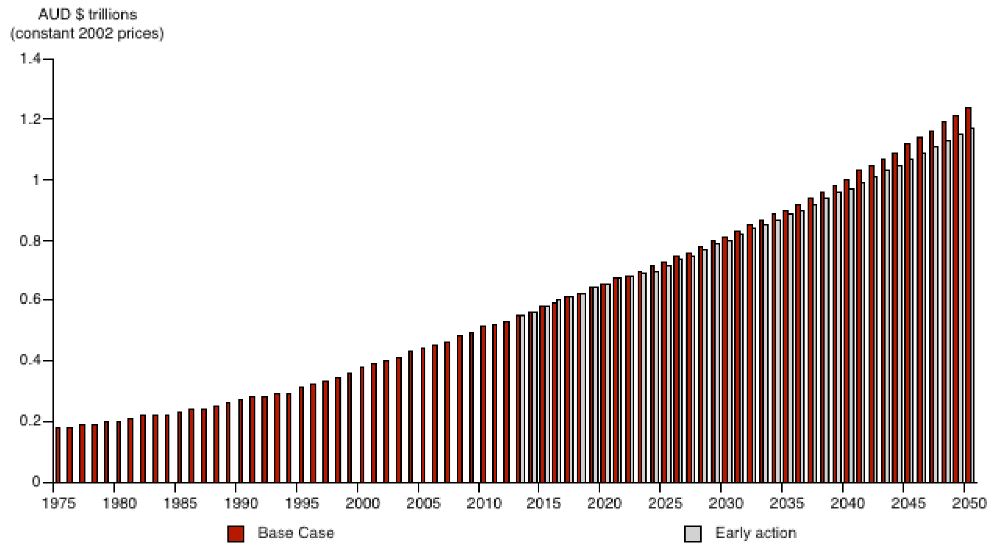
Taking account of (i), (ii) and (iii) allows us to explain nearly all of the relationship between changes (absolute and percentage) in real GDP and real consumption.

Early action scenario

In both the base case and the ‘early action’ scenario, real private consumption levels increase steadily over the period (see Figure 4.5).

Figure 4.5

EARLY ACTION SCENARIO, ACTUAL AND PROJECTED REAL PRIVATE CONSUMPTION



Source: MMRF–Green

By 2020, consumption is $653 billion under the base case. Under the ‘early action’ scenario, consumption in that year is actually $848 million higher than in the base case — as noted, this can be explained by the fact that the income generated by the carbon price adds to the income available for consumption, and in 2020, this effect dominates the income–reducing impact of the policy shock (noting that later in the forecast period, the relative impact of the two effects is reversed).

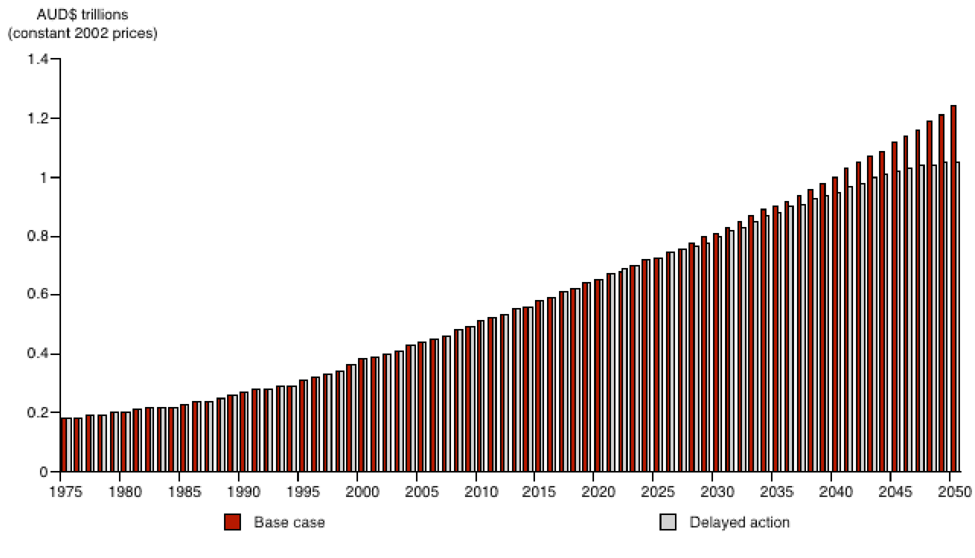
Real private consumption under the base case is forecast to reach $1.24 trillion in 2050. Under the 'early action' scenario, real private consumption is forecast to reach $1.17 trillion in 2050, a level which is reached in the base case by 2048. As was the case with real GDP, the rate of growth in real private consumption decreases between 2002 and 2050 under both scenarios.

Delayed action scenario

As with the base case and 'early action' scenarios, in the 'delayed action' scenario, real private consumption levels increase steadily over the period (see Figure 4.6). By 2020, real private consumption under the base case is forecast to reach $1.24 trillion in 2050, whereas under the 'delayed action' scenario, it is forecast to reach $1.05 trillion in the same year, a level which is reached in the base case by 2042. As was the case with real GDP, the rate of growth in real private consumption decreases between 2002 and 2050 under both the base case and 'delayed action' scenarios.

Figure 4.6

DELAYED ACTION SCENARIO, ACTUAL AND PROJECTED REAL PRIVATE CONSUMPTION

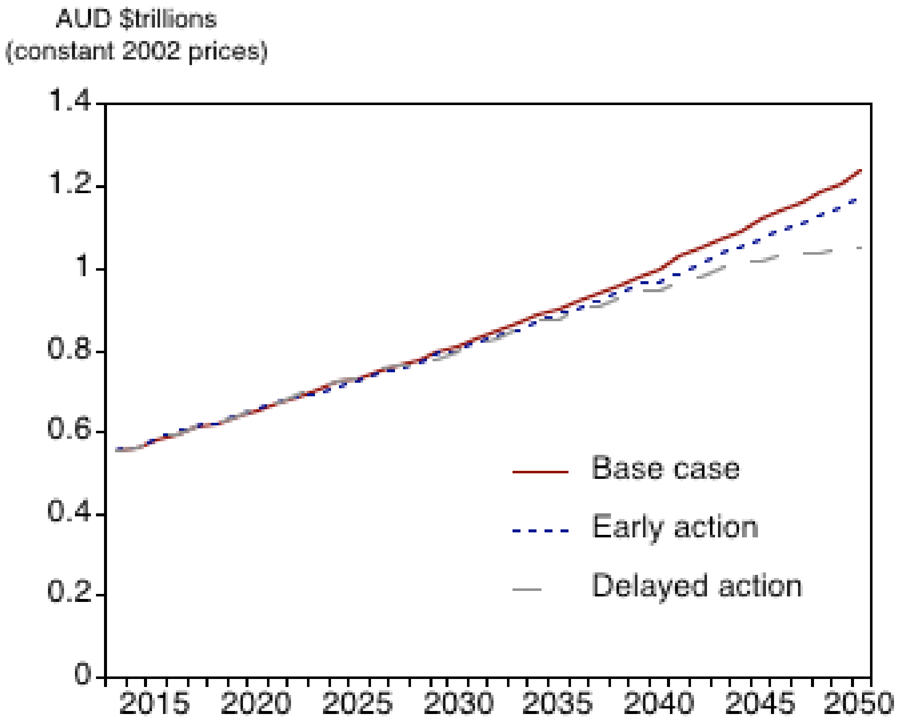


Source: MMRF–Green

Figure 4.7 below shows consumption in the base case, 'early action' and 'delayed action' scenarios.

Figure 4.7

CONSUMPTION FORECAST: EARLY ACTION, DELAYED ACTION AND BASE CASE



Source: MMRF–Green

Employment

It should be noted that in the MMRF–Green model it is difficult to generate any long–term impacts on employment. In general, real wages rather than employment levels are the mechanism by which economic 'shocks' are accommodated in the labour market. In this case, while the greenhouse policy shock does not have any significant lasting effect on employment in either the early or delayed action scenarios, real wages will be lower than they otherwise would have been.

Under the base case, employment grows by 38.9 per cent between 2010 and 2050. Under 'early action', this growth is slightly less at 38.7 per cent, representing a reduction of around 22,000 jobs in 2050. Under the 'delayed action' scenario, employment grows by only 36.2 per cent over the same period, representing a reduction of around 271,000 jobs relative to the base case in 2050.

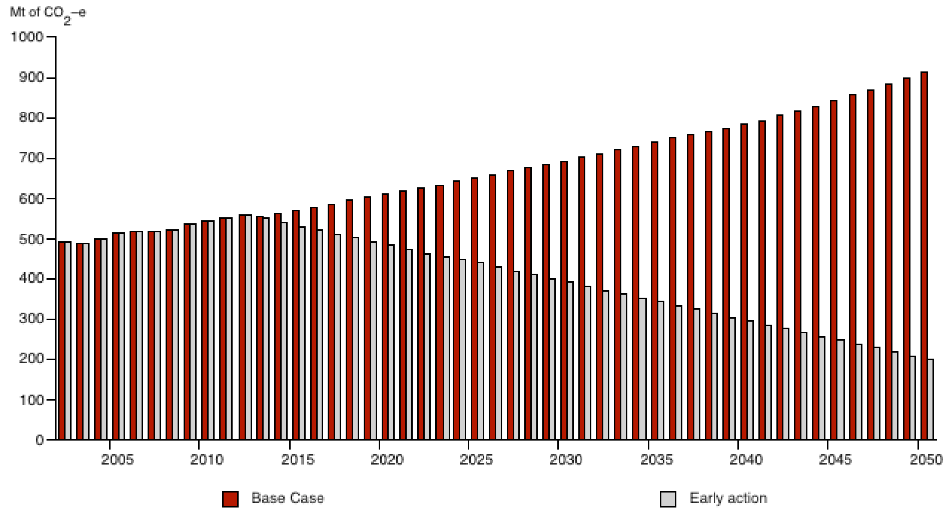
Greenhouse gas emissions

Early action scenario

In the base case, greenhouse gas emissions grow at a declining rate between 2002 and 2050, due to the changing nature of the economy forecast over that time, and to lower than current rates of economic growth forecast in future years. In contrast, under the 'early action' scenario, greenhouse gas emissions decline at an increasing rate (Figure 4.8). In line with the specification for the 'early action' scenario, the forecast for greenhouse gas emissions in 2050 under this scenario (199 Mt of CO_2) is significantly smaller than the forecast under the base case (914 Mt of CO_2).

Figure 4.8

EARLY ACTION SCENARIO, PROJECTED GREENHOUSE GAS EMISSIONS

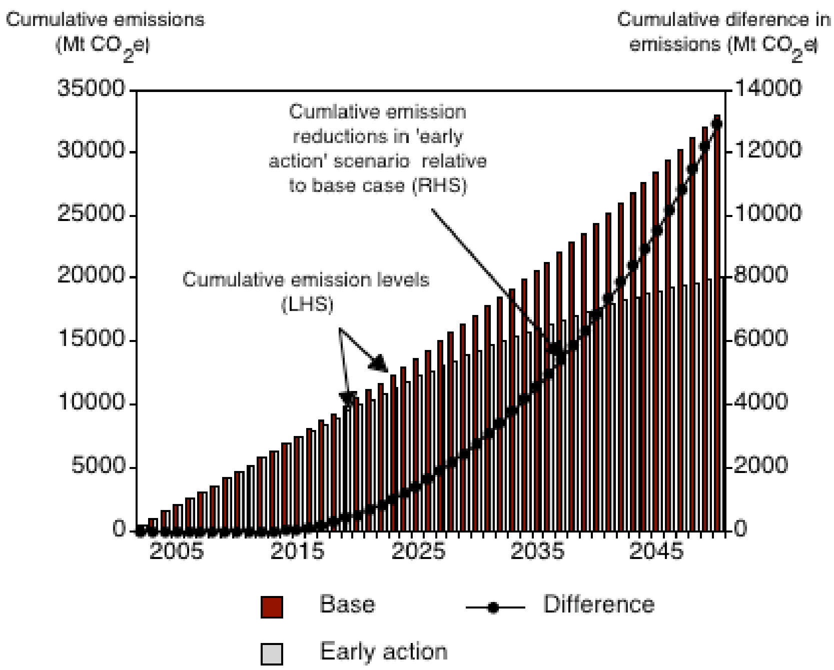


Source: MMRF–Green

In cumulative terms, emissions under the base case between 2002 and 2050 are 33 billion tonnes of CO_2–e, and under the 'early action' scenario are 20 billion (Figure 4.9).

Figure 4.9

CUMULATIVE EMISSIONS REDUCTIONS: EARLY ACTION SCENARIO



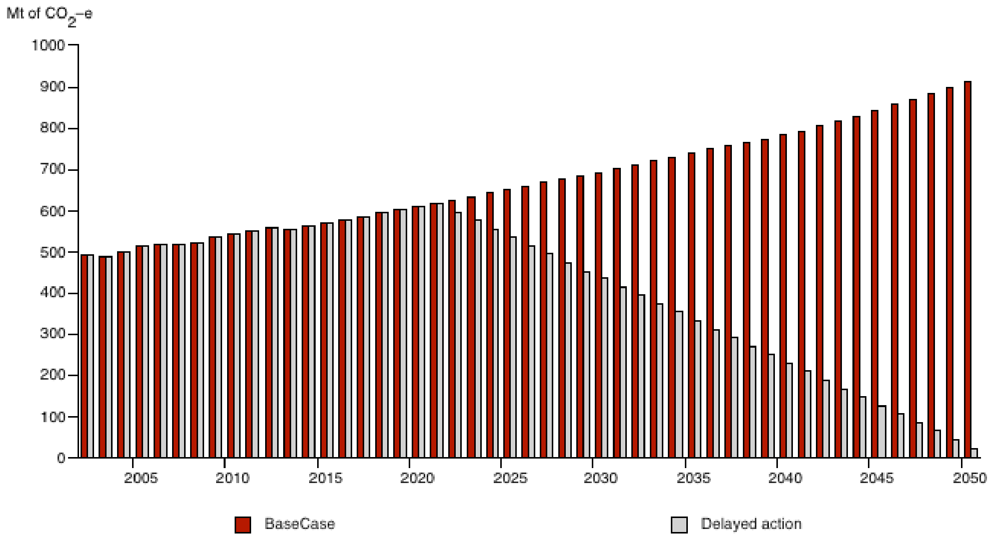
Source: MMRF–Green

The total quantum of emissions reduced under the 'early action' scenario over the entire forecast period (relative to the base case) is therefore around 13 billion tonnes of CO_2–e. The reduction in greenhouse gas emissions in 'early action' relative to the base case can be attributed largely to changes in the composition of the energy market, with particular reference to electricity generation. Reductions in emissions also occur in other sectors of the economy, notably transport and agriculture.

Delayed action scenario

Figure 4.10

DELAYED ACTION SCENARIO, PROJECTED GREENHOUSE GAS EMISSIONS

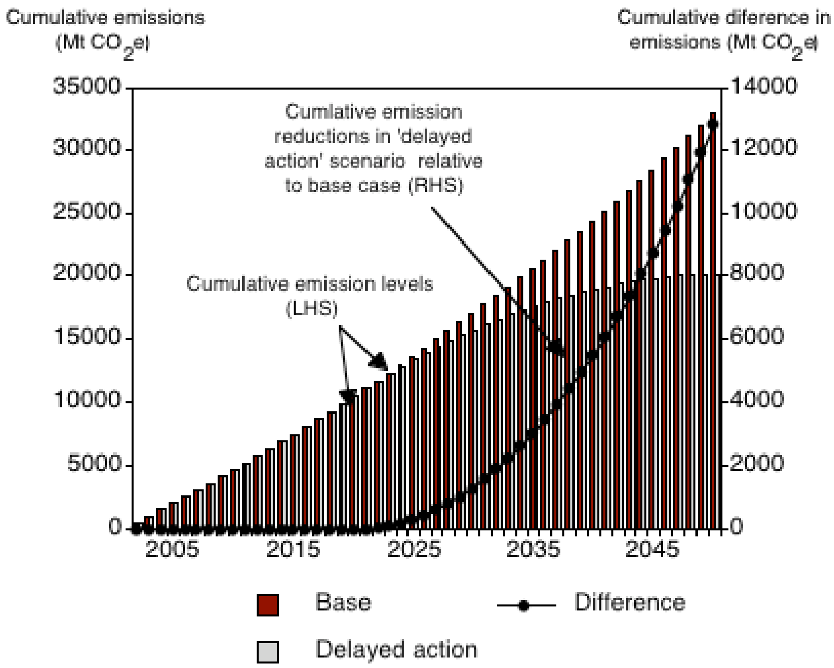


Source: MMRF–Green

Under the 'delayed action' scenario, greenhouse gas emissions in 2050 are 25 Mt of CO_2–e compared to 914 Mt in the base case (Figure 4.10), and 199 Mt in the 'early action' scenario. As noted earlier this occurs because in order to achieve the same quantum of emission reductions under a 'delayed action' scenario, annual reductions in each year are necessarily higher.

In cumulative terms, emissions under the base case between 2002 and 2050 are 33 billion tonnes of CO_2–e and under the 'delayed action' scenario are 20 billion tonnes (Figure 4.11). The total quantum of emissions reduced under the 'delayed action' scenario over the entire forecast period (relative to the base case) is therefore around 13 billion tonnes of CO_2–e. This is in line with the specification for the scenario which dictated that the quantum of emissions reduced under the early and delayed action scenarios was the same.

Figure 4.11
CUMULATIVE EMISSIONS REDUCTIONS: DELAYED ACTION SCENARIO



Source: MMRF–Green

Energy use

Early action scenario

In line with the fall in emissions, by 2050 total electricity generation under the ‘early action’ scenario (1140PJ) has fallen relative to the base case (1548PJ). Table 4.1 shows the breakdown of generation by source in 2020 and 2050 under ‘early action’. Generation in 2020 and 2050 is still dominated by coal under this scenario, although total generation from coal falls over the forecast period. Renewables and gas are boosted substantially under the ‘early action’ scenario.

Table 4.1

ELECTRICITY GENERATION BY SOURCE: THE 'EARLY ACTION' SCENARIO (PJ)

	2010	2020	2050	% change (2010–2050)
Black coal	465.9	410.0	326.3	–30%
Brown coal	199.1	164.1	72.3	–64%
Natural gas	134.9	197.1	289.5	115%
Liquids	3.5	3.5	3.5	0%
Hydro	64.8	74.2	84.5	30%
Biomass	18.5	37.9	193.5	946%
Biogas	3.2	6.5	32.4	913%
Solar	1.7	3.3	18.2	917%
Wind	10.2	23.0	119.7	1074%

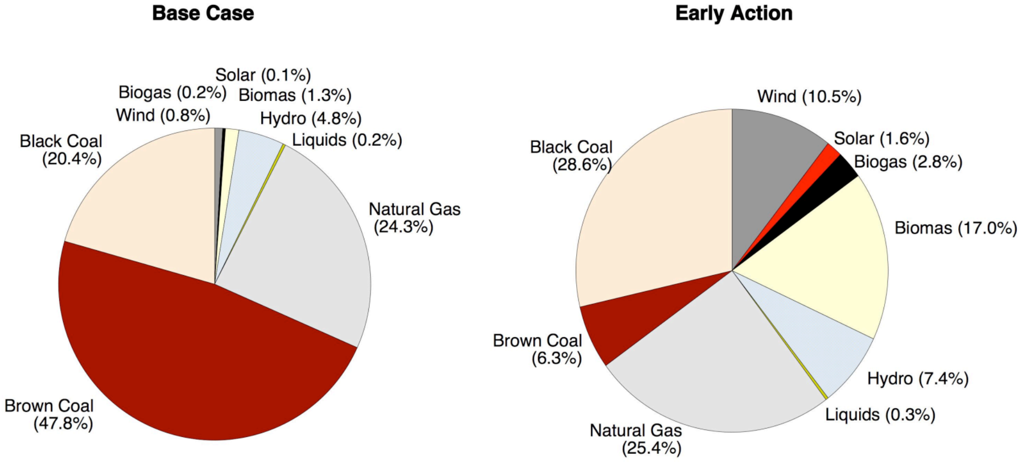
Source: MMRF–Green

Relative to the base case, the greatest proportional impacts are on electricity generated by coal (black and brown), biomass, wind and biogas (Figure 4.12). In 2050, generation from black coal accounts for only 29 per cent of total generation compared to 48 per cent under the base case. Similarly, the proportion of electricity generated by brown coal in 2050 falls from 20 per cent under the base case to 6 per cent in the 'early action' scenario. To some extent, these falls in the share of coal generation are ameliorated by the existence of opportunities for CCS in relation to the emissions from coal generation once this process becomes economic, in around 2022.

The decline in coal–generated electricity in the 'early action' scenario is offset by an increase in the proportion of electricity generated by renewable sources, particularly biomass, wind and biogas. Overall, renewables end up with around 40 per cent of the total generation mix in 2050 under the 'early action' scenario, compared to less than 10 per cent under the base case. Biomass shows the greatest increase, growing from one per cent under the base case to 17 per cent under 'early action'. Wind energy's share of the fuel mix grows from one per cent to 11 per cent, while biogas–generated electricity grows from a negligible contribution in the base case to 3 per cent under the 'early action' scenario.

Figure 4.12

EARLY ACTION SCENARIO, PROJECTED COMPOSITION OF ELECTRICITY GENERATION, 2050



Note: The 'solar' generation sector effectively refers to the amount of energy saved by the use of solar hot water systems.
Source: MMRF–Green

Delayed action scenario

In line with the fall in emissions, by 2050 total electricity generation under the 'delayed action' scenario (939PJ) has fallen relative to the base case (1548PJ) and the 'early action' scenario (1140PJ). Table 4.2 shows the breakdown of generation by source in 2050 under the 'delayed action' scenario. Generation in 2050 is no longer dominated by coal under the 'delayed action' scenario, with gas, biomass and wind energy supplying the majority of Australia's generation needs.

Table 4.2

DELAYED ACTION SCENARIO, ELECTRICITY GENERATION BY SOURCE (PJ)

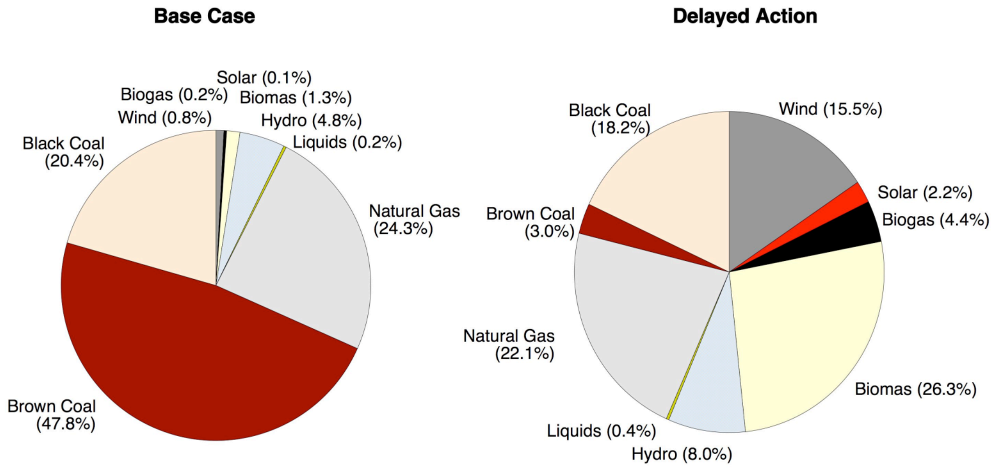
	2010	2020	2050	% change (2010–2050)
Black coal	465.9	522.9	171.1	–63%
Brown coal	199.1	221.6	28.1	–86%
Natural gas	134.9	178.4	208.2	54%
Liquids	3.5	3.5	3.5	0%
Hydro	64.8	67.4	74.8	15%
Biomass	18.5	20.2	246.7	1234%
Biogas	3.2	3.4	41.4	1194%
Solar	1.7	1.8	20.6	1112%
Wind	10.2	12.9	145.2	1324%

Source: MMRF–Green

As with the 'early action' scenario, the fuel mix changes substantially relative to the base case under the 'delayed action' scenario. In 2050, renewables account for around half of electricity generation under the delayed action scenario, with wind energy alone accounting for over a quarter of all generation (Figure 4.13). Coal generation in 2050 under the 'delayed action' scenario accounts for only 21 per cent of electricity generation, down from nearly 70 per cent in the base case.

Figure 4.13

DELAYED ACTION SCENARIO, PROJECTED COMPOSITION OF ELECTRICITY GENERATION, 2050



Note: The 'solar' generation sector effectively refers to the amount of energy saved by the use of solar hot water systems

Source: MMRF–Green

Electricity prices

Figure 4.14 below shows the wholesale electricity price under the 'early action' and 'delayed action' scenario, relative to the base case.

Early action scenario

By 2025, the price of electricity under the 'early action' scenario is forecast to be 17 per cent higher than the price of electricity under the base case, with this differential growing to 53 per cent by 2050.

The relative increase in electricity prices under the 'early action' scenario can be largely explained by the adoption of cleaner — although relatively more expensive — electricity generation sources from 2022 onwards, and by the imposition of a carbon price and/or abatement costs (for example, CCS) on more greenhouse–intensive generation such as coal.

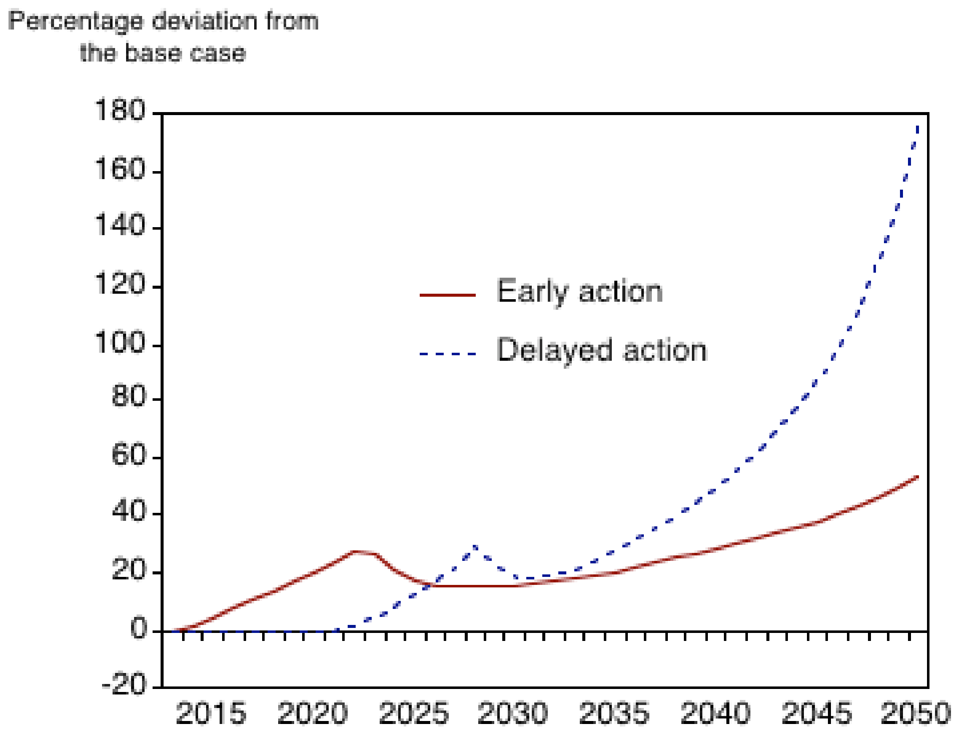
Delayed action scenario

By 2025, the price of electricity under 'delayed action' is forecast to be 12 per cent higher than under the base case, growing to 175 per cent higher by 2050 — significantly higher than under the 'early action' scenario (53 per cent higher in 2050).

The percentage deviation rises to a peak of 29 per cent in 2028 and subsides to 19 per cent in 2030, before rising steadily once again. This decline in the percentage deviation of electricity prices in the 'delayed action' scenario relative to the base case is once again due to the fact that CCS in relation to emissions from fossil fuel–

based electricity generation becomes viable in about 2027 (later than in the 'early action' scenario because of the delayed action assumptions).

Figure 4.14
ELECTRICITY PRICE: DEVIATION FROM BASE CASE UNDER EARLY AND DELAYED ACTION



Source: MMRF–Green

4.3 Sensitivity analyses

As noted, both the 'early action' and 'delayed action' scenarios incorporated a range of underlying assumptions that were imposed exogenously on the modelling scenario. In order to test the impact of two of these assumptions on the results — specifically those assumptions in relation to the terms of trade and the autonomous energy efficiency improvement rates for end use energy technologies — some sensitivity analyses were undertaken. The sensitivity analyses focus on the 'early action' scenario results, although the results are applicable to both scenarios.

Terms of trade

Overall economic impacts

Because exports and imports are a key component of Australia's economic performance, the assumptions made about the movements in supply and demand for some of Australia's traded commodities have the potential to impact on the overall economic impact of the emissions reduction target imposed in the 'early action' scenario. More particularly, the movements in economic activity under the 'early action' scenario are due primarily to three factors:

- the carbon price;
- the costs of abatement undertaken to avoid this carbon price; and

- shifts in the terms of trade.

Analysis of the modelling results by COPS determined that the first two of these factors account for around 85 per cent of the total impact on economic activity, while the terms of trade has only a moderate impact (15 per cent).

Of this moderate terms of trade impact:

- endogenous effects, as exchange rates move to shift demand and supply for exports and imports, are the main impact (about 80 per cent); and
- the imposed exogenous assumptions about changes in world demand and supply for energy–related goods have a relatively small impact (about 20 per cent).

We can therefore conclude that the terms of trade doesn't have a substantial impact on overall GDP, and of the impact that the terms of trade does have, only a small amount is derived from the exogenous assumptions about changes in supply of and demand for traded commodities. On this basis, we can conclude that the terms of trade assumptions do not have a substantial impact on overall macroeconomic outcomes in this analysis.

Impacts on specific sectors

While the terms of trade assumptions do not appear to have had a major impact on the overall economic results, the assumptions are likely to have played a significant role in the projected impacts for some individual industry sectors. This is consistent with the fact that, in reality, it is very likely that changes in world prices would be a key factor in driving the impacts of global emissions reductions on Australia's energy–intensive traded goods businesses.

Table 4.3

IMPACT OF TERMS OF TRADE ASSUMPTIONS ON EXPORTS FOR PARTICULAR INDUSTRIES

	Exogenous export assumption[a]	Ratio of exports to total sales	Industry outcome in 2050 (% from base case)	Impact of assumption in industry outcome
Iron ore	–10	79.3	–18.3	HIGH
Black coal	–50	75.0	–48.6	HIGH
Oil	–50	21.7	–40.2	MODERATE
Natural gas	+50	44.3	0.1	MODERATE
Chemicals	–20	14.4	–1.3	LOW
Steel	–20	20.3	1.2	MODERATE
Aluminium	–20	77.0	–78.9	HIGH
Non iron ore	+100	60.0	8.1	HIGH

Notes: [a] This is the shift in world demand schedules for a \$100 per tonne of CO_2–e carbon price.
Source: MMRF–Green

Any exogenous assumptions about imports and exports will essentially drive the trade outcome for those affected industries over the forecast period. It follows that the extent to which the assumption drives the overall industry output outcome depends on the importance of exports relative to domestic activity in each sector. Table 4.3 shows the importance of exports, and hence the exogenous terms of trade assumptions, in generating the overall industry outcome in 2050 for each of the relevant industry sectors.

The key conclusions illustrated by Table 4.3 are that:

- for the chemicals sector, the assumptions play only a small role in the industry's performance under the ‘early action’ scenario;
- for the oil, natural gas and steel sectors, the assumptions play some role, but other factors (such as, for example, the deleterious impact of increased energy prices on supply) are also likely to be driving the overall outcome for the industry sector; and
- for iron ore, black coal, aluminium and non iron–ore, the assumption accounts for a high proportion of the overall industry impact under the ‘early action’ scenario.

AEEI factors

The ‘early action’ scenario assumed an annual AEEI improvement of 1.2 per cent for end use energy technologies. Two further scenarios were run to test the sensitivity of the results to this AEEI assumption:

- an AEEI of 0.9 per cent i.e. slower energy efficiency improvement; and
- an AEEI of 1.5 per cent i.e. faster energy efficiency improvement.

The results of these additional scenario show that the change in the AEEI rate has virtually no impact on GDP outcomes — or, it follows, on any other major macroeconomic variables (Table 4.4).

This does not mean however that the assumptions regarding AEEI factors will have no impact on other key results. In particular, levels of energy usage — and the effects these have on structural aspects of the economy — can be expected to vary with the level of AEEI chosen.

Table 4.4

AEEI SENSITIVITY ANALYSIS: MACROECONOMIC OUTCOMES

	Base case	‘Early action’ (1.2%)	EAa* (0.9%)	EAb** (1.5%)
GDP in 2050 ($tr.)	2.11	1.99	1.99	1.98
% change in GDP		–5.8	–5.6	–6.1

Source: MMRF–Green.
Notes:*EAa reflects slower AEEI than the ‘early action’ scenario
** EAb reflects faster AEEI than the ‘early action’ scenario.

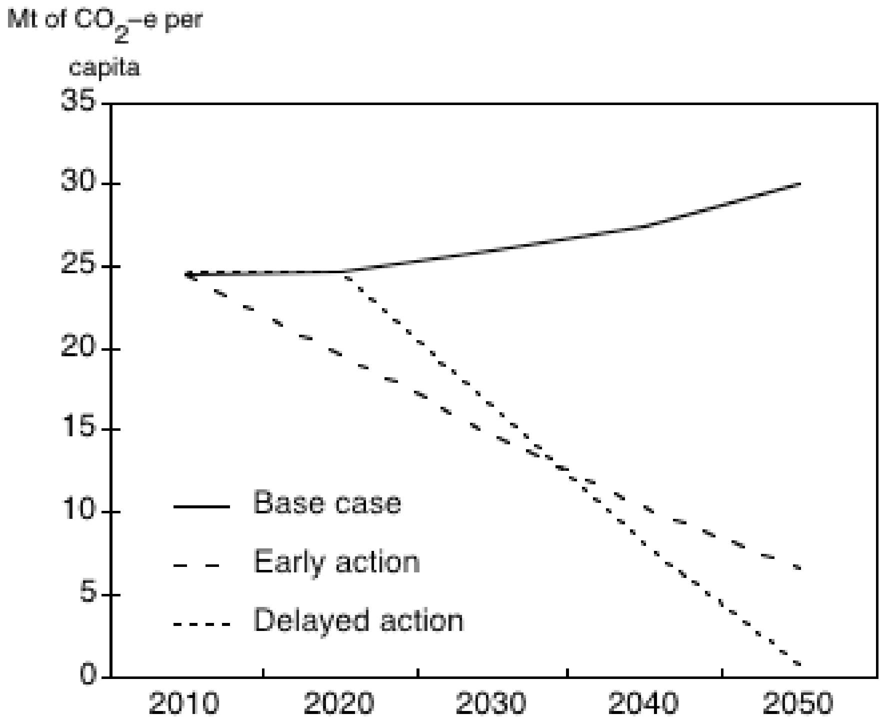
4.4 Other effects

Changes in Australia's emissions per capita

The achievement of the emissions target in 2050 is reflected in Australia's emissions per capita over the forecast period (Figure 4.15). In the 'early action' scenario, emissions per head of the population fall from 24.6 tonnes of CO_2–e in 2010 to 6.6 tonnes in 2050. In the 'delayed action' scenario, emissions per head fall to 0.8 tonnes by 2050. This compares to a level of emissions per capita in 2050 under the base case of 30.1 tonnes.

Figure 4.15

EMISSIONS PER CAPITA: EARLY AND DELAYED ACTION SCENARIOS



Source: MMRF–Green

Externalities

Finally, it is worth noting that may be a range of benefits from positive externalities associated with action to reach a long–term target for GHG emission reductions. These benefits have not been captured by the modelling done for this report. In particular, urban air quality is likely to improve under a scenario where substantial cuts in greenhouse emissions bring about a reduction in the use of fossil–fuel based passenger cars and other forms of transport. Other potential non–modelled benefits include reduced road congestion and reduced air pollution in areas of intensive electricity generation activity (e.g. the Latrobe Valley in Victoria).

Chapter 5

Conclusions and implications

5.1 Conclusions

The first major conclusion from the results of this analysis is that the cost to the Australian economy of achieving a 60 per cent reduction in emissions from 2000 levels by 2050, while high in absolute terms, is manageable over such a long period of time.

In GDP terms, the economy grows by 120 per cent between 2013 and 2050 in the 'early action' scenario compared with an expansion of about 130 per cent over the same time period under the base case. Put another way, the GDP cost of meeting the target under the 'early action' scenario ('early action') was estimated at around 6 per cent of GDP (relative to the base case) in 2050. Estimates of the GDP impact of other policy changes in recent years help to put this cost into context:

- Work by The Allen Consulting Group in 2000 estimated that the economic cost to Australia of meeting the Kyoto target was about 2 per cent of GDP (although it should be noted at that time that projections of the 'emissions gap' that needed to be bridged were highly pessimistic). The Kyoto Protocol is widely regarded as a partial and initial step in addressing the long term issue of climate change, and — on its own — will not result in anywhere near the global emission reductions needed to achieve CO_2 stabilisation at the levels required to avoid catastrophic climate change.[31]
- General equilibrium estimates of the negative impact of tariff protection in Australia in the 1970s typically lie around 3 per cent of GDP.[32]
- Work by the Productivity Commission has concluded that National Competition Policy (NCP) reforms will eventually boost Australia's GDP by at least 2.5 per cent, and possibly by up to as much as 5.5 per cent of GDP.[33]

In the general context of the impacts of these other policy changes, provided that the policy delivers the benefits required of it, a GDP cost of 6 per cent over four decades can arguably be described as manageable.[34]

The second major conclusion is that the modelling results demonstrate that 'early action' to reduce greenhouse gas emissions will be substantially less costly than a delayed response directed towards achieving the same quantum of emission reductions. The difference in economic impact between the two approaches to action is disproportionate to the nine–year delay embodied in the 'delayed action' scenario. In particular:

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[31] The Allen Consulting Group 2000, *Meeting the Kyoto Target: Impact on the Australian Economy*, report to the Minerals Council of Australia.

[32] J. Quiggin 1994, 'Tariff misunderstandings', *The Australian Financial Review*, 22 June 1994, sourced from http://www.uq.edu.au/economics/johnquiggin/news94/Tariff9406.html on 2 September 2005.

[33] Productivity Commission 2005, *Review of National Competition Policy Reforms*, Productivity Commission Inquiry Report No. 33, 28 February.

[34] While comparisons such as these are useful at a broad level, the economic impacts of different policy settings are not necessarily directly comparable due to the differing assumptions that are likely to be underlying each.

- With abatement action commencing in 2013, a 60 per cent reduction in emissions can be achieved with a loss in average annual GDP growth of 0.1 per cent and a 'delay' in GDP of 2.5 years. When action is delayed by just 9 years, the impact on GDP is considerably and disproportionately larger — average annual growth falls by 0.3 per cent and the delay in GDP increases to 6 years.
- In percentage terms, the fall in GDP in 2050 (relative to the base case) with delayed action is 13 per cent. This compares much less favourably with the alternative policy measures cited above than the 6 per cent impact associated with 'early action' under the 'early action' scenario.
- Employment grows at 38.7 per cent when action to meet the abatement target starts in 2013, but at only 36.2 per cent under delayed action.
- Electricity prices increase by 53 per cent in 2050 (relative to base) under 'early action' but by over three times this amount (173 per cent) when action is delayed by 9 years until 2022.

In the modelling this result is driven largely by:

- the expected outcome that larger annual reductions in emissions — such as those required when action is delayed — necessarily require greater adjustment which, in turn, results in sharper economic impacts; and
- the fact that technological advancement — as represented in the model by increasing autonomous energy efficiency improvements — accelerates over time. Technological change makes achieving emission reductions targets relatively easier (that is, less costly in economic terms) and so the earlier such action is commenced, the greater the eventual benefits.

Finally, it should be noted that it is difficult to put our results into perspective because the analysis does not incorporate the economic benefits of avoiding climate change. It is difficult to assess whether the costs of taking significant global action are high or low unless they can be related to the benefits of the policy, that is the costs of not taking action. Until the scientists can provide us with credible estimates of these costs, the value of studies such as this is necessarily limited.

5.2 Implications

It could be argued that some of our assumptions tended to reduce the economic cost of achieving the substantial reduction in emissions evaluated in this study. It is important to note, for example, that the economic impacts derived in this analysis were driven to a large degree by our assumptions in relation to the rate of technological change as well as a higher take–up of energy efficiency opportunities than has been the experience in the past.

In a wider sense, many of these assumptions are critical to future climate change policy in that they provide a framework within which substantial abatement of greenhouse gas emissions can feasibly be achieved. In that context, some important implications of this study relate to the role that policy can play in delivering the changes in behaviour that would make our assumptions realistic. The analysis in this report rests heavily on assumptions in four areas:

- the development of a global agreement to take concerted action;

- the achievement of substantial technological change;
- the achievement of significant energy conservation; and
- the existence of a carbon price.

The implications of our assumptions in each of these areas are considered below.

Securing a global agreement

> The truth is no country is going to cut its growth or consumption substantially in the light of a long–term environmental problem. What countries are prepared to do is to try to work together cooperatively to deal with this problem in a way that allows us to develop the science and technology in a beneficial way.
>
> Rt Hon Tony Blair, MP, British Prime Minister, New York, 15 September 2005

As is canvassed in Chapter 1, the major implication of taking action to address climate change is that such action needs to be on a global scale. Unilateral action on the part of Australia to make deep cuts in emissions would only serve to reduce the welfare of the community through carbon leakage while having a negligible impact on global warming. The analysis in this report is based on the assumption that Australia takes action in concert with the global community.

While it is clear that only action on a global scale can be effective, achieving an international agreement on effective action to combat climate change in the longer term will be difficult. The major efforts that were made in the 1990s, first with the 1992 Earth Summit at Rio de Janeiro and then five years later the conference of the parties to the UNFCCC at Kyoto, have not led to an agreed pathway to global action. The fundamental problem is that such action would require economic costs to be imposed now (on the present generation) in order to create benefits for the global community in the future. The political difficulty of such a course of action is likely to be a major contributor to the current level of relative inertia in international forums. Tony Blair, a strong advocate of the need to take remedial action to address climate change, acknowledged this recently (see above). This issue lies at the heart of what is presently a severe disconnect between what the majority of scientific experts tell us needs to be done and the lack of concerted action by world leaders.

The Kyoto Protocol, which entered into force in February 2005, still provides the obvious vehicle for longer term global action. The Protocol has some major problems including the fact that it covers only around 30 per cent of global emissions while the principal emitting nation, the United States, has rejected it. Nevertheless, while in its present form it will do little to slow down the rate of global warming, the overwhelming majority of nations represented at the conference of the parties held at Montreal in late–2005 voted to continue to seek agreement on post–2012 action within the framework of the Protocol. The challenge remains, however, to secure commitments from the world's major emitters to substantially reduce their emissions over time. Without such drastic action, it will not be possible to stabilise carbon concentrations in the atmosphere and arrest global warming.

While the US and Australia continue to reject the Protocol, the recent agreement on climate change between the United States, Australia, Japan, China, India and South Korea could, in principle, provide a platform for a complementary approach. The Asia–Pacific Partnership on Clean Development and Climate engages the major current and future emitters, namely the US, China and India in an arrangement analogous to the "Clean Development Mechanism" of the Kyoto Protocol – but with a longer term focus on technology transfer and development.

Of course, the Partnership is at an early stage and contains some obvious gaps. There is no discussion of a longer–term target nor any acknowledgement of the role that could be played by a market signal, in the form of a carbon price, both in stimulating research into greenhouse–friendly energy technologies and providing the incentive needed to deploy them. The partners will also need to examine issues such as equitable burden sharing between the parties and how to engage other emitting countries. These vexed issues are familiar to those who have tracked negotiations under the Kyoto Protocol.

Overall, however, the assumption of a global agreement is fundamental to our analysis. While some of our other assumptions may have made the modelling results more benign, it should also be noted that our analysis did not incorporate international emissions trading. If this policy instrument were to emerge from a future international agreement (it already forms part of the Kyoto Protocol), other things being equal it would be likely to lower the costs for individual countries of achieving its emissions target and the efficiency of global action overall.

Fostering the development of low emissions technologies

> 'The Stone Age didn't end because we ran out of stones…'
>
> Sheik Yamani, Saudi Arabian Oil Minister, during the first oil shock
>
> '… and the oil age won't end because we run out of oil.'
>
> Don Hubert, head of Shell Hydrogen, 2002

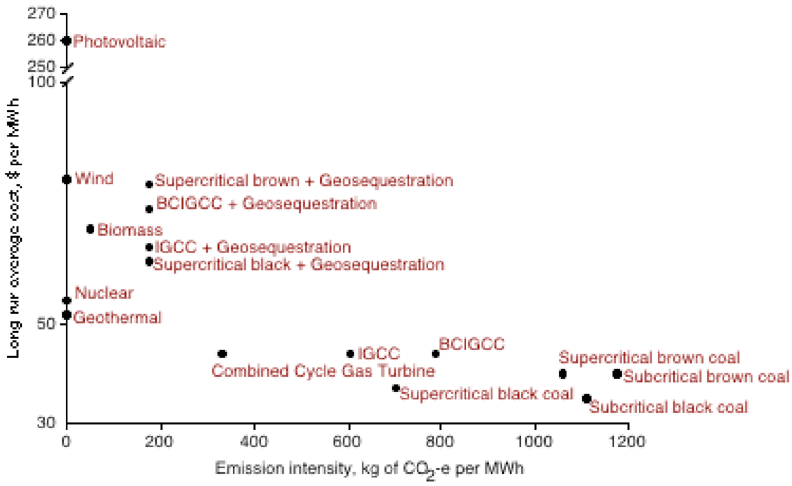
Some may assert that our assumptions on technological change are overly optimistic. On the other hand, the technologies already exist to provide the world with greenhouse–friendly energy sources. The main difficulty with these alternative sources of energy, however, is that they are all more costly than the fossil fuels that are the basis of current technologies. It is interesting that technological development in electricity generation has been relatively slow. As one observer noted recently, 'it is a curious lacuna that the most technologically progressive century in history ended with fuel technologies not fundamentally different from those employed when it began'.[35]

Some indicative data for the stationary energy sector are provided in Figure 5.1. At present, most greenhouse–friendly technologies are not cost–competitive. Geosequestration of emissions from coal–fired generators is still likely to be expensive, for example, with capture costs currently unlikely to be below around \$40–50/tonne CO_2 and transportation and injection costs around \$10/tonne each. Wind generation costs about twice as much as black and brown coal generation and needs to be substantially backed–up by more reliable energy sources, while biomass is not much less expensive. Geothermal technologies may well be cost–effective and Australia has some promising sites, but it is presently difficult to see how geothermal plants could account for more than a relatively modest proportion of electricity demand.

[35] John Kay 2005, *Financial Times*, 26 July.

Figure 5.1

ELECTRICITY GENERATION: INDICATIVE COSTS AND EMISSION INTENSITY BY FUEL SOURCE



Sources: MMA; The Allen Consulting Group; and The Australian Government, 2004, *Securing Australia's Future* (White Paper). Note: Based on assumed cost of geosequestration of \$50 per tonne of CO_2–e. Key: BCIGCC = Brown Coal Integrated Gasified Combined Cycle; IGCC = Integrated Gasified Combined Cycle; CCGT = Combined Cycle Gas Turbine.

A resurgence in interest in nuclear power is now under way globally, with 23 reactors currently under construction worldwide and 39 more at the planning stage. If global electricity markets switch to uranium from coal, Australia, with over 40 per cent of the world's economically recoverable reserves, is well–placed to supply it, while the price of uranium on world markets has more than tripled since 2001.[36] Since nuclear power is presently proscribed by law in Australia, however, potential investors have not undertaken feasibility studies and so the available evidence on relative costs is limited. International estimates from recent reports, however, suggest it could be up to 50 per cent more costly than current technology coal–fired electricity. While this also makes it uncompetitive with gas combined cycle, this would not be the case when the carbon price reached a relatively modest level of around \$25–30/tonne of CO_2.

It is widely recognised that nuclear power brings with it significant problems, such as waste disposal and weapons proliferation. These impediments are also of a global nature, however, and it would make little difference to resolving them if Australia, which is in any case a major player in the world's nuclear industry, chose not to participate in atomic generation.

Clearly significant R&D is required in order to bring these and other technologies to market at a competitive cost. This again is a global issue and the United States in particular, through the Department of Energy, has committed very substantial funding. Europe leads the world into research into renewable technologies, where costs clearly need to be reduced and the issue of reliability addressed. Australian researchers, however, can also contribute in an important way to this global effort, perhaps most effectively by specialising in niches where scientists and engineers

[36] P. Munter 2005, 'Finland stomachs extra nuclear plant to sate its growing energy hunger', *Financial Times*, 1 November, p. 3.

may have a particular expertise and in those fuels where Australia has a particular advantage. At present, there is a strong emphasis on cleaner coal technologies and geosequestration. This reflects Australia's strong global position as a supplier of coal, as well as the substantial reserves of lignite available in Victoria. Given that Australia's international position as a supplier of uranium is perhaps even stronger, this country could also direct some of its research efforts towards nuclear safety. Synroc is, after all, an Australian invention. CSIRO also has some advantages in solar photovoltaics, fuel cells and in hybrid car technologies, having combined with Holden to design and build a 'clean and green' Commodore. The relative cost-effectiveness of established, new and emerging technologies is a major issue — as is the question of how much further improvement can be expected from each of these in the future.

The Commonwealth Government has committed some funding to R&D, particularly in the areas of cleaner coal technologies, in the context of the Low Emissions Technology Development Fund. Victoria has also provided some funding. While action on the supply side is welcome, however, only the existence of a carbon price or some other market signal will encourage the private sector to develop greenhouse–friendly technologies and invest in their deployment. The Mandatory Renewable Energy Target (MRET) has performed this function for renewable technologies.

One immediate issue with introducing alternative technologies is timing. Baseload electricity generation plant in particular has a high capital cost and a long economic life of around fifty years. There are obvious costs involved in scrapping efficient plant prematurely. This is another reason why a long–term target — such as 50 or 60 per cent cuts by 2050 — may be appropriate. It allows investment in new greenhouse–friendly technologies to be planned so as to minimise cost, while most existing plant could be allowed to continue to operate for the duration of its economic life. This approach was not factored into our modelling, but it could be in the future if an engineering–based model of the energy sector were employed.

The key question for policy makers, however, remains. How can we encourage the necessary R&D into both developing new greenhouse–friendly technologies and reducing the cost of those that have already been developed? Ultimately a two–pronged approach is required, combining the provisions of incentives on the supply side together with the imposition of a market signal that encourages investors to deploy the new technologies.

Encouraging energy efficiency

One means of reducing greenhouse gas emissions is to pursue a policy of energy conservation. Energy is relatively cheap in Australia and there is considerable evidence to suggest that it is consumed in a fairly prodigal manner

In the economist's idealised and rational world there would be no need to encourage energy efficiency. Economic agents (households, industry and the government sector) would behave rationally and therefore would use energy with perfect efficiency in terms of its cost. Assuming profit maximisation, no economic agent would consume energy that they did not need to. Investment in equipment that would allow less energy to be consumed would occur when the pay–off from the capital expenditure matched that of other investments with a similar level of risk.

The more complex view is that the 'Economics 101' view of energy efficiency is overly simplistic in that economic agents do not always maximise profits or minimise costs. In most cases, the cost of energy used is not a big item in the budget. Businesses operating in industries that are not energy–intensive do not bother much about energy efficiency. The investment committee of company boards are generally much more interested in investments that directly grow the business or help to establish a sustainable competitive advantage than those that reduce costs. A number of studies have shown that households, companies and other agencies do not operate at optimal energy efficiency and do not take up available cost–effective measures to reduce their energy costs. Even energy–intensive businesses, like aluminium smelting, could often efficiently reduce their consumption of energy.

Two difficulties arise from a policy perspective. The first is to convince policy–makers that there is an issue here that needs to be addressed. This cause received a setback recently when the Productivity Commission's report on energy efficiency appeared to reject most policy options except the provision of more information, although it did acknowledge greenhouse as a justification for policy action.[37] Despite the findings of this report, however, the COAG Ministerial Council on Energy has the issue of energy efficiency on its agenda and will continue to examine policy solutions.

This takes us to the second difficulty, namely the lack of an obvious policy instrument. Early attempts to find an answer took the form of the provision of information, often by means of energy audits, on how companies could conserve energy and use it more efficiently. By and large, this approach has not been successful.

More recently, in certain jurisdictions, companies planning major new investments have been subject to audits and required to meet certain standards of energy efficiency (often some measure of world's best practice) and to invest in energy conservation measures where these meet a certain pay–off benchmark. This approach is more successful but necessarily only covers a small part of the overall economy and involves relatively heavy–handed intervention. Regulation, in terms of building standards, for example, can also be successful but again has a relatively small footprint in that it does not cover the existing stock of buildings.

Regulation may provide an appropriate approach in the transport sector. The recent report by the IEA noted that Australia had some of the least stringent fuel efficiency standards among its member countries. One reason for this is that, from the global perspective at least, the Australian vehicle industry is a niche producer of cars and that niche is inevitably to be found at the large vehicle end of the market.[38] Nevertheless, such vehicles do not need to be powered by large petrol engines. While more than half the new cars now sold in Europe are powered by more fuel–efficient, high technology diesel engines, no Australian producer offers a diesel engine in any of their models.[39] If fuel efficiency standards were to be tightened in Australia, the industry may choose to meet these standards by introducing some new powerplant options, such as diesels and hybrids.

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[37] Productivity Commission 2005, *Report on Energy Efficiency*, available at http://www.pc.gov.au

[38] 'Inevitably' because the Australian industry would be uncompetitive in other market segments due to a lack of scale.

[39] For example, the BMW 3–litre diesel engine now offers the same performance as the much admired 3–litre petrol engine but with superior fuel economy.

It seems apparent that judicious regulation can play a significant role in encouraging energy efficiency. But it needs to be supplemented by a wider measure that has yet to be designed. A market–based measure, if efficient and effective, would offer a prospective way forward.

Introducing a carbon price

Ultimately it is difficult to escape the need to introduce a signal into the market that effectively imposes a price on greenhouse gas emissions. We can design and implement the most innovative supply side measures in the world to provide incentives for the development of greenhouse–friendly technologies, but unless these processes are cheaper than existing systems, no rational investor will deploy them in the absence of a carbon signal. This also suggests that the level of investment in the necessary R&D will be substantially lower than it would be in the presence of a carbon signal.

On the other hand, it is unlikely that a rational Australian government will unilaterally introduce a *substantial* carbon price into the economy. Such a measure would have next to no impact on global warming while causing investment and jobs to flow overseas and reducing the economic wellbeing of the community. This is why the emphasis of the national government should be on negotiating measures to be introduced internationally by major emitters after 2012. In that context, the type of measure most likely to be acceptable, at least in the short to medium term, may be one along the lines of the McKibbin–Wilcoxen proposal where the future price of carbon would be known with reasonable certainty.[40] When the world has become used to emissions trading in a carbon constrained world, quantity–based targets may be more practical in about twenty years time if the idea of deep cuts by 2050 becomes enshrined in a global agreement. Notably, in the interim, price certainty can be facilitated through a formal "alternative permit seller" arrangement or a system of agreed non-compliance penalties that act as an explicit price capping mechanism.

Nevertheless, Australian governments may find it difficult to ignore the arguments in favour of the introduction of clearer carbon signals into the national economy in the near future.[41] The most immediate reason for this is that investment decisions will need to be taken in the next few years on new baseload electricity generation plant in the National Electricity Market. In the absence of an explicit or implicit carbon signal, logic suggests that investors would choose the most cost–effective technologies, namely brown or black coal. In the face of greenhouse policy uncertainty and in the absence of a government indemnity, however, what rational investor would commit billions of dollars to a greenhouse–unfriendly asset with a fifty–year life? On the other hand, without some market signal an investment in, say, a gas generator is unlikely to be forthcoming. A carbon signal of around $10–15/tonne of CO_2, for example, would be required to ensure that the next generation of baseload generators would use gas rather than coal.

Of course, such outcomes may be brought about without the imposition of an explicit carbon price. In some States where electricity assets are publicly owned, governments may mandate the technologies that are to be employed. In Western

40 W. J. McKibbin & P. J. Wilcoxen 2003, *Estimates of the Costs of Kyoto–Marrakesh Versus The McKibbin–Wilcoxen Blueprint*, The Brookings Institution, February.

41 The recent report by the IEA also endorsed this view. See IEA 2005, *Energy Policies of IEA Countries, Australia 2005,* International Energy Agency, OECD, Paris, August 2005.

Australia, for example, the government decided in August 2005 that the next generator would be fuelled by natural gas. This decision surprised many observers. The fact that in the 1990s the Court government had decided, somewhat controversially even then, that the Collie Stage 1 generator would be coal–based suggested that thereafter it would be more economic to use coal for Collie Stage 2.

Where electricity assets are not government–owned or the government is seeking private investment, an explicit carbon price is also not strictly necessary either. For example, governments could mandate a maximum level of carbon intensity for new generators. This could also be an appropriate approach in the period before international measures are introduced post–2012.

There is also an argument for an implicit or explicit carbon signal in the transport sector. New Australian cars are the most fuel–hungry in the world (we overtook the Americans, with their fabled gas–guzzlers, a long time ago). Among OECD countries, Australia also has one of the oldest stocks of cars, many of which are inefficient users of fuel as well as being more polluting than modern vehicles. Sensitivity to petrol price increases, however, will ensure that such measures are phased in gradually over a time frame when more fuel–efficient vehicles can be deployed.

Appendix A

The MMRF–Green model

The Monash Multi–Regional Forecasting (MMRF) Green model is a very detailed dynamic, multi–sectoral, multi–regional model of Australia. The model is ideally suited to modelling the industry, regional, State/Territory and national impacts of public policy changes, particularly energy and greenhouse–related policies. The model recognises:

- domestic producers classified by industry and domestic region;
- investors similarly classified;
- up to eight region–specific household sectors;
- an aggregate foreign purchaser of the domestic economy's exports;
- flows of greenhouse gas emissions and energy usage by fuel and user;
- up to eight state and territory governments; and
- the Federal government.

MMRF–Green is the ideal general equilibrium model for projecting macroeconomic outcomes under different scenarios and for examining the industry–specific and regional impacts of greenhouse and energy policy options. It is a dynamic, general equilibrium model — and so is ideally suited to estimating the direct and indirect impacts of policies designed to operate over a number of years — and was designed specifically to model the impacts of greenhouse policies on Australia’s regions.

The model contains explicit representations of intra–regional, inter–regional and international trade flows based on regional input–output data developed at COPS, and includes detailed data on state and Federal governments' budgets. As each region is modelled as a mini–economy, MMRF–Green is ideally suited to determining the impact of region–specific economic shocks. Second round effects are captured via the model's input–output linkages and account for economy–wide and international constraints. Outputs from the model include projections of:

- GDP and aggregate national employment;
- sectoral output, value–added and employment by region;
- export earnings, import expenditure and the balance of trade;
- greenhouse gas emissions by fuel, fuel user and region of fuel use;
- energy usage by fuel, energy user and region of energy use;
- State and Territory revenues and expenditures;
- regional gross products and employment; and
- regional international export earnings, international import expenditures and international balance of payments.

Numerous applications of MMRF–Green have been commissioned by commercial and government organisations. Some of these studies simulated:

- the regional effects of national policies;
- the effects of region–specific infrastructure projects;
- the effects of alternative regional forestry policies; and
- the effects of different policies to reduce Australian emissions of CO_2 in line with Kyoto commitments.

MMRF–Green has been enhanced in a number of areas to improve its capability for environmental analysis. These enhancements include:

- an energy and gas emission accounting module, which accounts explicitly for each of the 49 industries and eight regions recognised in the model;
- equations that allow for inter–fuel substitution in electricity generation by region; and
- mechanisms that allow for the endogenous take–up of abatement measures in response to greenhouse policy measures.

Table A1.1 below provides details on the 49 industry sectors contained in MMRF–Green.

TABLE A1.1

INDUSTRIES IN MMRF–GREEN

Name	Description of major activity
1. Agriculture	All primary agricultural activities plus fishing
2. Forestry	All forestry activities, including logging and management
3. Iron ore	Mining of iron ore
4. Non–iron ore	Mining of non–iron ores, including gold and base ores
5. Black coal	Mining of black coal – thermal and metallurgical
6. Crude oil	Production of crude oil
7. Natural gas	Production of natural gas at well
8. Brown coal	Mining of brown coal
9. Food, bevs and tobacco	All secondary agricultural activities
10. Textiles, clothing, f'twear	Manufacture of textiles, clothing and footwear
11. Wood and paper products	Manufacture of wood (including pulp) and paper prods
12. Chemical prods.	Manufacture of basic chemicals and paints excl. petrol
13. Petroleum products	Manufacture of petroleum products
14. Building prods (not cement & metal)	Manufacture of non–metallic building products excl. cement and metal
15. Cement	Manufacture of cement
16. Iron and steel	Manufacture of primary iron and steel.
17. Alumina and aluminium	Alumina refining and aluminium smelting
18. Other metal products	Manufacture of other metal products
19. Motor vehicles and parts	Manufacture of motor vehicles and parts
20. Other manufacturing	Other manufacturing including electronic equipment
21. Electricity – black coal	Electricity generation from black coal thermal plants
22. Electricity – brown coal	Electricity generation from brown coal
23. Electricity – gas	Electricity generation from natural gas
24. Electricity – oil prods.	Electricity generation from oil products thermal plants
25. Electricity – hydro	Electricity generation from renewable sources – hydro
26. Electricity – biomass	Electricity generation from renewable sources – biomass
27. Electricity – biogas	Electricity generation from renewable sources – biogas
28. Electricity – solar	Electricity generation from renewable sources – solar
29. Electricity – wind	Electricity generation from renewable sources – wind
30. Electricity supply	Distribution of electricity from generator to user
31. Urban gas distribution	Urban distribution of natural gas
32. Water and sewerage	Provision of water and sewerage services
33. Construction services	Residential building and other construction services
34. Trade services	Provision of wholesale and retail trade services
35. Road transport– direct	Provision of road passenger transport services
36. Road transport – freight	Provision of road freight transport services
37. Rail transport – direct	Provision of rail passenger transport services
38. Rail transport – freight	Provision of rail freight transport services
39. Water transport – direct	Provision of water transport for international freight and passenger carriage.
40. Water transport – freight	Provision of water freight transport services within Australia
41. Air transport – passenger	Provision of air transport services for international freight and passenger carriage.
42. Air transport – freight	Provision of air freight transport services within Australia

Source: COPS

The Productivity Commission undertook an evaluation of the four main, large–scale CGE models that could be used to assess the economy–wide and industry–specific impacts of greenhouse policies.[42] The Commission identified a number of additional advantages that MMRF–Green has over its main rivals. In particular, MMRF–Green was found to have the most detailed energy sector representation, allowing substitution of power generated by different sources on the basis of relative price differentials. The Commission also identified that MMRF– Green:

- has the most household detail, allowing it to provide estimates of the impact of greenhouse policies on households in each of Australia's 57 regions;
- is one of only two models to explicitly model electricity generation from renewables. Recent updates to the model have incorporated five separate renewable generation sectors (wind, solar, hydro, biomass and biogas) — we are not aware of any other model with this capability;
- accounts for an extended range of greenhouse gases (many models are only able to account for CO_2); and
- is one of the two most thoroughly documented models in terms of description, mathematical equations and source code — this facilitates peer review of MMRF– Green modelling results and boosts the model's credibility relative to those models that are not well documented.

MMRF– Green has been used recently to successfully model the economic impacts of a range of greenhouse policy alternatives including:

- both national and international emissions trading;
- the NSW greenhouse benchmark scheme for electricity retailers;
- an emissions intensity requirement, similar to the NSW scheme, applied at the national level;
- the Commonwealth's Mandatory Renewable Energy Target (MRET);
- a carbon price;
- energy efficiency standards; and
- demand–side measures.

MMRF–Green and the stationary energy sector

MMRF–Green has been enhanced in a number of areas to improve its capability for modelling the wider economic impacts of environmental issues as they impact on energy supply. These enhancements include:

- an energy and gas emission accounting module, which accounts explicitly for each of the 49 industries and eight regions recognised in the model;
- equations that allow for inter–fuel substitution in electricity generation by region; and
- a detailed treatment of generation technologies.

[42] Productivity Commission 2001, *CGE Models for Evaluating Domestic Greenhouse Policies n Australia: A Comparative Analysis*, April.

Inter–fuel substitution in electricity generated is handled using the technology bundle approach developed at the Australian Bureau of Agricultural and Resource Economics. A variety of power–generating industries are distinguished based on the type of fuel used. There is also an end–use supplier (Electricity Supply). The electricity generated in each state/territory flows directly to the local end–use supplier, which then distributes electricity to local and inter–state users. The end–use supplier can substitute between the different generation technologies in response to changes in their production costs. For example, the Electricity supply industry in NSW might reduce the amount of power sourced from coal–using generators and increase the amount sourced from gas–fired plants. Such substitution is price–induced; the elasticity of substitution between the various types of electricity used by the Electricity supply industry in each State is set to 5.

For other energy–intensive commodities used in industry, MMRF–Green allows for substitution possibilities by including a weak form of input–substitution specification. If the price of say, cement, rises by 10 per cent relative to other inputs to construction, the construction industry will use 1 per cent less cement and, to compensate, a little more of labour, capital and other materials. In most cases, a substitution elasticity of 0.1 has been imposed. For important energy goods, petroleum products, electricity supply, and urban gas distribution, the substitution elasticity in industrial use is 0.25. This input substitution is driven by price changes, and so is especially important in new technology pathway scenarios that make outputs of electricity supply more expensive.