Australia's Low Pollution Future

The Economics of Climate Change Mitigation

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FOREWORD

Climate change poses clear risks to Australia's future prosperity.

Only global action can reduce greenhouse gas emissions to a level that significantly reduces the risks of dangerous climate change. In working towards an effective global agreement, the developed world has to lead.

Australia will make its fair contribution, including by implementing efficient market-based policies to substantially cut domestic emissions in a cost-effective way. The Carbon Pollution Reduction Scheme will be the cornerstone of Australia's mitigation policy. This will safeguard our economic wellbeing, and stimulate sustainable low-emission growth that will form the basis of Australia's future prosperity.

This is a complex policy area, with important implications for our economy and society. The Government is taking a careful and deliberate approach, drawing on many sources of advice to ensure it understands the costs and benefits to the economy of reaching our emission reduction targets. This will ensure we meet our responsibility to not only protect the economy of today, but also prepare for the low-pollution economy of the future.

The Treasury has conducted one of the largest and most complex economic modelling projects ever undertaken in Australia. This report investigates the potential economic impacts of reducing emissions over the medium and long term. It spans global, national and sectoral scales, and looks at distributional impacts, such as the implications of emission pricing for the goods and services that households consume.

These issues are clearly important to decisions on Australia's scale and rate of emission reductions in coming years.

We are making the assumptions and results of the Treasury's analysis available to the public. We will consider public responses to this report before the Government makes its decisions on the national target range for the medium term. This will help take Australia to its goal of reducing emissions by 60 per cent below 2000 levels by 2050.

The Government will continue to build Australia's capacity for high quality analysis of the costs and benefits of climate change policy. This will ensure we continue to make a substantial contribution to global efforts, and have confidence that our domestic policies enhance the wellbeing of all Australians.

The Hon. Wayne Swan, MP
Treasurer

Senator the Hon. Penny Wong
Minister for Climate Change and Water

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A task of this scale and complexity requires the contributions of many people and many organisations.

This report is the product of a collaborative effort across the Australian Government, the Garnaut Climate Change Review and leading national and international climate change economists.

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Contents

ABBREVIATIONS AND ACRONYMS

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
BITRE	Bureau of Infrastructure, Transport and Regional Economics
CCGT	Combined cycle gas turbine
CCS	Carbon capture and storage
CCSP	Climate Change Science Program (United States)
CDM	Clean Development Mechanism
CGE	Computable general equilibrium (model)
CH_4	Methane
CIS	Commonwealth of Independent States (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan)
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CPI	Consumer price index
CPRS	Carbon Pollution Reduction Scheme
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCC	Department of Climate Change
EITES	Emission-intensive trade-exposed sector
ESM	Energy sector model
ETS	Emissions trading scheme
GCOMAP	Generalized Comprehensive Mitigation Assessment Process (model)
GDP	Gross domestic product
GNP	Gross national product
GSP	Gross state product
Gt	Gigatonne
GTAP	Global Trade Analysis Project
GTEM	Global trade and environment model
GVA	Gross value added
GWh	Gigawatt hour
GWP	Gross world product
HES	Household Expenditure Survey

HFCs	Hydrofluorocarbons
IEA	International Energy Agency
IGCC	Integrated gasification combined cycle
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
kt	Kilotonne
LNG	Liquefied natural gas
MAC	Marginal abatement cost
MAGICC	Model for the assessment of greenhouse gas induced climate change
MER	Market exchange rate
MMA	McLennan Magasanik Associates
MMRF	Monash Multi-Regional Forecasting (model)
MRET	Mandatory Renewable Energy Target
Mt	Megatonne
MWh	Megawatt hour
N_2O	Nitrous oxide
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PFCs	Perfluorocarbons
PJ	Petajoule
PRISMOD	Price revenue incidence simulation model
PRISMOD.DIST	Price revenue incidence simulation model and distribution model
ppm	Parts per million
PPP	Purchasing power parity
RET	Renewable Energy Target
SF_6	Sulfur hexafluoride
tCO_2-e	Tonne of carbon dioxide equivalent
TWh	Terawatt hour
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
VRET	Victorian Renewable Energy Target
WEO	World Economic Outlook
WRI	World Resources Institute

EXECUTIVE SUMMARY

Key points

The Treasury's modelling demonstrates that early global action is less expensive than later action; that a market-based approach allows robust economic growth into the future even as emissions fall; and that many of Australia's industries will maintain or improve their competitiveness under an international agreement to combat climate change.

Australia and the world continue to prosper while making the emission cuts required to reduce the risks of dangerous climate change. Even ambitious goals have limited impact on national and global economic growth.

Real household income continues to grow, although households face increased prices for emission-intensive products, such as electricity and gas.

Strong coordinated global action reduces the economic cost of achieving environmental objectives, reduces distortions in trade-exposed sectors, and provides insurance against climate change uncertainty.

There are advantages to Australia acting early if emission pricing expands gradually across the world: economies that defer action face higher long-term costs, as global investment is redirected to early movers.

Australia's comparative advantage will change in a low-emission world. With coordinated global action, many of Australia's emission-intensive sectors are likely to maintain or improve their international competitiveness.

Australia's aggregate economic costs of mitigation are small, although the costs to sectors and regions vary. Growth in emission-intensive sectors slows and growth in low- and negative-emission sectors accelerates.

Allocation of some free permits to emission-intensive trade-exposed sectors, as the Government proposes, eases their transition to a low-emission economy in the initial years.

Accurately predicting which mitigation opportunities will prove most cost effective is impossible. Instead, broadly-based market-oriented policies, such as emissions trading, allow the market to respond as new information becomes available.

INTRODUCTION

The global climate is changing. Greenhouse gas emissions from human activities very likely have caused most of the global warming since the 1950s. Some impacts are now unavoidable. Continued emissions at or above current rates would cause further warming and induce further changes in the global climate system over time (IPCC, 2007a).

Before the Industrial Revolution, the concentration of greenhouse gases in the atmosphere was around 280 parts per million of carbon dioxide equivalent (ppm CO_2-e).[1] Today, concentrations are around 430 ppm. Without policy action these concentrations are projected to rise to 1,560 ppm by 2100, more than five times pre-industrial levels. These concentrations are associated with very high risks of large-scale irreversible climate change.

This scenario, where no mitigation occurs, is the 'reference scenario'. It assumes current trends in economic activity continue into the future. The reference scenario does not include the impact of climate change on the economy.

Stabilising atmospheric greenhouse gas concentrations at levels that significantly reduce the risks of dangerous climate change requires a fundamental shift in current global emission trends. This requires considerable changes in global economic activity. The Treasury, in partnership with many of Australia's leading economic modellers of climate change and the Garnaut Climate Change Review, has explored how such a shift might affect Australia's economy.

This report examines four alternative scenarios in which Australia and the world follow pathways to a low-pollution future.

Two scenarios assume a global stabilisation goal of 550 ppm CO_2-e, which requires that global emissions peak within the next two decades, fall to below current levels by 2050, and fall further after 2050 (IPCC, 2007b). The key difference between the two scenarios is whether global action is united or staged. The other two scenarios assume more ambitious global stabilisation goals of 450 and 510 ppm, which require more rapid global emission reductions: 450 ppm is achieved through united global action and 510 ppm through staged action.

Prosperity increases while ambitious stabilisation goals are achieved. This occurs in all four scenarios.

Efficient mitigation policies that price greenhouse gas emissions from all sources, and in all regions, can break the link between economic growth and emissions, and allow the world economy to adjust efficiently to a low-pollution future. Changes in technologies, processes, production inputs and consumer choices generate most emission reductions. Even with an emission constraint, almost all sectors of the Australian economy grow, and key low-emission sectors grow strongly.

Framework for analysis

The analysis and modelling in this report focus on the economic impacts of policies to reduce greenhouse gas emissions ('mitigation policies'), particularly the Carbon Pollution Reduction Scheme (CPRS). This report focuses on the medium to long-term transformation of the Australian economy, not short-run fluctuations arising from events such as the current turmoil in global financial markets.

The report positions Australia within the context of global action to reduce greenhouse gas emissions and stabilise concentrations at 450-550 ppm around 2100. In all scenarios, Australia's action is comparable to that of other developed economies. Developing nations' contributions

1 References to greenhouse gas concentrations are to the aggregate warming effect of gases covered by the Kyoto Protocol.

are differentiated, either through relatively less stringent per capita-based national emission pathways within a united global action framework, or through gradual adoption of emission reduction obligations under a multi-stage framework.

Two scenarios, Garnaut -10 and Garnaut -25, assume an 'optimal' international emissions trading scheme, covering all emission sources and all economies, from 2013. National emission targets are based on the per capita allocation approach developed by the Garnaut Climate Change Review (Garnaut, 2008a). Australia's emission reduction targets in these scenarios are 10 per cent below 2000 levels by 2020 and 80 per cent below by 2050 for stabilisation at 550 ppm (Garnaut -10); and 25 per cent below 2000 levels by 2020 and 90 per cent below by 2050 for stabilisation at 450 ppm (Garnaut -25).

The other two scenarios, CPRS -5 and CPRS -15, examine the potential costs of Australia's Carbon Pollution Reduction Scheme within a more realistic multi-stage global framework. National emission targets gradually diverge from reference scenario emissions, so take greater account of the existing structure of national economies. International emissions trading gradually expands: developed economies participate from 2010; developing economies join over time; there is global participation by 2025. Australia's long-term emission reduction target in both scenarios is 60 per cent below 2000 levels by 2050. CPRS -5 assumes a slower start to global emission reductions and stabilisation at 550 ppm; Australia's medium-term target is 5 per cent below 2000 levels by 2020. CPRS -15 assumes a faster start and stabilisation at 510 ppm; Australia's medium-term target is 15 per cent below 2000 levels by 2020.

This report is not a complete assessment of the economic, social and environmental costs and benefits of climate change policies. The modelling does not include the economic impacts of climate change itself, so does not assess the benefits of reducing climate change risks through mitigation. Other studies explore these benefits in detail (Garnaut, 2008a; Pearman, 2008; Stern, 2007).

This report is a collaborative effort between leading climate change economists and the Australian Treasury. A suite of global, national, sectoral and distributional models are used to estimate the macroeconomic, sectoral and distributional impacts of the four emission reduction pathways. The stabilisation level, global framework, Australian targets and Australian policy settings are key to impacts on the Australian economy.

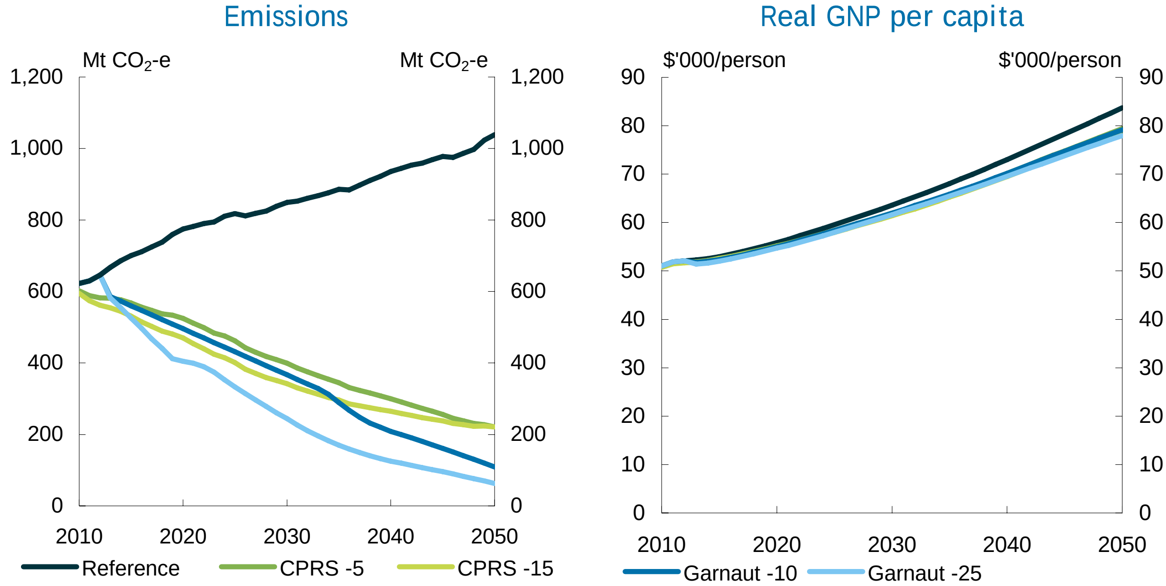
AUSTRALIA IN THE GLOBAL CONTEXT

Australia maintains strong economic growth and achieves its emission reduction targets in all scenarios.

From 2010 to 2050, Australia's real GNP per capita grows at an average annual rate of 1.1 per cent in the policy scenarios, compared to 1.2 per cent in the reference scenario.[2] By 2020, real GNP per capita is around 9 per cent above current levels, compared to around 11 per cent in the reference scenario. By 2050, real GNP per capita is 55-57 per cent above current levels, compared to 66 per cent in the reference scenario (Chart 1).

2 GNP (gross national product) measures the total output of the Australian economy and international income transfers. It is a more complete measure of the current and future consumption possibilities available to Australians than GDP (gross domestic product) (Box 2.3).

Chart 1: Five pathways for Australian emissions and GNP



Note: Units are in Australian dollars, 2005 prices. The reference scenario shows modelled emissions, while the policy scenarios show allocations (policy targets). Actual emissions differ from allocations due to banking of permits and international permit trade.
Source: Treasury estimates from MMRF.

Emission pricing has a slightly smaller impact on Australia's GDP, as GDP does not include income transfers associated with international emissions trading. From 2010 to 2050, real GDP per capita grows at an average annual rate of 1.2-1.3 per cent in the policy scenarios, compared to 1.4 per cent in the reference scenario.

Australia's emission price is determined by the global price. Higher emission prices are required to achieve lower stabilisation levels, and lower risks of dangerous climate change. Stabilisation at 550 ppm requires an initial emission price of \$23/tCO_2-e in 2010 in nominal terms (\$20 in 2005 dollars). The starting price is 40 per cent higher to achieve 510 ppm, and 110 per cent higher to achieve 450 ppm. Higher emission prices generally lead to higher aggregate impacts on Australia.

Table 1: Australia's emissions and economy

	Reference	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
Greenhouse gas stabilisation goal, ppm CO_2-e	n/a	550(a)	510(a)	550	450
Current levels – at 2008					
GNP per capita, \$'000/person	50.4	50.4	50.4	50.4	50.4
Start of scheme - at 2010 or 2013(b)					
Emission price, nominal, \$/tCO_2-e	n/a	23	32	30	52
Medium term – at 2020					
Emission allocation, change from 2000 level, per cent	+40	-5	-15	-10	-25
GNP per capita, \$'000/person	55.9	55.2	54.9	55.0	54.7
Long term – at 2050					
Emission allocation, change from 2000 level, per cent	+88	-60	-60	-80	-90
GNP per capita, \$'000/person	83.7	79.4	78.7	79.1	78.0
Overall mitigation cost, 2010-2050					
Real GNP per capita, average annual growth, per cent	1.2	1.1	1.1	1.1	1.1
Real GDP per capita, average annual growth, per cent	1.4	1.3	1.3	1.3	1.2

Note: Units are in Australian dollars 2005 prices. Emissions in the reference scenario are actual emissions from MMRF.
(a) Assuming comparable global mitigation effort is sustained after 2050.
(b) Emission pricing commences in 2010 in the CPRS scenarios, and in 2013 in the Garnaut scenarios.
Note: Units are in Australian dollars 2005 prices. Emissions in the reference scenario are actual emissions from GTEM.
Source: Treasury estimates from MMRF and MAGICC.

At any given stabilisation level, the global framework significantly affects national costs. Under a multi-stage framework (CPRS scenarios), Australia's costs as a share of GNP are slightly higher in the short term, but lower in the long term, than under a per capita based, unified framework (Garnaut scenarios). Two key factors drive this long-term result: under the multi-stage framework, Australia's long-term national target is less stringent (60 per cent rather than 80 per cent); and Australia benefits from acting early.

Where emission pricing is gradually introduced across the world, countries that defer action face higher long-term costs, because global investment is redirected to countries that act early. Australia therefore benefits from being an early mover in a multi-stage world.

Even so, the reasons for pursuing coordinated global action are compelling: early action accelerates cost reductions in low-emission technologies, helps prevent lock-in of more emission-intensive industry and infrastructure, and minimises distortions associated with trade-exposed industries.

In the face of uncertainty, strong coordinated global action has an insurance benefit: it keeps open the option of pursuing lower stabilisation levels in the future. Weaker global action may prove more costly in the longer term.

Compared to other developed economies, Australia faces relatively high mitigation costs as a share of GNP. Emission- and energy-intensive industries contribute substantially to the Australian economy, so Australia faces a relatively greater adjustment task. Differentiation of national emission reduction targets among developed countries, taking account of the structure of existing national economies, could narrow differences in mitigation costs.

Australia also has less mitigation potential at low-emission prices than many other developed and developing economies. Expanding access to international mitigation, through market-based mechanisms, such as international emissions trading and the Clean Development Mechanism, will help reduce the cost of Australia's contribution to the global mitigation effort.

SECTORAL EFFECTS

While mitigation policies impose relatively small aggregate costs on Australia, impacts vary widely across sectors and regions. Putting a price on emissions drives a structural shift in the economy, from emission-intensive goods, technologies and processes, towards low-emission goods, technologies and processes. As a result, growth in emission-intensive sectors slows, and growth in low and negative-emission sectors accelerates.

The global emission price, changes in global demand, changes in Australia's exchange rate, and the relative energy- and emission-intensity of global producers will determine the impacts on Australia's emission-intensive trade-exposed sectors. For other sectors, relative emission-intensity across the domestic economy, general macroeconomic impacts and technology options are key.

Australian producers will face falling global demand for emission-intensive goods and services. Nevertheless, many of Australia's emission-intensive trade-exposed sectors (EITES), such as coal, non-metallic minerals, livestock, and iron and steel, are likely to maintain or improve their competitiveness and share of global trade. These sectors are either less emission intensive or energy intensive than comparable sectors in competitor countries. Overall, these sectors are expected to grow, albeit at a slower rate than they would in a world without emission pricing.

Australia is likely to lose competitiveness where its production is more emission intensive than its competitors, such as for aluminium and petroleum refining. These sectors may contract.

In the absence of unified global action, an emission price may distort the international competitiveness of Australia's EITES. There is little evidence of carbon leakage.[3] Nevertheless, allocation of some free permits to EITES, in accordance with the shielding arrangements proposed in the *Carbon Pollution Reduction Scheme Green Paper*, eases the transition to a low-emission economy for shielded sectors while maintaining incentives for emission reductions. Shielding is projected to impose modest costs on other (unshielded) sectors through its impact on permit trading, electricity demand and energy prices, and redistribute costs amongst shielded sectors.

Coal's long-term future depends on developing new technologies — most importantly, carbon capture and storage. If these technologies do not prove commercially viable, Australia's coal production could fall from current levels. With commercially viable technologies, coal is likely to play a major role in future national and global energy supply, and Australian production is likely to grow.

Low-emission technologies, materials and production processes will become more competitive, and low-emission goods will become more attractive to consumers. Slower growth in world demand for energy commodities will lower Australia's terms of trade. The exchange rate acts as a buffer to changes in world demand, and would be expected to depreciate. This will improve the competitiveness of other sectors, such as manufacturing and iron ore mining.

Emission pricing creates a new source of revenue for sectors that can generate credits through carbon sequestration, such as forestry, stimulating strong growth.

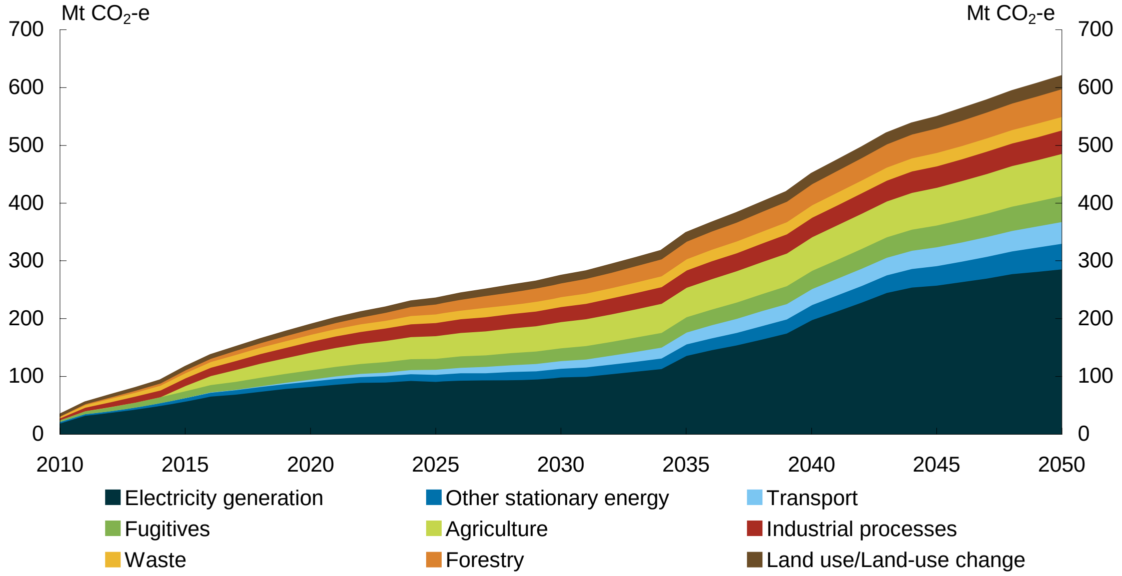
Emission pricing is expected to result in early retirement of some emission-intensive plant and capital, and lead, at least initially, to slightly slower growth in wages and some redistribution of employment. However, these impacts are likely to be restricted to firms in a few specific industries, such as some coal-fired electricity generators, and could be managed through effective structural adjustment assistance.

Australia's wide range of low-emission technology options suggests electricity generation could deliver large emission reductions over time, even if some technologies do not prove cost effective. This report finds no evidence that mitigation policies will compromise the security of energy supply. Under all scenarios modelled, new generation capacity is established in sufficient time to meet projected demand.

Emission pricing could reduce emissions in all sectors (Chart 2). Accurately predicting which mitigation opportunities will prove most cost effective is impossible. Broadly-based market-oriented policies, such as emissions trading, will allow the market to respond as new information about mitigation opportunities becomes available.

3 Carbon leakage occurs when EITES move to other locations that are more emission intensive than Australia, but do not yet price emissions.

Chart 2: Emission reductions by sector
CPRS -5 scenario



Note: The difference between the total emission reductions in this chart and the gap between reference and policy scenario emissions in Chart 1 is met by Australia importing permits.
Source: Treasury estimates from MMRF.

IMPACTS ON HOUSEHOLDS

Household income continues to grow strongly. Real disposable income per capita grows at an average annual rate of around 1 per cent in the policy scenarios, compared to 1.2 per cent in the reference scenario.

In the CPRS scenarios (in which emission pricing is introduced in 2010), a one-off rise in the price level of around 1-1.5 per cent is expected, with minimal implications for ongoing inflation. For the average household, this corresponds to an extra $4-5 per week spending on electricity and $2 per week on gas and other household fuels. Prices of petrol and emission-intensive meat products will not be affected initially, due to reductions in fuel taxes and agriculture's initial exclusion from the Carbon Pollution Reduction Scheme.

Emission pricing will have a slightly greater impact on low-income households as they spend a higher share of their income on emission-intensive goods. The Government, as it outlined in the *Carbon Pollution Reduction Scheme Green Paper*, is committed to helping households adjust to the scheme, including by increasing benefit payments and other assistance to low-income households through the tax and payment system.

ANALYSIS OVER LONG TIMEFRAMES

This report uses policy scenarios to explore how the Australian economy might change in response to emission pricing. Changes are analysed relative to a reference scenario in which no new policies are introduced.

Like much long-term economic analysis, including that presented in the *Intergenerational Report* (Australian Government, 2007), the modelling approach used here focuses on medium to long-term trends in the economy rather than shorter run fluctuations. The actual path of

Australian and global economic growth from now out to 2050 will be affected by a wide range of factors. Business cycles and economic shocks, such as the current global financial crisis, will have a substantial impact on the economy in the short term. Other factors, such as the rate of population growth, could change the trend rate of economic growth in the long term.

These factors should not materially affect the analysis in this report. The economic modelling focuses on changes in the economy resulting from climate change mitigation policies. In principle, even if the reference scenario was different, the direction and scale of these changes should be broadly unchanged.

The results would be sensitive to changes that affect the distribution of economic activity between high and low emission activities. This is why the analysis has been carefully constructed to incorporate the Treasury's best current estimates of longer run trends in the sectoral distribution of output in the Australian and global economies.

CHAPTER 1: CONTEXT FOR REDUCING EMISSIONS

Key points

This report uses economic models to analyse the macroeconomic, sectoral and household impacts of Australia reducing its greenhouse gas emissions under different targets and trajectories.

This report is a collaborative effort between leading climate change economists and the Australian Treasury.

This report examines the cost of reducing greenhouse gas emissions on the Australian economy. This report does not examine the economic benefits of reducing emissions, such as lower risks of dangerous climate change.

This report should be evaluated in the broader context of all the costs and benefits of climate change mitigation.

Much of the world's economic activity results in greenhouse gas emissions. The primary sources of emissions from human activity are combustion of fossil fuels, deforestation and agriculture (IPCC, 2007). As the world economy expands, global emissions continue to rise. While the world economy's emission intensity fell in the past three decades (World Resources Institute, 2008), global emissions from human activities increased 70 per cent between 1970 and 2004 (IPCC, 2007).

With the global community producing more greenhouse gases each year, the stock of emissions in the atmosphere is growing. Since the industrial revolution, when fossil fuel combustion began driving economic growth, global atmospheric concentrations of greenhouse gases have increased markedly. Current concentrations of carbon dioxide and methane — two of the most significant anthropogenic greenhouse gases — far exceed the range estimated over the past 650,000 years (IPCC, 2007).

Changes in atmospheric concentrations of greenhouse gases change the global climate system's energy balance. The Intergovernmental Panel on Climate Change (IPCC) concludes that warming of the climate system is unequivocal and is evident in increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (IPCC, 2007).[1]

While the extent to which human activity is responsible for the observed warming is uncertain, emissions from human activities have very likely caused most of the global warming since the 1950s, and continued emissions at or above current rates would cause further warming and induce many changes in the global climate system over coming decades and centuries (IPCC, 2007). Climate science projects that warming is likely to drive changes in wind patterns,

1 The issue of whether there is a warming trend in global temperature data was examined in the Garnaut Climate Change Review (Garnaut, 2008, Box 4.1, p 79).

rainfall, snow and ice cover, extreme weather events (for example, heat waves and intense storms), and increasing acidification of the ocean (IPCC, 2007).

For Australia, climate change could severely affect agriculture, infrastructure, biodiversity and ecosystems (Garnaut, 2008). Australia's hot and dry climate, geographical proximity to developing countries, and economic structure make Australia particularly vulnerable to climate change and give it a stronger reason to effect a global agreement to mitigate climate change than other developed countries (Pearman, 2008; Garnaut, 2008).

1.1 AUSTRALIAN POLICY CONTEXT

The Australian Government has identified responding to the challenge of climate change as one of its highest priorities. The Government's climate change policy is built on three pillars:

- reducing Australia's greenhouse gas emissions;
- adapting to climate change that cannot be avoided; and
- helping to shape a global solution.

The Government has adopted a long-term greenhouse gas emission reduction target of 60 per cent below 2000 levels by 2050, and is considering the scale and timing of the emission reductions Australia should pursue towards this goal.

As a party to the Kyoto Protocol, Australia is obliged to limit its national greenhouse gas emissions to no more than 108 per cent of 1990 levels during the Kyoto commitment period (2008-2012). Post-2012 targets for developed countries are being negotiated internationally, with negotiations scheduled to conclude in Copenhagen in 2009 (Box 1.1).

The Government will introduce a Carbon Pollution Reduction Scheme (CPRS) as the primary mechanism to achieve its emission reduction goals in a responsible and flexible manner and at the lowest possible cost to the economy (DCC, 2008). As part of the design features of the scheme, the Government will announce a national emissions target range for 2020 by the end of 2008.

The emission caps for this scheme will be set in 2010, in light of the national emissions trajectory and targets and final decisions regarding scheme design. The Government will take a range of factors into account in setting the trajectory and targets, including the work of the Garnaut Climate Change Review, modelling in this report, consultation with stakeholders and the international negotiations now underway.

Box 1.1: The international response to climate change

The global community has recognised the risks associated with climate change and the need for a coordinated global response. The United Nations Framework Convention on Climate Change established in 1992 has almost global membership, with 192 parties. The Convention aims to stabilise greenhouse gas concentrations at a level that would prevent dangerous human-driven interference with the climate system.

No global agreement exists on what constitutes a 'safe' concentration level. With higher levels come increasing risk of greater temperature change and greater impacts on the climate system. A concentration of 450 parts per million CO_2-equivalent (ppm CO_2-e) generally is associated with a 50 per cent chance of limiting the increase in global average temperature to 2°C above pre-industrial levels, while 550 ppm CO_2-e is associated with a 50 per cent chance of limiting the temperature increase to 3°C (IPCC, 2007).

The Convention recognises that all countries should act, and an important principle is that developed countries should take the lead given their historical contribution to greenhouse gas emissions and the economic development they have enjoyed as a result. The Kyoto Protocol to the Convention commits developed country parties (known as Annex B parties) to binding national emission targets for the period 2008-2012, with the aim of reducing their collective emissions by at least 5 per cent from 1990 levels.

The Bali Conference in 2007 set in place two negotiation tracks, collectively known as the Bali Roadmap, on an arrangement to follow on from the first Kyoto period in 2013.

The Convention track seeks to involve major developing countries and non-Kyoto developed countries such as the United States in efforts to reduce emissions. Critically, it aims to develop a long-term global goal for emission reductions. This will highlight the scale of the mitigation task and the need for action by all major emitters. The Protocol track will determine post-2012 emission reduction targets for Annex B parties.

1.2 Purpose of this report

This report uses economic models to analyse the macroeconomic, sectoral and household impacts of Australia reducing its greenhouse gas emissions under different targets and trajectories. Because responding to climate change is a global challenge, this report evaluates the impacts on Australia in the context of global action to reduce emissions.

This report also describes possible economic, environmental and technological pathways that Australia and the world could take to reach their objectives.[2] Given the long timeframes involved in climate change mitigation policy, this analysis extends to 2050 and, in some scenarios, to 2100.

2 The scenarios are illustrative and their primary focus is to explore the economic effects of different emission constraints to inform decisions by government, business and households. The estimates of emissions in this report, including the reference scenario, do not represent the official policy or negotiating position of the Australian Government and are not an official Government or Treasury forecast.

Achieving greenhouse gas emissions reduction targets will lead to significant changes in the structure of the Australian economy. Continued strong economic growth is likely. These changes will arise domestically, primarily through transforming the way energy is produced, distributed and consumed, as well as from international factors, such as through trade, as Australia's trading partners respond to their own emission constraints.

Decarbonising the Australian economy will lead to adjustment costs for some individuals, industries and regions. It will create benefits for some individuals, industries and regions, and lead to new industries and employment opportunities. It will affect almost every Australian in some way.

In mid-2007, the Australian Treasury established a climate change modelling unit to analyse the possible macroeconomic, sectoral and distributional impacts of greenhouse gas emission reduction targets and trajectories on the Australian economy.

Treasury's modelling program is extensive and includes model development, engagement with domestic and international experts, and consultation with stakeholders across industry, community organisations and government agencies. The result, an integrated modelling analysis of the global, national, industry, household, technological and environmental dimensions of greenhouse gas mitigation, is the most comprehensive exercise of its kind in Australia to date.

This report presents the results of this modelling program.

This report uses a reference scenario and four main policy scenarios. Two policy scenarios — Garnaut -10 and Garnaut -25 — were modelled for the Garnaut Climate Change Review, and two other scenarios — CPRS -5 and CPRS -15 — were based on the Government's *Carbon Pollution Green Paper Scheme Green Paper* (DCC, 2008). To complement the four main policy scenarios, several sensitivity scenarios explore key uncertainties.

The Treasury's analysis cannot be considered in isolation when exploring policy choices for Australia, as it focuses only on the costs of mitigation — that is, the costs of reducing greenhouse gas emissions. This report does not consider the costs of climate change impacts. The benefits from global action to reduce greenhouse gas emissions are not included in the Treasury's analysis, but are explored by the Garnaut Climate Change Review. Benefits include the reduced risks of climate change impacts and lower costs of adapting to the climate change that does occur. The Garnaut Climate Change Review used three scenarios (the reference scenario, Garnaut -10 and Garnaut -25) as inputs to its independent analysis of the costs of action versus inaction on climate change (Garnaut, 2008).

1.2.1 Structure of this report

The less technical summary of this report outlines the main modelling results and messages. It is available as a separate publication.

Chapter 1 describes the purpose of this report and the context for Australia's action on climate change mitigation policy.

Chapter 2 sets out the report's analytical framework, describing the models and how to interpret the results.

Chapter 3 describes how the Australian and global economy could evolve if new policies to reduce emissions are not introduced. The reference scenario provides the benchmark to judge emission reduction policies.

Chapter 4 describes the domestic and international policy frameworks of the policy scenarios.

Chapter 5 describes the international results and analysis from the policy scenarios.

Chapter 6 describes the modelling results and analysis for Australia in terms of the macroeconomic, sectoral and household impacts of greenhouse gas emissions targets and trajectories.

Chapter 7 discusses key findings and areas for future work.

Reports on the analysis and modelling commissioned from external consultants are on the Treasury website.

1.3 REFERENCES

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CHAPTER 2: FRAMEWORK FOR ANALYSIS

Key points

This analysis uses a suite of models to explore the global, national, sectoral and household dimensions of emission reductions. A suite of models approach provides a natural hedge against the inherent uncertainty in economic modelling.

This chapter sets out the framework used to analyse the macroeconomic, sectoral and household impacts of Australian and global action to reduce greenhouse gas emissions.

2.1 STABILISING EMISSIONS IS AN ECONOMIC PROBLEM

The policy scenarios in this report assume Australia and the world implement emissions trading schemes to reduce greenhouse gas emissions and stabilise atmospheric concentrations of greenhouse gases.

Many types of economic activity lead to the emission of greenhouse gases (Box 2.1). While fossil fuel combustion is the major source of human induced greenhouse gas emissions, it has also delivered heat, light and motion to firms and households, and underpinned rising living standards.

Continued growth in greenhouse gases emissions from human activities increases the risk of dangerous, human-driven interference with the Earth's climate (IPCC, 2007a). To respond to these risks, the international community needs to agree to limit the right of nations to release greenhouse gases into the atmosphere.

This report analyses the impacts on Australia of such an agreement. Because climate change impacts are related to the concentration of emissions in the atmosphere over time, and not emissions in any one year, this report assumes global mitigation action over time will be sufficient to stabilise atmospheric concentrations at low levels.[1]

To stabilise the atmospheric concentration of greenhouse gases, the world will need to limit its emissions in the long term to no more than the capacity of the natural environment to absorb carbon. This limit is currently understood to be much less than half of current emissions levels (Canadell et al., 2007; Pearman, 2008).

The transition from current trends in emissions growth to levels consistent with atmospheric stabilisation will involve policies across national, multinational and global jurisdictions. Such policies must face the challenge of limiting emissions without compromising economic growth and living standards, particularly in parts of the world where living standards currently are low.

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1 The relationship between the concentration of emissions and projected climate change is addressed in detail in Pearman, 2008.

Box 2.1: Sources of greenhouse gas emissions

Emissions come from a range of sources:

- **Stationary energy** includes combustion emissions from fuel in generating electricity and refining petroleum; combustion emissions from fuels used in manufacturing, construction and commercial sectors; and other sources, such as domestic heating.
- **Transport** includes direct combustion (or end-use emissions) of fuels used by road, rail, domestic air transport and domestic shipping.
- **Fugitives** include methane, carbon dioxide and nitrous oxide emitted in producing, processing, transporting, storing and distributing raw fossil fuels (coal, oil and gas).
- **Industrial processes** covers non-energy emissions from mineral processing, chemicals and metal production. These emissions usually arise from chemical reactions during manufacture (for example, calcification during cement manufacture releases carbon dioxide).
- **Agriculture** includes methane and nitrous oxide emissions from soil, manure management, rice cultivation and livestock.
- **Waste** includes methane emissions from solid waste disposed to landfill and the treatment of domestic, commercial and industrial wastewater.
- **Land-use, land-use change and forestry** include emissions from burning forests and decaying unburnt vegetation, and from soil disturbed during land clearing. Emissions from these sources are offset partly by sequestration as vegetation regrows.

Source: Australian Government, 2008.

The most efficient, low-cost mechanism to reduce greenhouse gas emissions is to price emissions from all sources in all regions (Box 2.2). The Garnaut scenarios modelled as part of the Garnaut Climate Change Review explore this comprehensive framework. For the Carbon Pollution Reduction Scheme (CPRS) scenarios, the emissions trading scheme component outlined in the Government's *Carbon Pollution Reduction Scheme Green Paper* was the primary domestic mitigation mechanism applied to Australia (Box 2.3) (DCC, 2008).

This report assumes that Australia links its emissions trading scheme into the world trading scheme. Australia is a small economy representing around 1.5 per cent of the world's emissions; consequently, the buying and selling of Australian emission permits is unlikely to materially affect the world emission price. If the number of international permits that can be used within Australia is not limited, the global emission price will drive the emission price in Australia (Baumert et al., 2005).

Individuals, firms, sectors and nations facing an emission price will have incentives to mitigate — that is, to reduce their production and consumption of emissions. For instance, electricity consumers will be encouraged to economise on their use of electricity; electricity producers will look for ways to become more efficient in their use of fossil fuels to generate electricity; and nations will look for options to move towards low or zero emissions sources of electricity.

Box 2.2: Market-based policy responses to climate change

From an economic perspective, climate change is a global 'externality'. The externality, a form of market failure, arises because those emitting the gases do not bear all the risks of adverse climate change impacts from emissions, but share them across the world.

As a result of this externality, the prices of goods, services and activities that generate emissions do not incorporate the costs of climate change, leading to an oversupply. This is an inefficient allocation of resources that does not maximise economic wellbeing when the risks of adverse climate change impacts are included. A similar externality is over-fishing, where individual decisions about how many fish to catch do not take account of the ability of fish stocks to reproduce, affecting others' ability to catch fish.

The most effective way to reduce risks of climate change at the lowest cost is to price emissions. Two market-based approaches would price emissions: first, a cap and trade system, where the amount of emissions is capped, and then rights to emit are traded in a market; and, second an emissions tax. By pricing emissions, the price of goods and services that generate emissions rises to better reflect their true costs. Pricing the externality improves the efficiency of the economy. The emission price balances the value of emissions in economic activity with climate change risk management objectives.

An emission price operates by increasing the price of emission-intensive goods relative to other forms of economic activity. This achieves the emission reduction goal at least cost by allowing individual firms and households to evaluate their options and decide whether to pay the emission price or reduce emissions by changing practices or consumption mixes. It also stimulates innovation to find new ways to do things without emissions.

Other policy options are available to reduce emissions, such as more command and control style regulations, that prescribe technology standards or ban certain types of activity that lead to emissions. However, these generally will be more costly than a market-based policy mechanism, because regulators do not have perfect knowledge of mitigation opportunities, costs, and preferences of firms and households. Non-market policies have often obscured less transparent costs and welfare consequences (Productivity Commission, 2008 and 2005).

As over time the world's greenhouse gas emission reduction objectives become more ambitious, the emission price is likely to rise, as relatively easier options to reduce emissions are exhausted, and individuals, firms, sectors and nations need incentives to undertake relatively more expensive mitigation options.

Just as the buying and selling of any commodity determines how that commodity is allocated among different economic activities and nations, the buying and selling of the right to emit will also determine how the world's allowable emissions are allocated among different types of economic activities at any time.

Some firms or nations will find it relatively easy to reduce emissions. They will likely sell their rights to emit to others engaged in other types of economic activity that find it relatively difficult to reduce emissions.

Given that Australia's emissions trading scheme is assumed to be linked into the international emissions trading scheme, this means that if Australia finds it more costly to reduce emissions than other economies, Australia can buy permits on the international market at the world emission price. Conversely, if mitigation opportunities in Australia are cheaper, Australia will sell permits to the world markets.

Box 2.3: Policy assumptions in the modelling

This report makes several assumptions about future Australian and international policy responses to climate change. These assumptions do not represent the Treasury's or the Australian Government's formal position or proposal. Rather, the assumptions explore the possible economic costs of responding to climate change.

Global stabilisation objectives modelled in the policy scenarios are not the bounds of 'acceptable' levels or judgments on what the world should aim for. Instead, the 450-550 ppm range draws on targets in literature and illustrates the implications of achieving different levels of emissions reductions.

The nature of the post-2012 global mitigation framework and possible Australia contributions to global efforts are being negotiated. The outcomes are impossible to predict. This report makes simplifying assumptions about global frameworks and the relative contributions of Australia and other nations.

The domestic policy assumptions for the CPRS scenarios come from the *Carbon Pollution Reduction Scheme Green Paper* (DCC, 2008). Where the Government's preferred position was not indicated, but the modelling required an assumption, this should not be taken as the Australian Government's formal position. The economic modelling in this report is one input into the Government's decision-making framework.

Policy assumptions are more fully discussed in Chapter 4 and Annex B.

2.2 Modelling framework

Climate change operates over very long timeframes, with significant time lags projected between greenhouse gas emissions and resulting impacts. As a result, quantitative analysis of climate change must take a long-term view. This report makes projections to the year 2050, and in some scenarios, 2100. This difficult exercise requires assumptions for a wide range of economic, social and environmental variables which can change in unpredictable ways.

To make long-term projections and analyse greenhouse gas mitigation costs to Australia, this report uses economic models. Economic models mathematically represent how the economy operates and how various agents respond to changing signals. Economic models are a useful tool for exploring the costs of climate change mitigation, as they ensure internally consistent long-term projections of economic activity and the resulting greenhouse gas emissions.

The approach to estimating greenhouse gas mitigation costs to Australia is a two-step process.

First, the models are used to construct the reference scenario, which projects the future path of the world and Australian economies if new policies to reduce emissions are not introduced.

Second, the models are used to project several policy scenarios where the world reduces greenhouse emissions. The comparison of outcomes between the reference scenario and the policy scenarios shows the impact of emissions reduction policies on the Australian and global economies.

This report uses economic models to analyse climate change mitigation policy in Australia in four dimensions:

- **Global** — including the rate and pattern of economic growth, technology development and greenhouse gas emissions. This determines the magnitude of climate change that will occur, the scale of the global mitigation task, and the trade and capital flows affecting the Australian economy (Box 2.4).
- **National** — including the overall performance of the macroeconomy and patterns of growth across industry sectors and the states and territories.
- **Sectoral** — including likely technology developments and the timing and scale of opportunities to reduce energy use and greenhouse gas emissions.
- **Household** — including the impact on household prices, incomes and consumption.

Box 2.4: Australia as a part of international action

Achieving the United Nations Framework Convention on Climate Change goal of stabilising the atmospheric concentration of greenhouse gases requires that, in the long term, global emissions come down to the level that creates a balance with the Earth's natural capacity to remove greenhouse gases from the atmosphere. That capacity is currently estimated to be significantly less than half of current emission levels.[2]

Accordingly, global action to reduce emissions is required. Australia, which accounted for around 1.5 per cent of total world emissions in 2000[3] (Baumert et al, 2005) and around 1.4 per cent of global CO_2 emissions from energy (Table 2.1), will contribute to any concerted global effort. Accordingly, the analysis of the impacts of Australia reducing emissions is nested in the context of a global mitigation effort.

Table 2.1: CO_2 emissions from energy, 2005

	Emissions			Emissions per capita	
	Mt CO_2	Rank	Per cent	tCO_2/person	Rank
United States	5,817	1	21.4	19.6	7
China	5,060	2	18.6	3.9	66
India	1,147	5	4.2	1.0	101
Australia	377	14	1.4	18.4	8
World	27,136			4.2	

Source: International Energy Agency, 2007.

2 Recent evidence suggests that the efficiency of natural emission sinks (such as forests, soils and the ocean) is declining, so that if emission reductions are delayed, deeper cuts will be required to achieve stabilisation (Canadell et al., 2007).

3 This includes the greenhouse gases covered by the Kyoto Protocol: CO_2, CH_4, N_2O, HFCs, PFCs and SF_6.

2.2.1 The suite of models approach

No single existing model adequately captures the global, national, sectoral and household dimensions or focuses on all relevant aspects of climate change policy in Australia. Previous Australian studies of climate change mitigation policy focus on one or other of these dimensions — a particular sector (for example, electricity generation) in isolation from the broader national economy, or on the national economy but without a consistent global analysis. In contrast, this analysis uses a suite of models that together span global, national, sectoral and household scales to simultaneously explore these four dimensions.

The following section briefly describes the range of models used in this report. (See Annex A for more detail, including modifications made to the models and the process used for linking models.)

Computable general equilibrium models

The Treasury's climate change mitigation policy modelling is centred on three top-down, computable general equilibrium (CGE) models developed in Australia: Global Trade and Environment Model (GTEM); G-Cubed model; and the Monash Multi-Regional Forecasting (MMRF) model. These CGE models are whole-of-economy models that capture the interactions between different sectors of the economy. GTEM and G-Cubed are models of the global economy; whereas, MMRF is a model of the Australian economy with state and territory level detail.

GTEM: a technology-rich global model

GTEM is a recursively dynamic general equilibrium model developed by the Australian Bureau of Agricultural and Resource Economics (ABARE) to address policy issues with long-term global dimensions, such as climate change mitigation costs (Pant, 2007).[4] It is derived from the MEGABARE model (ABARE, 1996) and the static Global Trade Analysis Project (GTAP) model (Hertel, 1997). The dimension of GTEM used for this report represents the global economy through 13 regions (including Australia, the United States, China and India) and 19 industry sectors. The model also disaggregates three energy-intensive sectors into specific technologies: electricity generation, transport and iron and steel.

G-Cubed: a forward-looking global model with macro dynamics

G-Cubed is a model of the global economy designed for climate policy mitigation cost analysis (McKibbin and Wilcoxen, 1998). The version used for this report represents the global economy through nine regions (including Australia, the United States and China) and 12 industry sectors (including coal, oil, gas, agriculture and manufacturing). An important characteristic of G-Cubed is that economic agents are partly forward-looking: they make decisions based not only on the present day economic situation, but also based on expectations of the future. G-Cubed has limited technology detail.

MMRF: a detailed model of Australia

The Monash Multi-Regional Forecasting (MMRF) model is a detailed model of the Australian economy developed by the Centre of Policy Studies at Monash University (Adams et al., 2008).

4 A recursively dynamic model solves for equilibrium in each year without taking account of information about the future.

MMRF has rich industry detail (with 58 industrial sectors) and provides results for all eight states and territories. In this modelling exercise, MMRF draws international assumptions from GTEM and is augmented with disaggregated bottom-up modelling for three emission-intensive sectors: electricity, transport and forestry.

Sectoral models

The CGE models are complemented by a series of bottom-up sector specific models for electricity generation, transport, land use change and forestry. Detailed analysis of these emission-intensive sectors is useful in understanding the economy's likely response to climate change mitigation policy, particularly over the short to medium term.

Detailed analysis which relies on current views about technology is generally less robust over the long term, as technology and other mitigation opportunities become more uncertain. As a result, bottom-up modelling of the transport and electricity sectors is limited to 2050. However, technology plays a much smaller role in land use change and forestry emissions, so analysis of this goes to 2100.

Electricity sector modelling

McLennan Magasanik Associates provides detailed bottom-up modelling of the Australian electricity generation sector with projections of electricity generation by technology and by state, fuel use, new investments and retirements, and electricity prices (McLennan Magasanik Associates, 2008). The highly detailed models aim to closely represent actual market conditions and take account of the economic relationships between individual generating plants in the system, with each power plant divided into generating units, defined by their technical and cost profiles.

A range of fuels and technologies are incorporated, including black and brown coal, natural gas, renewables (including hydro, biomass, solar and wind) as well as new technologies, such as carbon capture and storage and geothermal. Electricity demand is modelled on an hourly and monthly basis to capture the daily and seasonal fluctuations in energy use.

Transportation sector modelling

Australian transport sector modelling was conducted with CSIRO in conjunction with the Bureau of Infrastructure, Transport and Regional Economics (BITRE). CSIRO use a partial equilibrium model, the Energy Sector Model (ESM), of the Australian energy sector which includes detailed transport sector representation (CSIRO, 2008). The ESM was co-developed by CSIRO and ABARE in 2006. The model has an economic decision-making framework based around the cost of alternative fuels and vehicles. It incorporates detailed information about technical fuel and vehicle technical characterisation.

The model evaluates the uptake of different technologies based on cost competitiveness, practical constraints in transport markets, current excise and mandated fuel-mix legislation, greenhouse gas emission limits, each state's existing plant and vehicle stock, and lead times in the availability of new vehicles or plant.

Land use, land use change and forestry

The Treasury commissioned modelling of the forestry sector from ABARE (for Australia) and from Lawrence Berkeley National Laboratory (for the rest of the world).

ABARE's modelling examines the impact of an emission price on forestry and land-use change in the Australian agriculture sector (ABARE, 2008). The framework used is spatially explicit, and involves analysing the opportunities for emission sequestration provided by land use change and forestry on cleared agricultural land. These opportunities are determined when the net present value of returns from forestry investments are compared to the corresponding expected agricultural land value to estimate the potential area of clear agricultural land that is competitive for forestry within each spatial grid cell.

The Lawrence Berkeley National Laboratory uses its GCOMAP model (Sathaye et al., 2006). GCOMAP simulates how forest land users respond to changes in prices in forest land and products and to emission prices. GCOMAP calculations of net change in emission stocks associated with land use change and forestry were incorporated into GTEM and G-Cubed.

Other sectors

Sectors other than electricity, transport and land use change and forestry were modelled within the CGE models. Assumptions about mitigation options for these sectors were informed by historical data, stakeholder consultations and literature reviews.

Households modelling

Modelling of the impact of the emission price on households and the consumer price index is undertaken with the Treasury's Price Revenue Incidence Simulation Model (PRISMOD). PRISMOD is a large-scale, highly disaggregated model of the Australian economy which captures the flows of goods between industries and final consumers. The data used in PRISMOD comprise the transactions and consumption patterns of 109 industry categories and seven categories of final demand. The 2008 version of PRISMOD is based on data from the ABS (2008) publication *Australian National Accounts, Input-Output Tables 2004-05,* (Cat. no. 5209.0.55.001).

This distributional implication for households of emission pricing was analysed using Treasury's Price Revenue Incidence Simulation Model and Distribution Model (PRISMOD.DIST). This model is a static micro simulation model which can be used to examine the distributional effects of government policies on household income. The 2008 version of the model is based on data from the ABS (2006) publication *Household Expenditure Survey 2003-04*, (Cat. no. 6540.0).

2.2.2 Integrating the models

The results from each of these models are drawn together into an integrated set of projections that are broadly consistent at the macroeconomic level and sufficiently detailed in large emission-intensive sectors (Chart 2.1).

Modelling of the global economy with GTEM and global land use change and forestry with GCOMAP provides the international economic and emissions context for modelling of the Australian economy within MMRF, which in turn is informed by the bottom-up modelling of the electricity, transport and land use and forestry sectors. G-Cubed is broadly calibrated to the GTEM reference scenario, and provides comparative cost estimates for the policy scenarios, strongly emphasising the macroeconomic adjustment process.

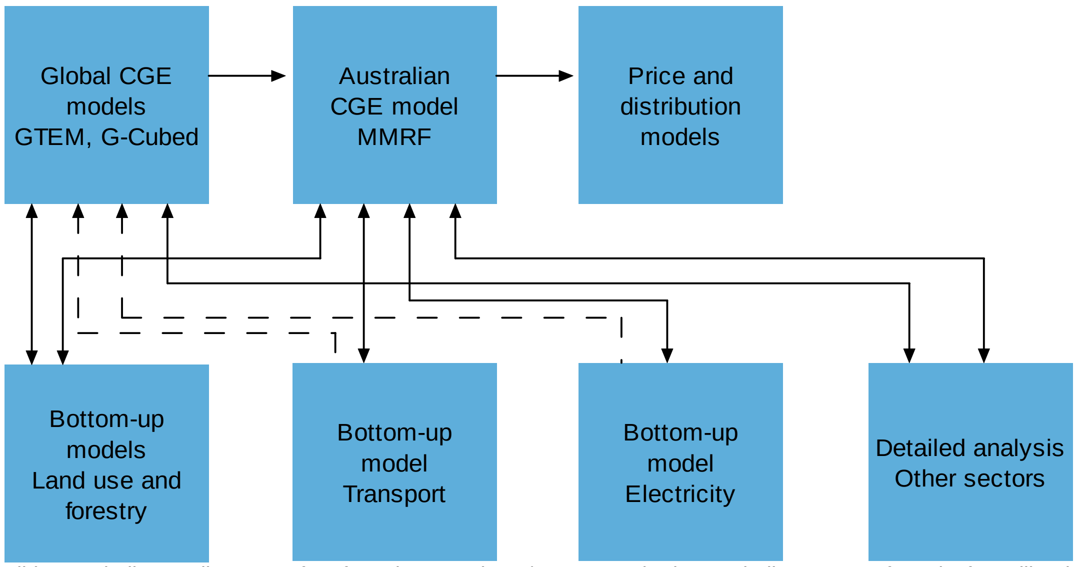
Linking economics models with different economic structures is not straightforward. The report team undertook significant research to ensure the models in the 'suite of models' were linked sensibly.

For example, MMRF and GTEM both have internally consistent, but different, assumptions about the supply responsiveness of Australian exports. Harmonising the structural features of the models for this exercise was not possible or desirable. However, MMRF requires input assumptions about world demand and price responses to determine shifts in its export demand schedules. This required careful linking to ensure the world demand curve determined within GTEM was made into an appropriate input for MMRF.

Similarly, ensuring that the bottom-up electricity (and transport) supply side information was correctly integrated within MMRF often required several iterations. The initial level of electricity (transport) demand was determined within MMRF. The level of demand, combined with emission prices and other input assumptions, then were inputted into the bottom-up supply side models. The detailed supply side information such as technology shares and price levels was fed back into MMRF, which then modelled a new level of demand. This feedback loop was continued until the changes in demand were minimal.

However, some models were relatively easy to link as they took outputs from one model to provide additional detail. For example, PRISMOD was used to determine a highly disaggregated set of industry price impacts from a certain emission price. This information was then fed into PRISMOD.DIST, which captured the distributional implications for households.

Chart 2.1: Integrating the suite of models



Note: Solid arrow indicates direct transfer of results as an input/output. Dashed arrow indicates use of results for calibration.

Using a suite of models provides a natural hedge against the inherent uncertainty of economic modelling. While input assumptions, as much as possible, have been harmonised across GTEM, G-Cubed and MMRF, the projections in the three models generated for Australia are not identical. The differences arise primarily from the different structures of the models, and these differences demonstrate the uncertainty surrounding modelling estimates.

To ensure that this report remains tractable, most Australian results are from MMRF in the first instance. However, where the Australian results determined in the global models differ significantly, or provide additional insights, these are provided for comparison. Similarly, the global results — including Australia as a region of the world — are from GTEM, with comparative analysis from G-Cubed. Where the bottom-up models provide insights, these results are given primacy.

2.3 How to interpret the results

To estimate the macroeconomic, sectoral and household impacts to Australia of reducing emissions, this report uses a range of economic and other models to project five scenarios for Australia and the world to 2050, and in three of these scenarios, to 2100. As with all modelling assessments, caveats need to be kept in mind when interpreting the results. Despite these limitations, models continue to be important analytical tools to help questions and answer questions relevant to long-term economic policies.

The scenarios analysed in this report, including the reference scenario, are illustrative and do not represent the official policy or negotiating position of the Australian Government, are not an official Government or Treasury forecast.

2.3.1 Scenario modelling

This report estimated the costs of reducing emissions by modelling five scenarios. Scenario modelling does not predict what *will* happen in the future. Rather, it is an assessment of what *could* happen in the future, given the structure of the models and input assumptions.

Scenarios are an analytical lens through which to view a problem; they are not the 'real world', especially as this exercise assumes no new mitigation policy and no climate change impacts. Scenarios guide understanding of the impacts of policy, the relativities between different policy options, and the extent to which development paths (technology, preferences and so on) need to shift from current trends.

Input and policy assumptions are particularly important. Many important variables affect the estimated cost of responding to climate change. The future path of these variables is not known, but values are required for the modelling analysis, so assumptions must be made.

The Treasury developed these assumptions through research, through consultation with stakeholders and domestic and international experts, and on the basis of expert consultancies. While they intend to be plausible central estimates within a range of uncertainty, other analysts could well form different judgments.

For instance, the assumptions underpinning the reference scenario determine the level of baseline emissions which is a major (and perhaps the single biggest) determinant of the estimated costs of mitigation, as it determines the magnitude of emissions reductions required (IPCC 2007b; den Elzen et al., 2007; Stern, 2007). To the extent that the reference scenario over (or under) estimates emissions, all else equal, the costs of mitigation are over (or under) estimated.

Equally, the policy scenarios assume that the world implements emissions reduction arrangements through a global emissions trading scheme. While the international emissions trading scheme is an analytical proxy for the mix of policy instruments that are likely to be deployed, such an 'optimal' policy mechanism, with complete coverage of regions, gases and emissions sources, tends to give lower cost estimates than a less efficient global arrangement (Box 2.5, Stern, 2007). For instance, a global emissions trading scheme with only partial coverage of regions could increase costs for achieving the same environmental objective, as it prevents access to low-cost abatement in non-participant regions.

Box 2.5: Measuring emissions

Carbon dioxide (CO_2) the most important anthropogenic greenhouse gas, accounts for around three quarters of global emissions (IPCC, 2007a). Other important gases include methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), and sulphur hexafluoride (SF_6).

This report expresses emissions and emissions pathways in CO_2-equivalent (CO_2-e), which aggregates the different gases based on their relative warming potential. The CO_2-e emission values indicate total emissions of the six gases covered under the Kyoto Protocol, from all sources, combined using the 100-year global warming potentials applied under the Protocol. While the global warming potential concept is the subject of scientific debate (IPCC, 2007a), this is a convenient and widely used measure, and is embedded in the structure of the models used in this report.

The atmospheric concentration levels presented in this report are not calculated using global warming potentials. The concentrations are calculated directly from the combined radiative forcing of the six Kyoto gases using the simple climate model MAGICC.[5]

The inherent difficulty in developing assumptions and undertaking simulations is compounded by the long timeframes involved (Box 2.6). As the model looks further into the future, historical information used to build the model or provide input assumptions becomes less robust. While different models are more useful over different timeframes, generally the further into the future the projections extend, the greater the caution required in interpreting results. For this reason, while the modelling continues to 2100 for the Garnaut scenarios, the focus of long-term results is generally 2050 in this report.

Given all the uncertainties about future variables, the Treasury has explored several sensitivities around the reference scenario and the policy scenarios.

5 Model for the Assessment of Greenhouse Gas Induced Climate Change (Wigley, 2008).

Box 2.6: Projections over long timeframes

Climate change operates over very long timeframes, with significant time lags between greenhouse gas emissions and resulting impacts. As a result, quantitative analysis of climate change must take a long-term view.

As the timeframe expands, assumptions necessarily become more speculative. Just as it would have been impossible to accurately foresee the current state of the world in 1908, it is today impossible to accurately foresee the state of the world in 2100.

For instance, 1908 saw the beginning of the popular use of cars with production of the Model T Ford. The first two-person plane flew in May of that year, but the first flight of Qantas was still 12 years away. Australia's GDP per capita was around the same level as China's today. Bendigo was the seventh largest city in Australia. Less than 3 per cent of Australian imports came from Asia. The largest occupation was agriculture, making up over 15 per cent of employment (Commonwealth Bureau of Consensus and Statistics, 1908). Who at that time could have predicted developments such as the internet, containerised shipping or modern air freight?

Results therefore must be interpreted with caution. The economic and greenhouse gas emission projections presented here are not forecasts or predictions. The results illustrate a scenario, constructed to allow analysis of the possible economic impacts of policies to reduce greenhouse gas emissions.

2.3.2 How to measure costs?

The modelling underpinning this report encompasses many variables that could be used as measures of economic cost.

Measuring economic output

This report focuses on gross national product (GNP) as the high level measure of economic welfare impact rather than gross domestic product (GDP). GNP reflects changes in GDP, terms of trade and international income transfers. Reducing greenhouse emissions, in a least-cost efficient way, may involve the transfers of income between economies, and influence nations' terms of trade. In that context, GNP is a better measure of welfare, as it excludes income accruing to overseas residents, thereby better depicting the current and future consumption possibilities available to Australians; it measures what a nation can afford to buy.

Likewise, different measures indicate the output of an industry or economy. Two common definitions are gross value added (GVA) and gross output. GVA measures the returns accruing to the owners of the primary factors such as land, labour and capital used in the production process plus taxes less subsidies on production. GDP is the sum of GVA across industries. Gross output is the value of output produced by an industry — the value of inputs produced by other industries used in the production process (intermediate inputs) plus GVA and any taxes less subsidies on production. Gross output is a measure of turnover or activity. The most appropriate measure of output will vary with context. GVA provides an indication of the contribution that an industry makes to national economic activity as it excludes the value of inputs produced by other industries. Gross output is important for emissions analysis as emissions are created during the production process.

After a relative price change, gross output and GVA can move in different directions. Introducing emission pricing results in substantial substitution between intermediate inputs and primary factors, driving a wedge between these two measures. Value added by industry sums to GDP, and thus is a good measure of the 'economic impact' of an emission price. However, gross output is an important concept in the modelling, as a substantial share of emissions is produced in the production process and substitution among intermediate inputs is an important part of the transformation in response to an emission price.

All gross world product (GWP) and regional comparisons of gross domestic product (GDP) levels and growth rates in this report are reported in 2005 US dollar purchasing power parity terms (Box 2.7).

Box 2.7: Market exchange rate versus purchasing power parity

The market exchange rate (MER) is the rate of exchange between currencies in foreign exchange markets in the 'real world'. In contrast, purchasing power parity (PPP) exchange rates are hypothetical exchange rates that adjust for differences in prices levels across countries. Under a PPP exchange rate, one Australian dollar buys the same amount of goods and services in every country: no more, no less.

The MER/PPP debate is about which exchange rate is more appropriate for converting different countries' GDP into a single currency (usually US dollars) to make economic comparisons and growth projections. The choice of measurement method significantly affects the validity of economic growth projections and energy use and, hence, projections of future climate change (Castles and Henderson, 2003).

PPP exchange rates take into account the different price levels across countries, so they more accurately describe relative standards of living between the developed and developing world. In contrast, MER valuations undervalue developing economies relative to developed economies, so they overstate GDP gaps.

The MER/PPP debate is important for productivity convergence assumptions, as overstating income gaps will overstate economic growth in developing countries. This assumption is also important for estimates of global mitigation costs: cost estimates based on MER exchange rates tend to understate global abatement costs. Accordingly, whether modelling uses MER or PPP exchange rates is important in comparing costs estimates between models.

All national and trade accounts in the models in this report use MER data. However, global aggregate labour productivity assumptions were derived using PPP data. Using PPP data to compare starting level income per capita ensures that the level of developed economies' GDP is not under-estimated. Sector-specific productivity assumptions result in productivity growth being faster in tradable than in non-tradable industries. These differences lead to an appreciation of the real exchange rate through the Baumol-Balassa-Samuelson effect. Along with the conditional convergence framework, these productivity assumptions suggest the PPP and MER exchange rates converge over time, reducing the implications of the MER data used in the CGE models (Bagnoli, Chateau and Sahin, 2006).

Presenting cost estimates

As with any quantitative analysis, care needs to be used when reporting and interpreting modelling results. Statistics and numbers can mean different things when reported within different contexts.

For example, discussing results relative to a hypothetical future such as the reference scenario is the more common way of explaining the impact of a policy intervention within an economic model. This is a sensible approach when attempting to see how the policy will influence the economy in isolation from other events. However, a focus on the opportunity cost of a policy could give rise to a reference point bias where people believe the loss is relative to current levels rather than a forgone gain through smaller increases in future incomes.

Therefore, results reported in this way must not be interpreted as suggesting that policy will have an absolute impact relative to the current world. For example, if cutting interest rates would raise economic growth by 1 percentage point relative to what would have happened otherwise, this should not be interpreted as saying that the economy will fall by 1 per cent from its current levels.

Furthermore, empirical research indicates some economic cost measures could be commonly misunderstood and public attitudes to action on climate change are significantly affected by how these costs are communicated (Hatfield-Dodds, 2006; Morrison, 2008).

To represent as complete a picture as possible of the economic implications of reducing greenhouse emissions, this report presents a range of measures when reporting high level results (Box 2.8).

Discount rates and inflation

Discount rates in climate change policy are highly topical (Quiggin, 1996; Nordhaus, 2007; and Stern, 2007). They are used to compare estimates of the costs and benefits of climate change mitigation over long timeframes.

This report only focuses on the costs of mitigation, not the benefits, so the debate about discount rates is not important here. The modelling shows the costs of mitigation as they happen in that year. In other words, a loss of one dollar in 2050 is equivalent to a loss of one dollar in 2010, which is akin to assuming a zero discount rate. If, however, these modelling results are used to judge the importance of future costs from today's perspective, this would require a consideration of discount rates.

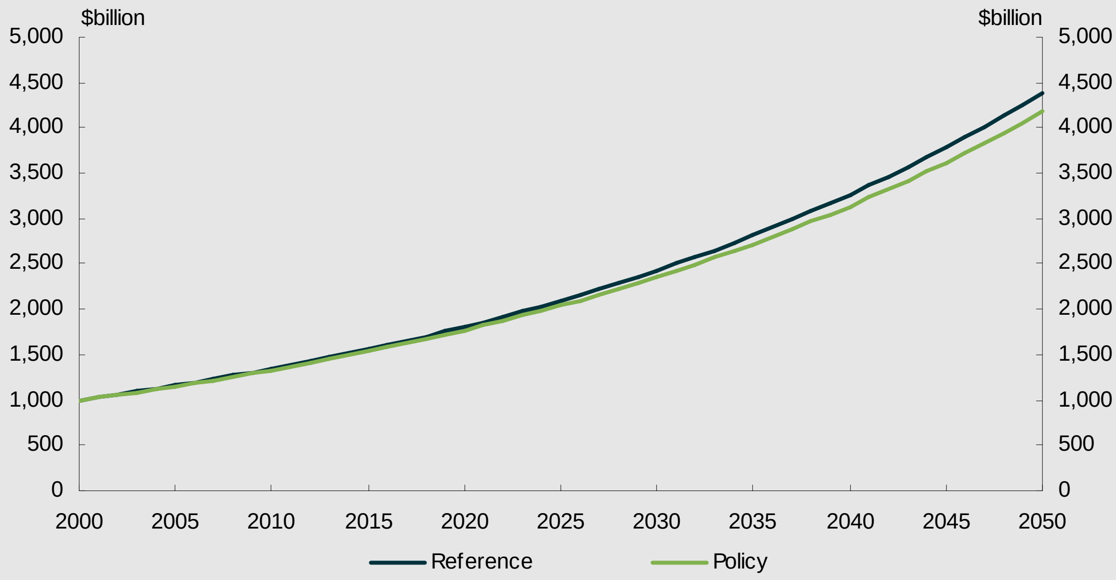
Box 2.8: Alternative way to report on modelling — a hypothetical example

The same modelling results reported differently can convey different impressions to non-experts. For instance, Chart 2.2 presents the impact on GDP of a policy scenario on a hypothetical economy where under a reference scenario the economy grows from $1,000 billion in 2000 to nearly $4,500 billion by 2050.

These six statements describe the 'cost' of the policy scenario relative to the reference scenario. They all report exactly the same result.

- GDP growth is 0.1 per cent per year lower over 50 years.
- GDP is $208 billion lower at 2050.
- GDP is 4.7 per cent lower at 2050.
- The cumulative GDP loss is $3,485 billion over 50 years.
- The cumulative GDP loss is 3 per cent of total GDP over 50 years.
- GDP is 4.4 times higher than 2000 levels in 2052 instead of in 2050, a delay of two years.

Chart 2.2: GDP — hypothetical reference and policy scenarios



In addition, the CGE models are all in 'real' dollars, and thus abstract from the devaluing influence on purchasing power from inflation.

Across the suite of models used in this report are a range of databases, all with their own base years when prices are set equal to one. For example, GTEM has a base year of 2001; MMRF has a base year of 2005; and G-Cubed has a base year of 2006. To compare real variables across models, the data were adjusted to the same base years.

Emission prices can be reported in different units. Nominal emission prices include the impact of inflation on prices. When an emission price is reported in nominal terms, such as A$23 in 2010, this would be the actual nominal price of a permit in 2010 using the dollars available in 2010. Often, to abstract from inflation, emission prices are referred to in base year prices: for example, an emission price of A$20 in 2010, in 2005 prices. This reflects the purchasing power of A$20 in 2005 dollars. Emission prices in this report are reported in both measures, depending on the context, and are clearly labelled.

2.3.3 Model limitations and uncertainties

Economic models are always an approximation, or simplified version, of the vastly complex real world. Thus, models always have limitations. The models used in this exercise have high level limitations; this affects the interpretation of results. However, despite their limitations, models examine complex issues rigorously and in an internally consistent way across long timeframes.

The models used for this exercise are aggregated models. The least aggregated is PRISMOD, which has 109 industries. Aggregation is a necessary simplification of the real economy owing to limitations in data and in computing power. In industries where the firms are reasonably homogenous, with similar patterns of inputs and emissions intensity, this simplification has little effect. But in industries where firms have different, sometimes dramatically different, patterns of inputs and emissions intensity this simplification will reduce the accuracy of the modelling and the results.

The models exclude the risks and impacts of climate change itself. This means that mitigation policies are assumed to impose a 'cost' by moving the economy away from its 'optimal' economic path in the reference scenario to a 'less efficient' economic structure. This result requires careful interpretation: in an economic sense, mitigation policy improves the efficiency of the economy by pricing the externality associated with emissions (Box 2.2). The costs presented in this report need to be considered in the context of broader benefits of mitigation action, including the economic benefits of reduced risks and impacts of climate change (Stern, 2007; Garnaut, 2008).

The models do not capture well the short-term economic adjustment costs; instead, they explore long-term multi-sector impacts. To different degrees, the CGE models approximate short-term adjustment paths. At one end of the spectrum, GTEM assumes that labour and capital are perfectly mobile across industries, at all times and at no cost. Thus, GTEM does not capture any short-term adjustment costs. At the other end of the spectrum, G-Cubed assumes immobility of capital, slow adjustments to wages and liquidity constraints, and includes partial forward-looking behaviour. MMRF assumes capital and labour take time to adjust, but does not attach any cost to that adjustment process. The CGE models, therefore, provide a more robust analysis of the post-transition economy than of the transitional process. The bottom-up models do provide some insights into the adjustment process electricity generation and transport sectors.

The models do not capture market failures caused by asymmetric information, strategic interaction between agents, public goods and externalities.

The models do make some allowance for learning to reduce the cost of some technologies. However, the industry-level technological pathways are exogenous in the CGE models. For example, an increase in the scale of adoption of renewable technologies in electricity generation sector results in faster capital cost reductions. The models used in this report do not allow for endogenous economy-wide technological improvements, or for development of a 'backstop' technology.[6] The sensitivity of the results to alternative technology assumptions are explored in the sensitivity analysis.

The models do not capture transaction costs associated with emission permit allocation, whether domestically or internationally. In the real world, transaction costs will be associated with implementing and monitoring emission markets, and search costs associated with identifying mitigation opportunities. These costs may be particularly high in some developing economies, where the legal and regulatory regimes required for efficient market operation are not yet established.

The models do not capture the potential co-benefits of climate change mitigation policy. In some circumstances, co-benefits can occur between mitigation policy and other environmental objectives. For example, the simultaneous reduction in local and regional air pollution, alongside a reduction in greenhouse emission from coal burning.

The models do not capture non-market goods and services. In addition to reducing the risks of climate change, mitigation policies will affect other non-market values. Non-market benefits include improved health outcomes and lower urban pollution stemming from reductions in petroleum fuel use in road transport; non-market costs include the personal impacts of changing employment and relocation arising from structural adjustment.

6 A 'backstop' technology provides an unlimited amount of emissions mitigation at a given cost. It effectively acts as a global ceiling on the emission price.

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Chapter 3: The reference scenario — Assumptions and projections

Key points

The reference scenario presents a development pathway for the Australian and world economies, in the absence of climate change. It provides a robust starting point for the analysis of various climate change mitigation scenarios.

The reference scenario is a major determinant of the estimated costs of mitigation because the emissions level in the reference scenario defines the amount of mitigation required to reach the environmental goals of the policy scenarios.

The reference scenario describes a world of strong economic growth and continued improvement in technology and resource use efficiency.

Australian and world emissions continue to grow strongly. By 2050, world greenhouse gas emissions increase by over 140 per cent from current levels and Australia's greenhouse gas emissions nearly double. As a result, the concentration of greenhouse gases in the atmosphere rises strongly to over 1,500 ppm CO_2-e by 2100.

Global world output per capita increases three times to 2050, and is dominated by developing economies; productivity convergence gradually narrows the GDP per capita gap between economies.

Australia's GDP per capita is 1.7 times higher by 2050 than today, with Australia benefiting from the pattern of global development.

Fossil fuels continue to be the engine of economic growth and dominate energy supply to 2050.

The reference scenario presents a development pathway for the Australian and world economies to 2100. As this report's focus is on mitigation policies, this chapter's focus is on the period to 2050. This pathway has no new policies to reduce emissions and no impacts of climate change (Box 3.1).[1] It presents a plausible future path for economic growth, population levels, energy consumption and greenhouse gas emissions in a world without climate change. The reference scenario is not a prediction and does not include risks arising from climate change itself.

The reference scenario provides a robust starting point for the analysis of various climate change mitigation scenarios. It is a point of departure to highlight the possible implications for the Australian and world economies of policies to reduce greenhouse gas emissions.

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1 While the reference scenario aims to project a world as if climate change mitigation policies did not exist, firms and households probably anticipate climate change mitigation policies and modify their actions. Accordingly, the impact of climate change mitigation policies may indirectly be included in the reference scenario to the extent that it affects historical data.

The reference scenario is a major (and perhaps the single biggest) determinant of the estimated costs of mitigation because the emissions level in the reference scenario defines the amount of mitigation required to reach the environmental goals of the policy scenarios. The Treasury researched and consulted extensively in developing this scenario, particularly on historical trends and possible future economic, social and technological developments.

Expert opinion on many key variables varies widely. The Treasury, in partnership with the Garnaut Climate Change Review and other expert advisers, developed a set of assumptions which represent its best assessment of likely trends.

Where possible, assumptions used in the reference scenario are consistent across the suite of CGE and sectoral models. However, differences in the structure and level of detail contained in the models will result in differences in the reference scenario across models. The reference scenario provided the basis for the Garnaut Climate Change Review's independent analysis of the potential economic impacts of climate change.

Box 3.1: Climate change policies in the reference scenario

Governments in Australia and around the world have implemented a range of climate change mitigation policies. Many others are being considered and developed.

Given this evolving policy landscape, defining a reference scenario with no new climate change mitigation policies is not straightforward. It is complicated by the multifaceted aims of some greenhouse gas mitigation policies, such as local environmental protection or industry support.

For Australia, the pre-existing policy measures included in the reference scenario include the 9,500 gigawatt hour (GWh) Mandatory Renewable Energy Target (MRET), the Victorian Renewable Energy Target (VRET), the NSW and ACT Greenhouse Gas Reduction Scheme and the 15 per cent Queensland Gas Scheme. However, major new mitigation policies, such as the planned expansion of the Renewable Energy Target to 45,000 GWh a year, the CPRS and the Australian Government's target to reduce emissions by 60 per cent from 2000 levels by 2050 are not included.

For the world, the reference scenario does not include any specific targets or measures. However, industry-specific policy measures, such as mandatory technology targets, are captured the extent to which they have altered historical emission intensity or influenced technology shares in sectors producing energy services.

3.1 THE WORLD

Economic output is determined by three components: population, participation and productivity (the '3Ps').[2] The pattern and rate of GDP growth is therefore a function of the assumptions regarding movements in population; changes in participation rates; and the growth of productivity. Trends in these variables differ across geographic regions and industry sectors.

2 The 3Ps framework is discussed in the Australian Government's second intergenerational report (2007), p 10.

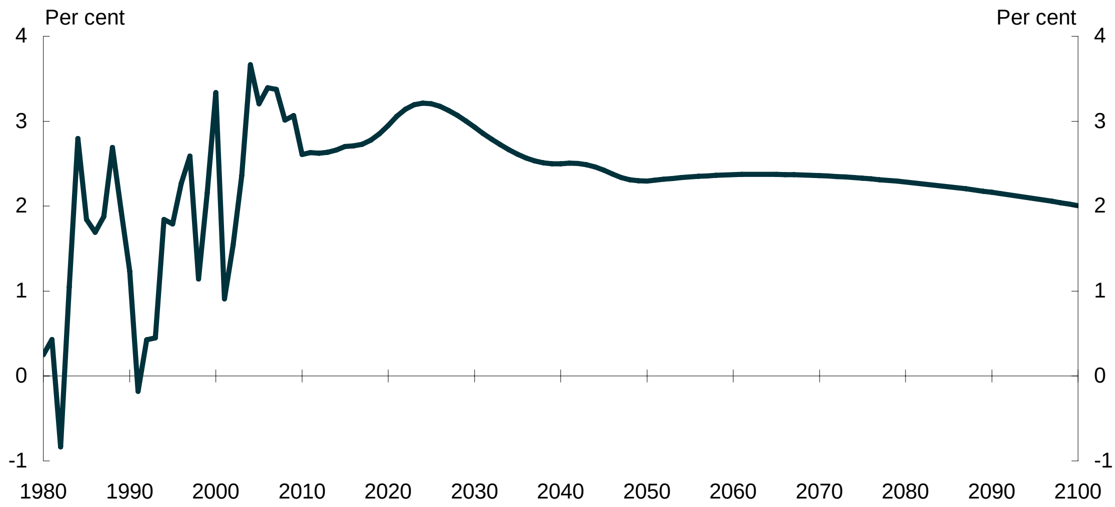
The reference scenario describes a world of strong economic growth and continued improvement in technology and efficient resource use. Global population peaks in the second half of the century, and the productivity gap between economies narrows, reducing regional differences in per capita income.

Productivity growth primarily drives the global economy, with per capita GDP projected to increase by more than 940 per cent from 2005 to 2100, compared with a 380 per cent increase from 1900 to 1999 (Chart 3.1). Overall, the global economy is projected to be roughly five times larger by 2050 and 15 times larger in 2100 than in 2005.

Productivity growth rates vary across economies, reflecting their different stages of development and an expectation of conditional convergence in productivity levels. Despite some evidence of conditional convergence in living standards, growth in world living standards has not been uniformly distributed across economies over the past century. In 2005, the GDP per capita of the world's poorest economies was up to 80 times less on average than the GDP per capita of the world's high income economies.

Existing differences in productivity levels are expected to narrow. Developed economies all improve their productivity at around the same rate, while developing economies accelerate towards, but do not reach, the productivity levels of developed economies. This acceleration occurs for all developing economies, but the rate of acceleration in the nearer term takes into account each economy's recent growth performance.

Chart 3.1: Gross world product per capita growth



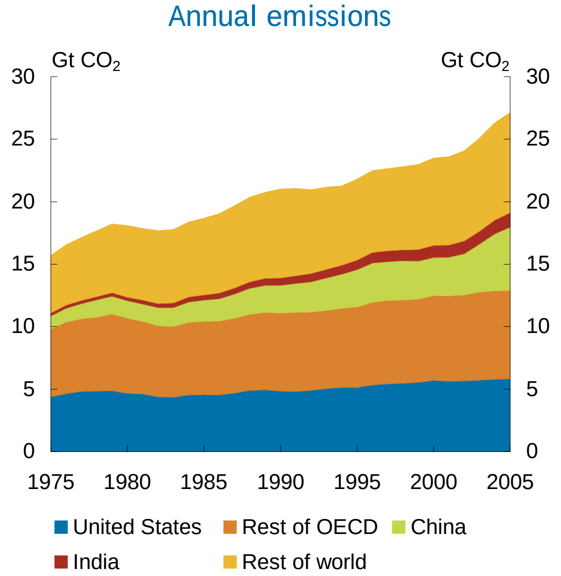
Source: IMF, 2008; and Treasury.

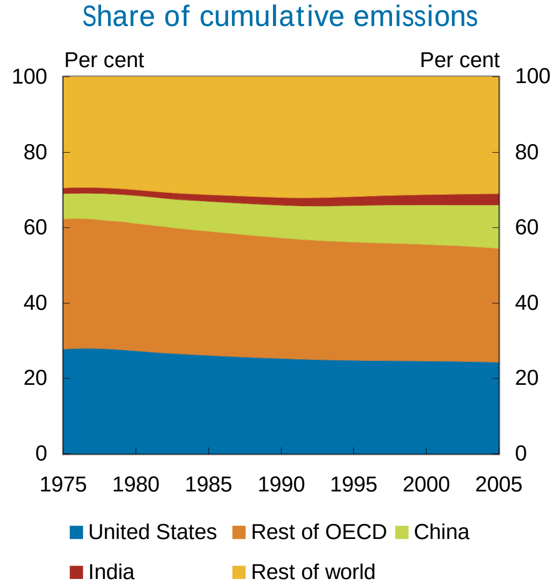
3.1.1 World emissions

Much of the world's economic activity has depended, and will continue to depend, on emission-intensive energy. Despite an overall fall in the energy intensity of world output, total primary energy demand grew more than 80 per cent from 1975 to 2005, with most energy coming from fossil fuels (IEA, 2007a).

A growing world economy and rising energy consumption have caused the world's greenhouse gas emissions to rise considerably over the past 30 years (Chart 3.2). This growth has occurred despite a fall in the emission intensity of output. Most of the world's historical emissions come from the world's high income economies, with the OECD accounting for 48 per cent of CO_2 emissions from fuel combustion in 2005 and 55 per cent of the total volume of CO_2 emissions from fuel combustion over the past 30 years (OECD/IEA, 2008). In contrast, India, accounted for just 4 per cent of CO_2 emissions from fuel combustion in 2005 and around 3 per cent of total cumulative CO_2 emissions from fuel combustion over the past 30 years.

Chart 3.2: Fuel combustion emissions





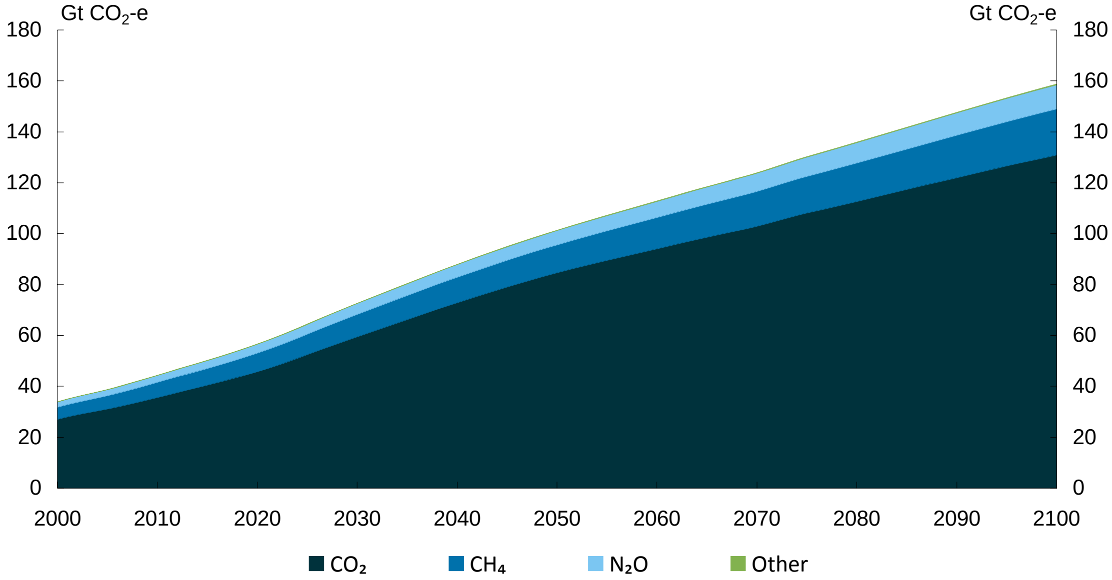
Source: OECD/IEA, 2008.

In the reference scenario, the world economy continues to rely on fossil fuel combustion to power growth, which in turn leads to increased greenhouse gas emissions, despite considerable falls expected in the emission-intensity of growth.

With the world economy projected to grow strongly this century, annual greenhouse gas emissions increase by over 2½ times between 2005 and 2050, from 39 Gt of CO_2-e to just over 102 Gt in 2050. By 2100, annual emissions are projected to be higher still at 161 Gt (Chart 3.3). The annual rate of growth of emissions is expected to slow from around 2 per cent now to less than 1 per cent by 2100. In total, around an extra 10,000 Gt of greenhouse gases are projected to be released into the atmosphere this century (Box 3.2).

These emissions are mostly carbon dioxide from energy use and deforestation, and methane and nitrous oxide from agriculture (Table 3.1). Other gases such as hydrofluorocarbons HFCs and perfluorocarbons (PFCs) maintain a small share (less than half of 1 per cent).

Chart 3.3: Global emissions by gas



Source: Treasury estimates from GTEM.

Table 3.1: Global emissions

Emissions by region

	2005 CO_2-e	2020 CO_2-e	2050 CO_2-e
United States	7.2	7.7	9.4
EU-25	4.9	5.2	5.5
China	7.2	16.1	31.4
Russia + CIS	3.3	4.7	5.5
Japan	1.4	1.3	1.1
India	1.8	3.7	11.7
Canada	0.8	0.9	1.2
Australia	0.6	0.7	1.0
Indonesia	0.8	1.0	2.2
South Africa	0.5	0.7	1.4
Other South and East Asia	1.7	1.9	3.7
OPEC	1.8	2.9	6.2
Rest of world	7.2	10.2	22.2
Total	39.1	57.2	102.3

Emissions by gas and type

	2005 CO_2-e	2020 CO_2-e	2050 CO_2-e
Carbon dioxide	31.1	45.7	84.5
Combustion	27.0	42.0	78.1
Fugitive/Industrial process	1.2	2.3	5.8
Waste	0.04	0.04	0.03
LUCF	2.8	1.4	0.5
Methane	5.3	7.3	11.0
Combustion	0.4	0.5	0.8
Fugitive/Industrial process	3.6	5.3	8.4
Waste	1.3	1.5	1.8
Nitrous oxide	2.4	3.4	5.6
Combustion	1.4	2.1	3.1
Fugitive/Industrial process	0.9	1.3	2.4
Waste	0.03	0.03	0.03
Other gases	0.4	0.7	1.3
Total	39.1	57.2	102.3

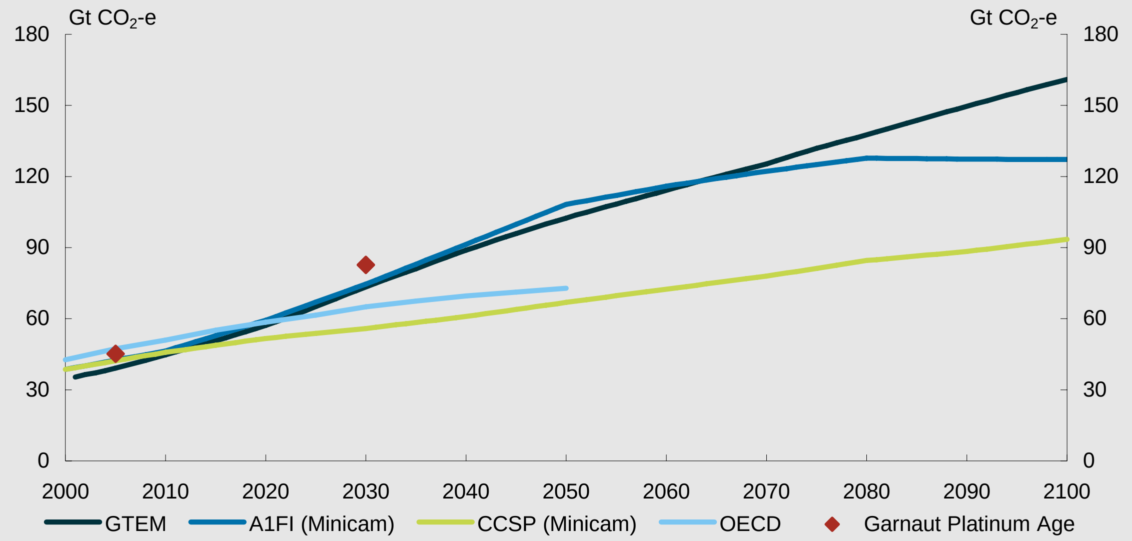
Source: Treasury estimates from GTEM.

Box 3.2: Reference scenarios compared

Global emissions projected under the reference scenario are substantially higher than other recent studies, and roughly equivalent to the highest emission scenario of the IPCC Special Report on Emission Scenarios, A1FI (IPCC, 2000).

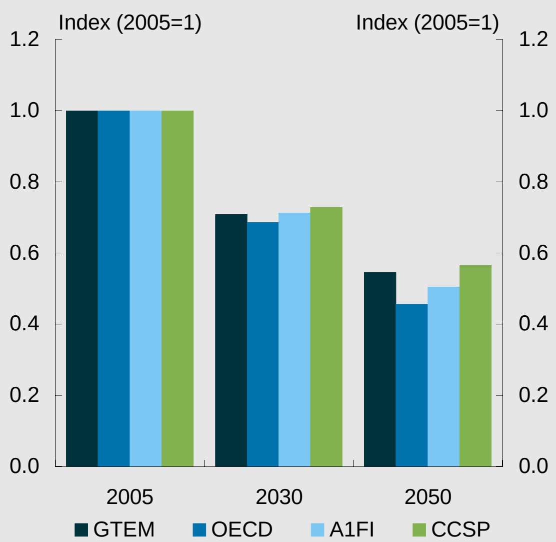
The GTEM reference scenario is higher than results from the OECD Environmental Outlook, a United States Climate Change Science Program (CCSP) report and the A1FI scenario from the IPCC's Special Report on Emissions Scenarios (Chart 3.4) (OECD, 2008; IPCC, 2000; CCSP, 2007). However, it is slightly lower at 2030 than the Platinum Age scenario explored by Garnaut (Garnaut et al., 2008). The GTEM reference scenario projects stronger global GDP growth, particularly in developing economies, than the OECD and CCSP scenarios. As incomes rise, demand for energy and other emission-intensive goods and services grow. Given significant reserves exist, and without an emission constraint, fossil fuels remain the primary source of energy and the biggest source of emissions.

Chart 3.4: Global greenhouse gas emissions



Source: Treasury estimates from GTEM; CCSP, 2007; OECD, 2008; IPCC, 2000; Garnaut et al., 2008a.

Chart 3.5: Emission intensity



Emission intensity (emissions per unit of economic output) is quite similar across the four studies, falling substantially and reflecting the factors discussed in this reference scenario (Chart 3.5).

Differences in emission levels across studies largely reflect assumptions about the likely rate of economic growth to 2050, not assumptions about technology. Economic growth in the CCSP and OECD scenarios is considerably lower than the reference scenario.

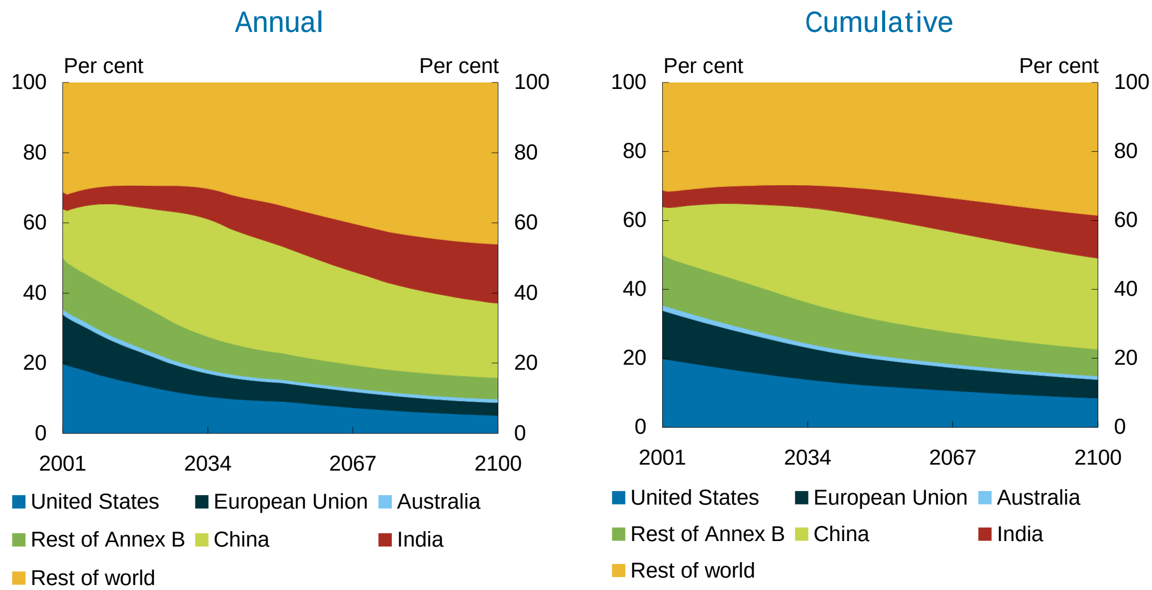
The composition of world emissions changes over this century, with developed economies' share of emissions declining each year, while the developing economies' share rises (Chart 3.6).

In the medium term China dominates world growth in emissions, overtaking the United States to become the world's highest emitting economy. China's share of global emissions grows from 18 per cent in 2005 to 33 per cent of global emissions in 2030, then falls back to 31 per cent in 2050 and 21 per cent in 2100. In contrast, the United States and European Union together generated 31 per cent of global emissions in 2005, but their share falls to 18 per cent in 2030, then to less than 15 per cent in 2050 and 9 per cent in 2100.

While the current high income economies are responsible for most of the emissions currently in the atmosphere, developing economies are projected to be responsible for most cumulative emissions released into the atmosphere this century (Chart 3.6). By 2050, around 30 per cent of this century's emissions are from China; around 12 per cent from the United States; only 8 per cent from India; and 1 per cent from Australia.

The projected future composition of world emissions highlights the economies currently responsible for the atmospheric concentration of greenhouse gases and the economies likely to be responsible in the future. This distinction underscores the importance of global agreements to limit emissions in the future, and the difficulties in international negotiations requiring agreement over emissions allocations between economies.

Chart 3.6: Shares of global emissions



Source: Treasury estimates from GTEM.

Global emissions are expected to rise strongly, despite considerable falls in the emission intensity of growth (Table 3.2). The emission intensity of the world economy falls by more than 45 per cent by 2050 compared with 2005. The progressive fall in emission intensity of world growth is a result of changes in the composition of the world economy (with service sectors capturing a rising share in the longer term), ongoing energy efficiency improvements and the advancing technological frontier.

While the emission intensity of output varies significantly across regions, these differences are expected to narrow as differences in economic structures and technology diminish across economies (Table 3.2). Nevertheless, variations in key factors, such as consumer preferences, geographical location, resource endowments and comparative advantage, will cause some differences in emission intensity to remain.

While emissions per unit of output are projected to decline, global per capita emissions are projected to almost double between 2005 and 2050 (Table 3.2).

Differences in per capita emission levels are projected to narrow as incomes in developing regions rise, flowing through to increased consumption of energy and other emission-intensive goods. China's emissions per capita quadruple to 2050 and approach the same levels as the United States. India's emissions per capita remain below the world's average by 2050, despite strong growth. Emissions per capita are projected to be quite stable for developed economies, reflecting continued energy efficiency, technological change and rising consumption of low-emission services.

Table 3.2: Emissions by region

Emission intensity of GDP

	2005	2020	2050
	kg CO_2-e/$US		
United States	0.55	0.43	0.29
European Union	0.37	0.30	0.22
Australia	0.80	0.62	0.43
Rest of Annex B	0.72	0.66	0.50
China	1.38	0.95	0.57
India	0.81	0.52	0.35
Rest of world	0.88	0.58	0.34
World average	0.70	0.57	0.38

Emissions per capita

	2005	2020	2050
	t CO_2-e/person		
United States	23.9	22.6	23.3
European Union	10.7	10.9	11.9
Australia	28.9	28.8	29.3
Rest of Annex B	12.3	16.1	20.0
China	5.4	11.3	22.2
India	1.6	2.7	7.1
Rest of world	4.2	4.7	7.4
World average	6.0	7.46	11.1

Note: Emission estimates vary from Table 3.2 due to database differences between the MMRF and GTEM models. GDP measured in 2005 US dollars (purchasing power parity).
Source: Treasury estimates from GTEM.

3.1.2 The world economy

In the reference scenario, the world economy shows continued strong growth, driven by the continued process of catch-up of lower income economies towards the GDP per capita levels enjoyed by high income economies.

Gross world product (GWP) is projected to rise from $54 trillion in 2005 to $268 trillion in 2050.[3] The average projected annual increase of GWP of 3.5 per cent is slightly slower than the 3.9 per cent experienced on average over the past 50 years. GWP growth is expected to be around 4 per cent to 2030, before slowing due to likely demographic developments (Chart 3.7).

World population growth is expected to slow, reflecting likely demographic developments in turn driven by rising living standards and economic transformation (United Nations, 2004 and 2006). After growing from 2.5 billion in 1950 to 6.1 billion in 2000, the world's population is expected to peak at 9.5 billion in 2075, before falling slightly to 9.3 billion in 2100 (Chart 3.8). Most population growth occurs in South Asia, the Middle East and Central Asia, Africa, and South America.

3 Unless otherwise noted, all gross world product (GWP) and regional comparisons of gross domestic product (GDP) levels and growth rates in this report are reported in purchasing power parity terms, 2005 US dollar terms.

Box 3.3: Climate change projections in the reference scenario

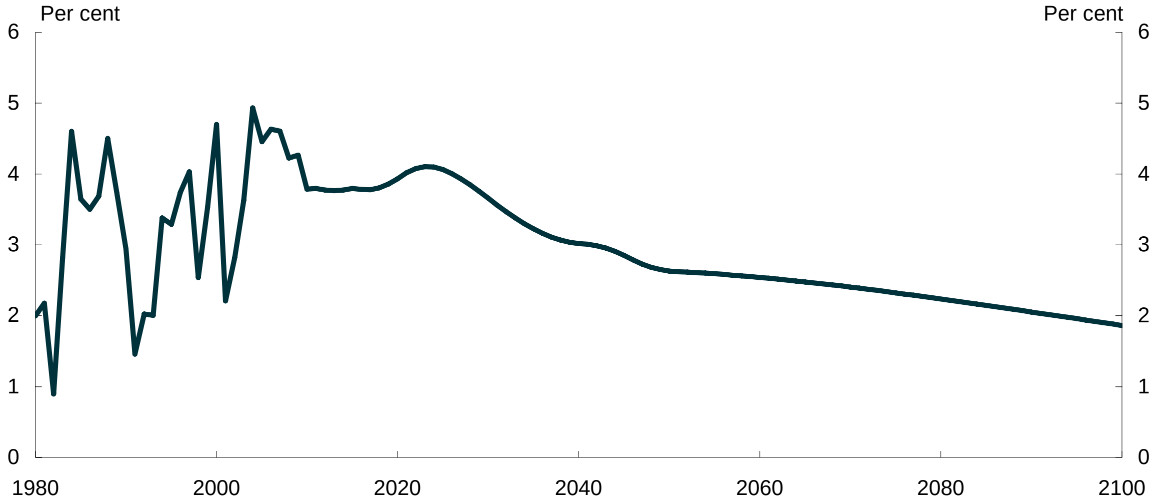
Without new policies to reduce greenhouse gas emissions, the reference case sees continued strong growth in global emissions. As a result, the concentration of greenhouse gases in the atmosphere rises to over 1,500 ppm CO_2-e by 2100.

This corresponds to an increase in global average temperature of 5°C above pre-industrial levels by 2100, and of 8°C or more above pre-industrial levels[4] in the following centuries (assuming concentrations stabilise around this level) (Garnaut, 2008a). A temperature increase of this magnitude brings very high risks of extreme and irreversible climate change impacts, including:

- loss of complete ecosystems, such as the Great Barrier Reef;
- severe water availability problems, seriously limiting the viability of human occupation and agriculture;
- significant and widespread shortages of food;
- large areas of Australia's coastline permanently or periodically inundated;
- significant infrastructure costs associated with asset protection and replacement; and
- greater international instability, particularly in the developing world (Pearman, 2008).

The Garnaut Climate Change Review extensively discusses likely economic, social and environmental impacts of such a 'no mitigation' scenario (Garnaut, 2008b).

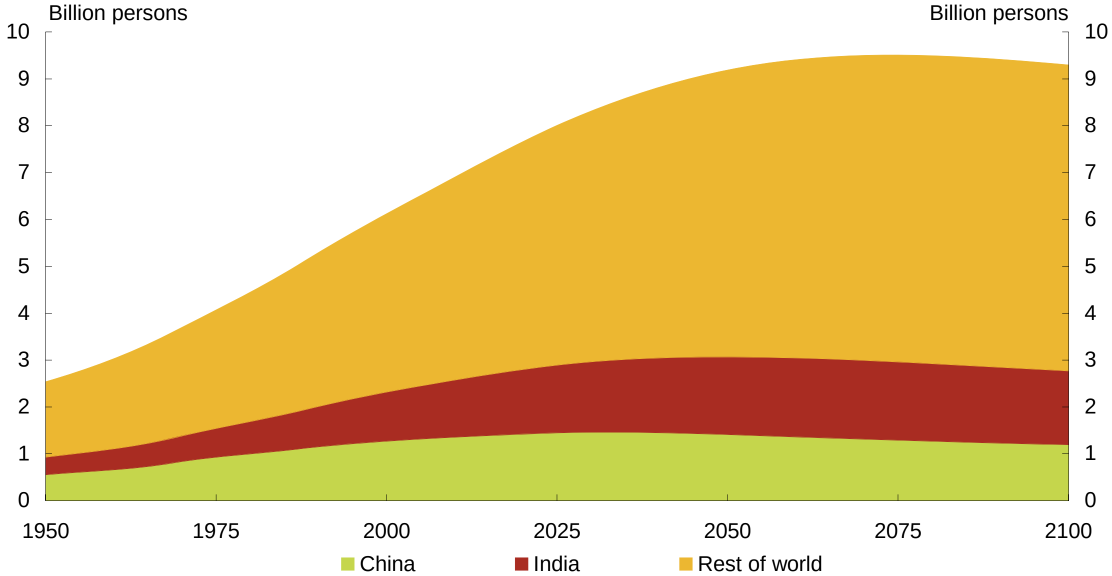
Chart 3.7: Gross world product growth



Source: IMF, 2008; and Treasury.

4 All temperature changes are based on the median estimate of climate sensitivity, calculated using the simple climate model MAGICC (Garnaut, 2008a). There is substantial uncertainty in such estimates (Pearman, 2008).

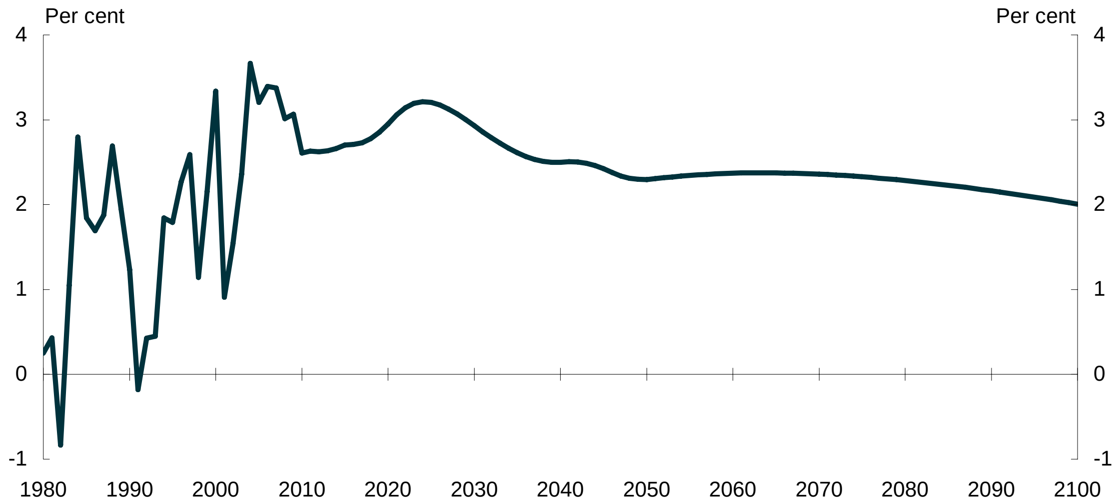
Chart 3.8: World population



Source: United Nations, 2006.

Per capita GWP growth is projected to remain strong throughout this century (Chart 3.9).

Chart 3.9: Gross world product per capita growth



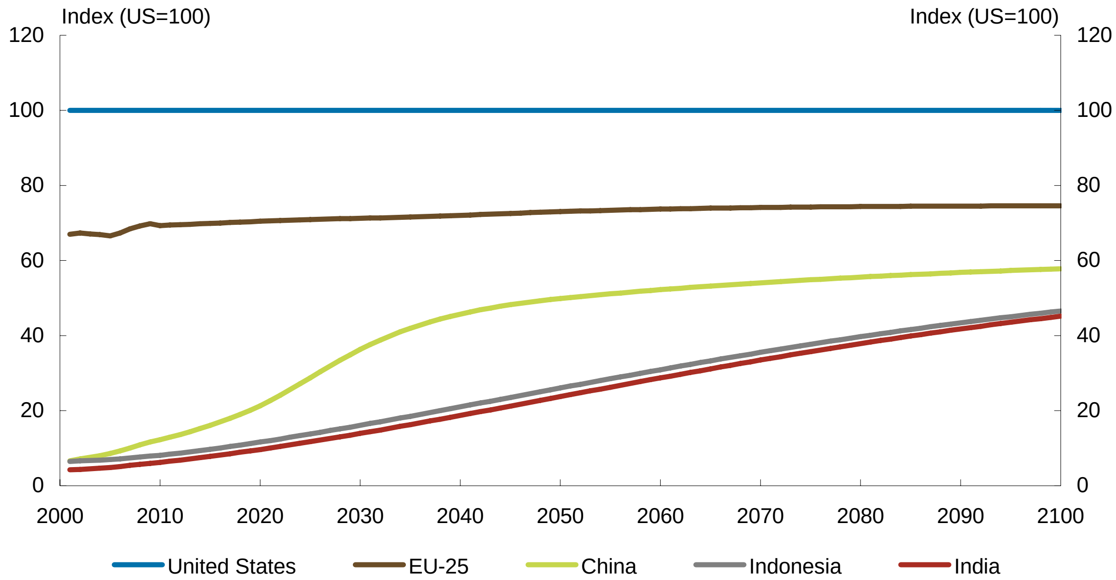
Source: IMF, 2008; United Nations, 2006; Treasury.

The main driver of the strong per capita growth is the catch-up, or convergence, of lower income economies towards the income levels of richer economies (Barro and Sala-i-Martin, 1992). In the past 50 years, several economies have demonstrated convergence (Japan, Hong Kong, Singapore, Ireland and South Korea), but some low-income economies have grown more slowly than convergence would suggest (Pritchett, 1997). Explanations for this divergence include internal conflict, poor governance or natural disasters.

The reference scenario assumes that conditional convergence occurs across low-income economies, as some of these difficulties are resolved (Chart 3.10). The European Union remains at around the same level relative to the United States, while less developed regions such as China, Indonesia and India catch up, but do not draw equal to the United States. China's growth is relatively rapid until 2030, reflecting continued strong growth in productivity and investment

(Garnaut et al., 2008). However, by 2050 China still remains considerably below the income level of the United States, reflecting the remaining gap in capital stocks and productivity. Indonesia and India grow more slowly, with substantial increases in their income levels.

Chart 3.10: Gross domestic product per adult



Source: Treasury.

The projected productivity convergence leads to both rising living standards across the world and reductions in the variations in living standards between regions over time. In 2005, US GDP per capita is highest, around 4 times larger than per capita GWP, while both Chinese and Indian per capita GDP is less than half the average world per capita GWP. By 2050, China's per capita GDP reaches 2005 United States levels and by the 2070s India reaches this level. By 2100, per capita GDP has moved closer between all regions, with the United States approximately only twice as large as per capita GDP, and both China and India within 10 per cent of world per capita GDP (Table 3.3).

Table 3.3: Gross domestic product per capita

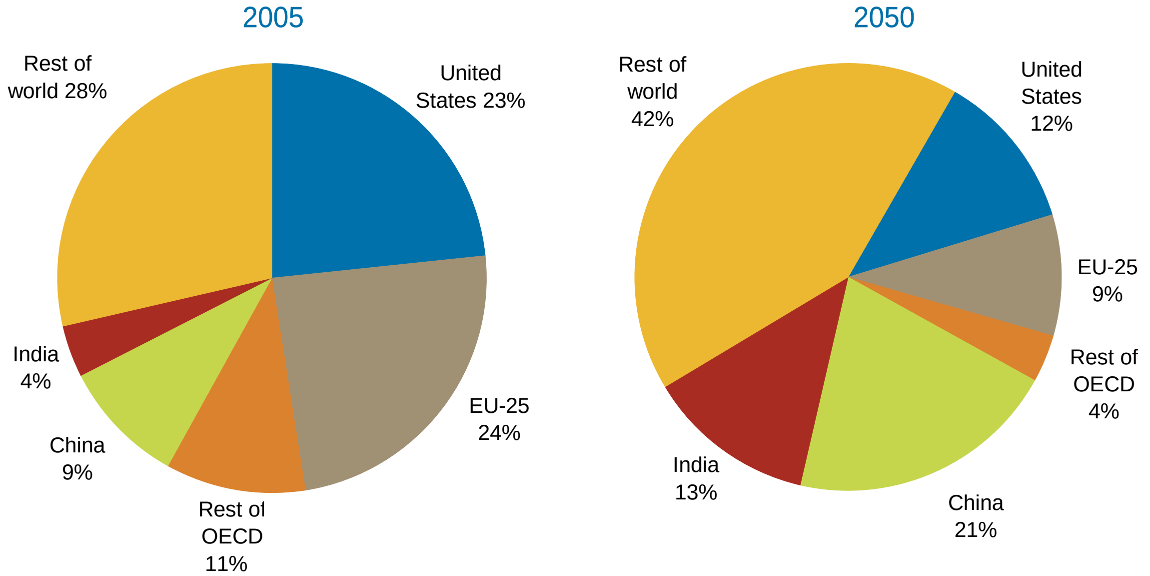
	2005	2050	2100	2050-2005	2100-2005
	$'000/person			Growth, per cent	
Australia	36	68	137	1.9	3.8
United States	44	79	171	1.8	3.9
EU-25	29	53	118	1.8	4.1
China	4	39	97	9.9	24.6
India	2	20	84	10.4	42.4
Rest of Annex B	17	40	102	2.3	6.0
Rest of world	5	22	79	4.5	16.4
Average	9	29	89	3.4	10.4

Source: Treasury projections.

Given the catch-up in productivity and the higher population in the developing world, the distribution of world economic activity is expected to change substantially by 2050. The OECD's share of GWP will fall from nearly 75 per cent in 2005 to around 34 per cent in 2050, the same share as China and India combined, which today comprises 13 per cent of GWP (Chart 3.11). The largest expansion is the 'rest of world', from 28 per cent of GWP in 2005 to 42 per cent in 2050.

By 2021, China overtakes the United States as the world's largest economy; in 2083, India overtakes China, largely due to higher population growth. India's GDP reaches nearly US$34 trillion by 2050. By 2050, China, India and other currently developing economies comprise over 67 per cent of global GWP (Chart 3.11).

Chart 3.11: Distribution of gross world product



Source: Treasury projections.

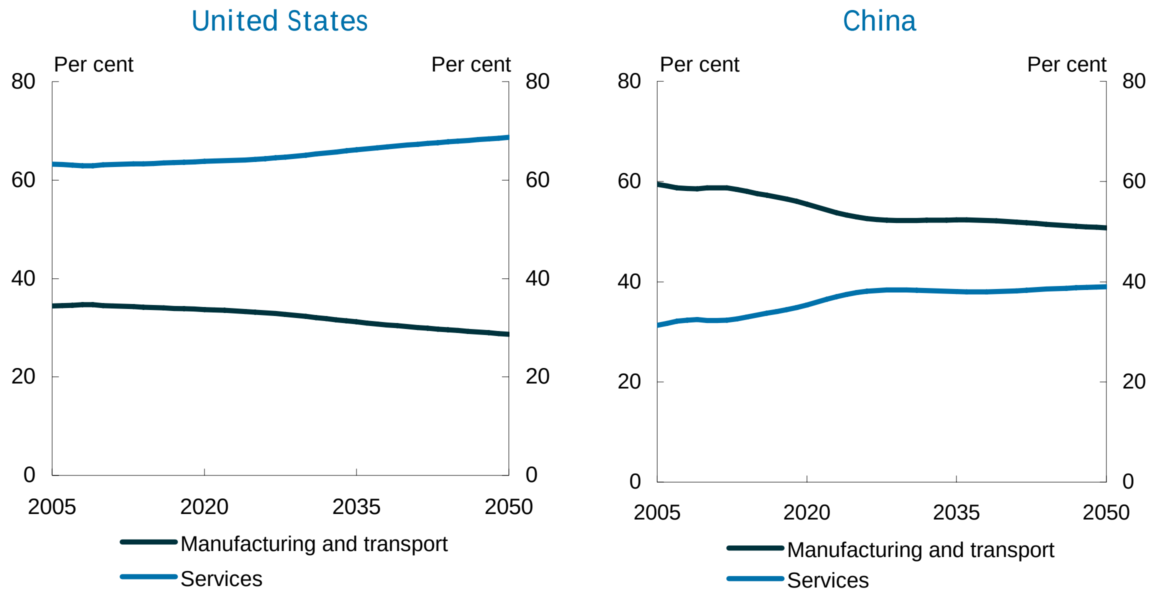
3.1.3 Sectoral analysis

As developing economies' living standards improve, the composition of their economies is expected to adjust. The share of GDP being derived from the services sectors will shift as more luxury goods appear in developing economies. This generally lowers the emission intensity of output, as the services sector is relatively low in emissions.

However, other trends push in the other direction. Adjustments occur in the types of goods in demand within sectors. For example, meat consumption, which is relatively more emission intensive, is expected to increase, while grain consumption is expected to fall in relative terms.

Developed economies continue the trend towards an increased share of the service sector (Chart 3.12). The United States service sector increases from around 63 per cent of total output in 2005 to over 68 per cent in 2050. At the same time, the share of other sectors such as manufacturing declines. A similar pattern occurs in developing regions, where the share of the service sector increases from around 32 per cent of total output in 2005 to 41 per cent by 2050.

Chart 3.12: Share of total output by sector



Source: Treasury estimates from GTEM.

Emission intensity declines in all industries as productivity, including energy efficiency, improves. However, in some scenarios, the increased share of activity in sectors offsets the downward trend (Chart 3.13).

Electricity and manufacturing's share of global emissions rises, owing largely to electricity's expansion and continued strong demand for manufactured goods in the developing world.

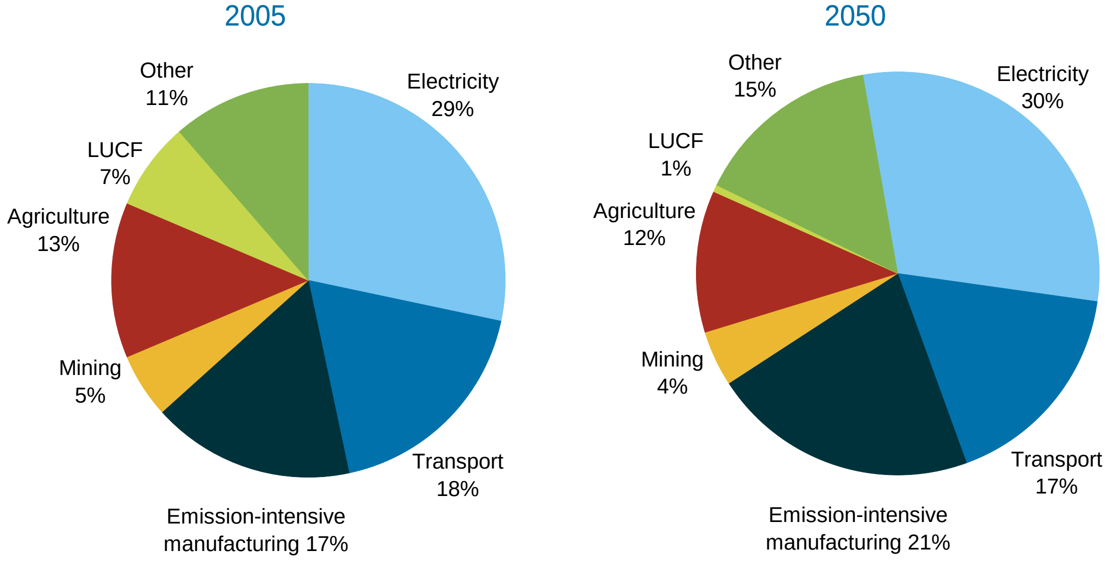
Transport's share of global emissions falls slightly; demand grows strongly in developing economies, while developed economies are already close to saturation (particularly for road transport demand) and experience efficiency improvements due to technological innovation.

Globally, more than a billion hectares of land is projected to be deforested, particularly in Africa and South America. Plantation expansion offsets some of the emissions from deforestation. However, the land-use change and forestry sector is projected to be a net source of 49 Gt CO_2 emissions between 2005 and 2050. This falls within the broad range of estimates from other projections (Sathaye et al., 2006).

Services' share of emissions increases, reflecting its growing share of global economic activity.

Agriculture's share rises slightly, despite its falling share of global GDP, reflecting a change in the emission intensity of products with agriculture.

Chart 3.13: Global emissions by sector



Note: 'Other' includes the production of rubber, plastics and metals, and land-use change and forestry.
Source: Treasury estimates from GTEM.

Electricity

World electricity generation increased more than 200 per cent from 5,256 Terra Watt hours (TWh) in 1971 to 18,307 TWh in 2005 (OECD/IEA, 2008). Developed economies generate most of the world's electricity, with the OECD accounting for 57 per cent of electricity generation in 2005 (OECD/IEA, 2008). Coal was used to generate 40 per cent of the world's electricity in 2005 (IEA, 2007b).

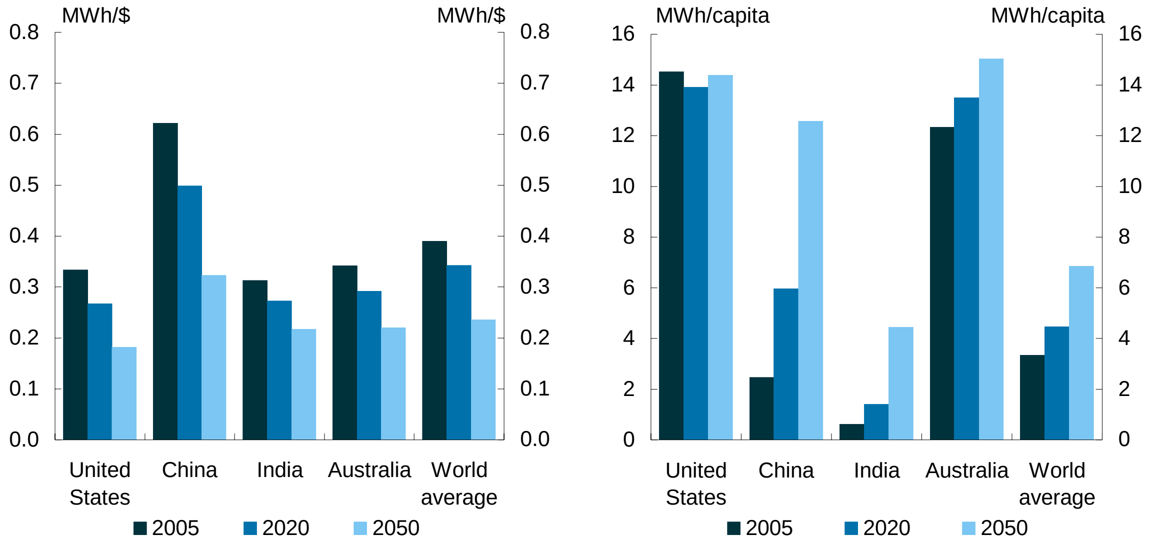
Under the reference scenario, global electricity generation increases to 63,000 TWh in 2050, an average annual growth rate of 2.3 per cent. Most demand growth comes from developing regions, with India and China accounting for 35 and 16 per cent of the growth from 2005 to 2050.

Access to electricity is uneven throughout the world; the average Indian currently consumes one-twentieth of the electricity of the average Australian (Chart 3.14). As developing economies grow more strongly over coming decades, their generation of electricity is expected to increase.

Electricity demand is expected to grow more slowly than output, with the global economy using around 0.5 to 1 per cent less electricity per dollar of GDP each year (Chart 3.14). This reduction in the electricity-intensity of output reflects the changing composition of regional growth, sectoral output and continued overall energy efficiency improvements in the economy.

Chart 3.14: World electricity demand

Electricity intensity of GDP | Electricity per capita

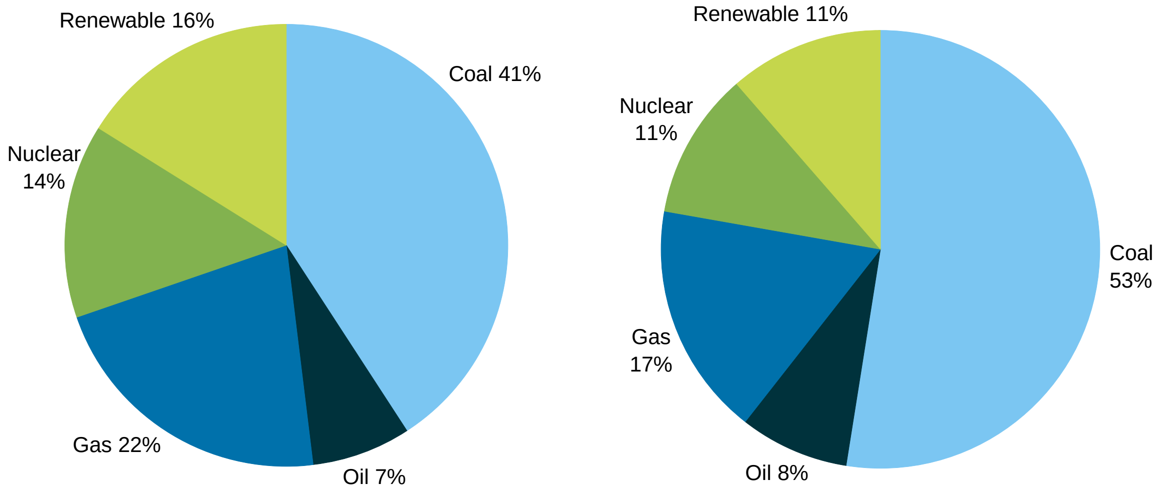


Source: Treasury estimates from GTEM.

Coal continues to dominate electricity generation, reflecting its global abundance and low cost, particularly for base load generation. Coal's share of electricity generation comprises more than half of world electricity generation after 2050 (Chart 3.15). The share of renewables rises gradually to 2020, before falling, as viable sites for hydropower are exhausted. Generation of wind and solar power increases by more than 10 and 30 times, reflecting their low starting levels. However, their combined share remains less than 2 per cent by 2050.

Chart 3.15: World electricity generation by fuel

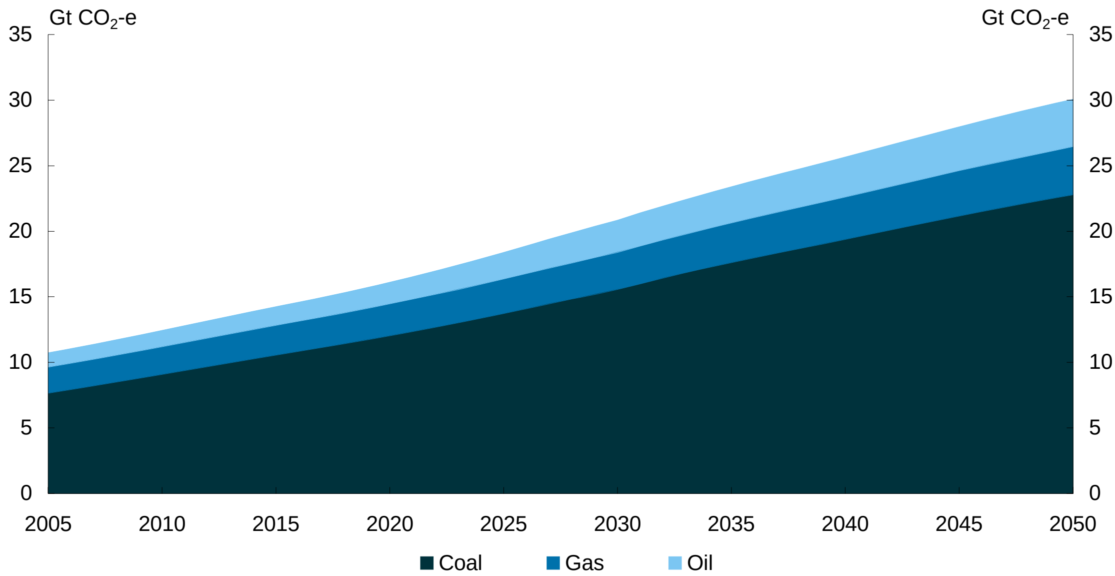
2005 | 2050



Source: Treasury estimates from GTEM.

With fossil fuels continuing to dominate global electricity generation, global electricity emissions nearly triple by 2050, rising from roughly 11 Gt CO_2-e in 2005 to around 30 GT CO_2-e in 2050 (Chart 3.16). The emission intensity of global electricity supply remains broadly constant, at around 0.5 t CO_2-e/MWh.

Chart 3.16: World electricity emissions by fuel

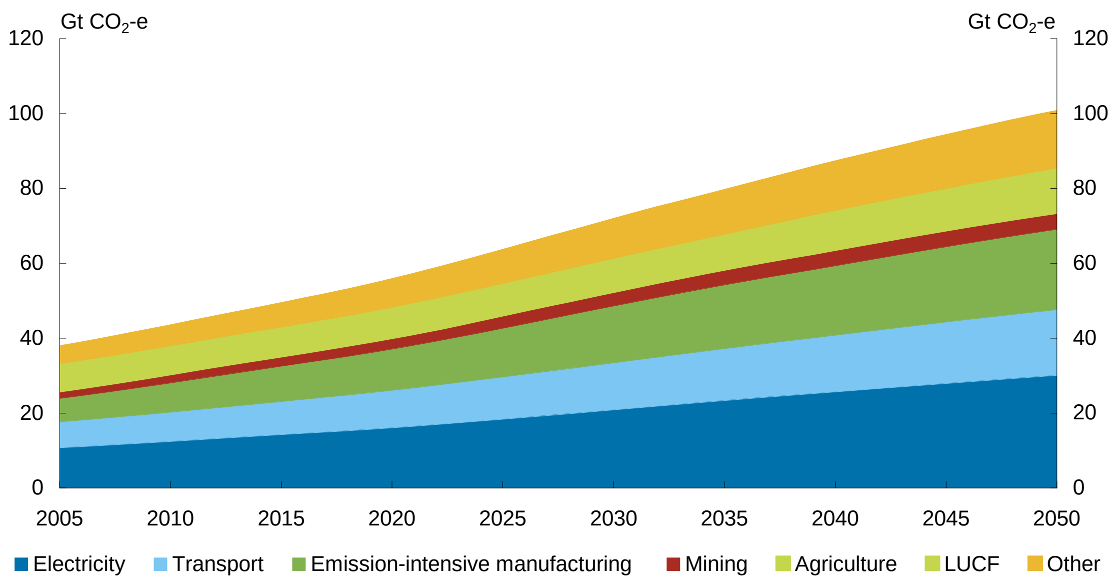


Source: Treasury estimates from GTEM.

Transport

World transport sector emissions grow strongly in absolute terms, but fall as a share of total emissions (Chart 3.17). Global transport demand rises modestly. Air and water transport grow faster than road and rail transport, owing to strong growth in incomes.

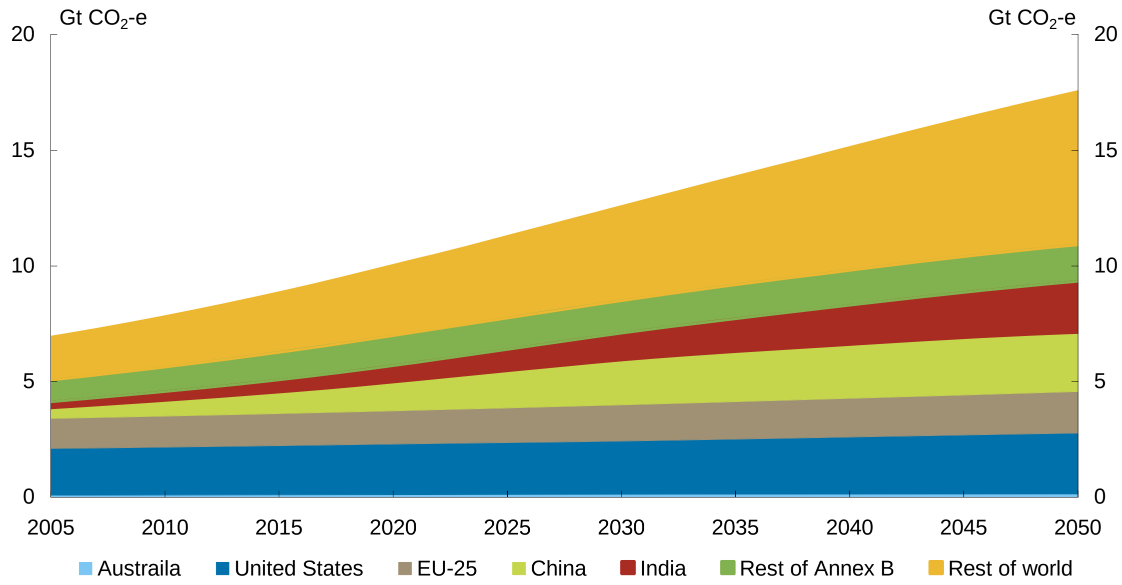
Chart 3.17: Sectoral Emissions



Source: Treasury estimates from GTEM.

Transport emissions grow strongest in developing economies (Chart 3.18). China's share of total transport emissions increases from around 7 per cent in 2005 to around 15 per cent in 2050.

Chart 3.18: Global transport emissions

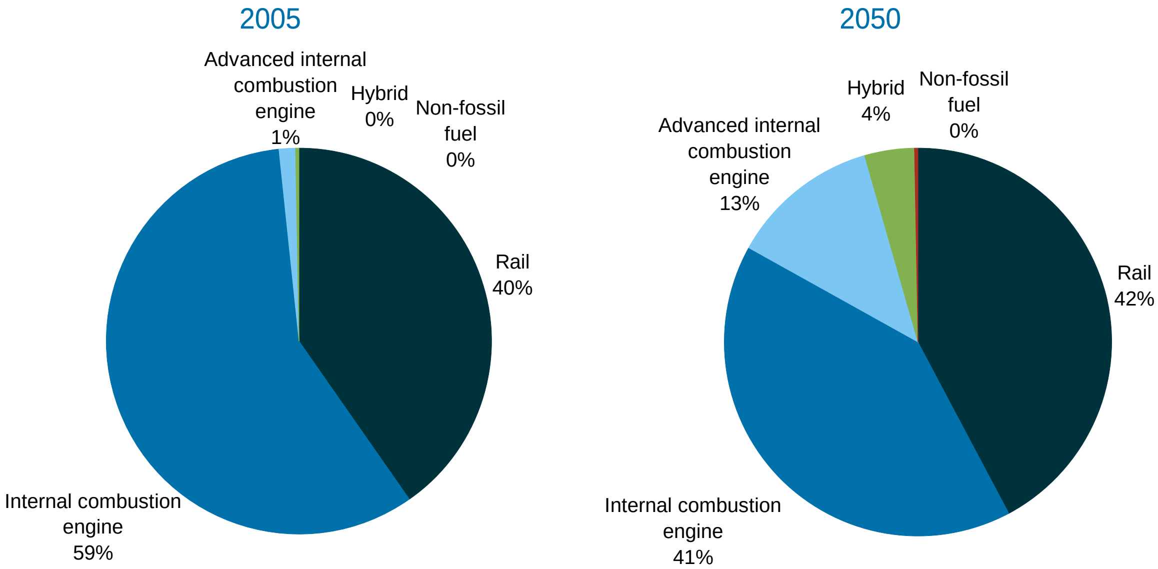


Source: Treasury estimates from GTEM.

In road transport, demand is expected to slow reflecting slowing population growth. Rail's share in land transport is expected to remain broadly constant. However, as oil prices rise relative to other energy prices, the road transport sector will deploy increasingly efficient technologies and diversify fuel sources.

Cars with internal combustion engines dominate the road transport sector in 2005; advanced internal combustion engines (including partial hybrid engines) meet only a small share of demand. As oil prices rise relative to other energy sources, and the capital cost of advanced vehicles falls, the share of conventional internal combustion engines falls. By 2050, advanced internal combustion engines comprise almost 15 per cent of total road transport output and full hybrid cars have a noticeable share. The advanced internal combustion engine captures a growing market share after 2050, eventually eclipsing its conventional counterpart. Non-fossil fuel vehicles such as electric and hydrogen cars remain uncompetitive compared with combustion vehicles, with only a 0.2 per cent share by 2050 (Chart 3.19).

Chart 3.19: Global road transport technology share



Source: Treasury estimates from GTEM.

Land-use change and forestry

Globally, around 580 million hectares is projected to be deforested by 2050, half in Africa (Table 3.4). This reflects continued demand for forestry products and land clearing for agriculture. In contrast, plantations are projected to expand by only 280 million hectares by 2050, mostly in Asia and the United States. The net global effect by 2050 is a loss of forested area of around 300 million hectares.

Table 3.4: Global plantations and deforestation
Cumulative since 2000

	2010		2020		2050		2100	
	Plantation	Deforestation	Plantation	Deforestation	Plantation	Deforestation	Plantation	Deforestation
	Million hectares		Million hectares		Million hectares		Million hectares	
Africa	2	55	4	117	10	283	20	501
Central America	1	9	2	17	4	37	8	64
China	14		29		63		63	
European Union	2		4		11		21	
India	7		13		22		22	
Oceania	2		4		9		18	
Rest of Asia	15	21	29	40	73	90	146	159
Russia	6	0	11		29		57	
South America	3	36	6	72	16	173	32	329
United States	10		19		48		97	
Total	61	122	121	246	284	583	483	1053

Source: Lawrence Berkeley National Laboratory estimates from GCOMAP (Sathaye, 2008).

With the substantial loss in global forested area by 2050, the sector is a net source of emissions, contributing around 49 Gt CO_2 from 2005 to 2050. Emissions are highly concentrated in South America and Africa, while reafforestation delivers substantial net sequestration in Asia and the United States (Table 3.5).

Table 3.5: Cumulative global land-use change and forestry emissions since 2005

	2020	2030	2040	2050
	Gt CO_2	Gt CO_2	Gt CO_2	Gt CO_2
Africa	-20	-33	-46	-57
Central America	-2.4	-3.7	-4.9	-6.1
China	3.3	7.0	11	16
European Union	0.5	1.3	2.4	3.8
India	3.0	6.0	8.5	9.0
Oceania	0.6	1.3	2.3	3.3
Rest of Asia	2.2	10	19	26
Russia	0.4	1.1	2.2	3.7
South America	-22	-35	-48	-61
United States	2.5	5.9	11	16
Total	-32	-40	-42	-47

Note: Negative numbers indicate emissions, positive numbers indicate sequestration. These estimates do not include emissions from land-use change in Australia.
Source: Lawrence Berkeley National Laboratory estimates from GCOMAP, 2008.

Other emission-intensive sectors

Four other industry groups together comprise around 40 per cent of world emissions: mining, resource processing (particularly steel and aluminium), emission-intensive manufacturing and agriculture (Table 3.6). Mining growth is projected to be strong in most regions, reflecting the continued strong demand for coal, iron ore, oil and other mined products. Strong mining growth, in turn, leads to strong growth in resource processing, dominated by the transformation of mined products into steel and aluminium. Emission-intensive manufacturing and agriculture grow, but generally not as strongly as overall economic growth, reflecting the falling share of the overall manufacturing and agriculture sectors.

Table 3.6: Growth of other emission-intensive sectors

	Mining		Resource processing		Emission-intensive manufacturing		Agriculture	
	2005-2020	2020-2050	2005-2020	2020-2050	2005-2020	2002-2050	2005-2020	2020-2050
	Per cent per year		Per cent per year		Per cent per year		Per cent per year	
United States	2.9	2.0	1.9	1.3	1.6	1.1	3.2	2.4
EU-25	1.9	0.8	0.8	0.4	1.0	0.4	2.0	1.6
China	9.2	4.4	8.7	4.1	6.2	2.4	8.2	4.3
Russia + CIS	4.6	1.5	4.6	1.7	4.3	1.7	4.4	2.0
Japan	1.2	0.7	0.6	-0.1	0.4	-0.3	1.0	0.3
India	7.9	5.6	6.7	4.9	5.3	3.3	6.8	4.4
Canada	3.1	1.8	0.3	0.1	1.5	0.8	3.6	2.5
Australia	2.8	2.2	1.3	0.6	2.3	1.6	3.7	2.5
Indonesia	5.0	4.1	3.0	3.6	4.0	2.7	5.9	4.8
South Africa	5.0	3.7	4.5	3.4	4.0	2.5	5.0	3.3
Other South and East Asia	3.2	2.9	4.2	2.9	3.6	2.3	4.5	3.2
OPEC	5.6	3.5	5.6	4.4	4.3	3.2	4.7	3.5
Rest of world	4.6	4.2	5.0	4.3	4.4	4.0	5.0	4.4

Source: Treasury estimates from GTEM.

The share of total emissions remains broadly constant, with mining's slight fall offset by emission-intensive manufacturing's rise (Table 3.7).

Table 3.7: Share of world emissions (direct and indirect)

	2005	2020	2050
	Per cent	Per cent	Per cent
Mining	5.9	6.2	5.1
Resource processing	8.4	9.1	7.6
Other emission-intensive manufacturing	15.5	18.0	20.6
Agriculture	12.8	12.5	11.4
Total	42.6	45.8	44.7

Source: Treasury estimates from GTEM.

Box 3.4: The reference scenario in G-Cubed

G-Cubed models the world economies in a more aggregated way than GTEM, making it less suited to providing disaggregated sectoral projections of the world economy although it gives a richer dynamic story. Because of this limitation at the sectoral level, the reference scenario was implemented differently from in GTEM. Assumptions about energy intensity, electricity technology mixes, and non-combustion emission intensity cannot be applied directly to the model, so a calibration approach was followed.

In this approach, rather than focus on the inputs for the reference scenario, the modelling took the results of the GTEM reference scenario and calculated a set of reference scenario assumptions that would produce consistent results on key variables. The results were calibrated as emission levels by gas. The calibration used an iterative approach and does not perfectly match the emission levels between the two models.

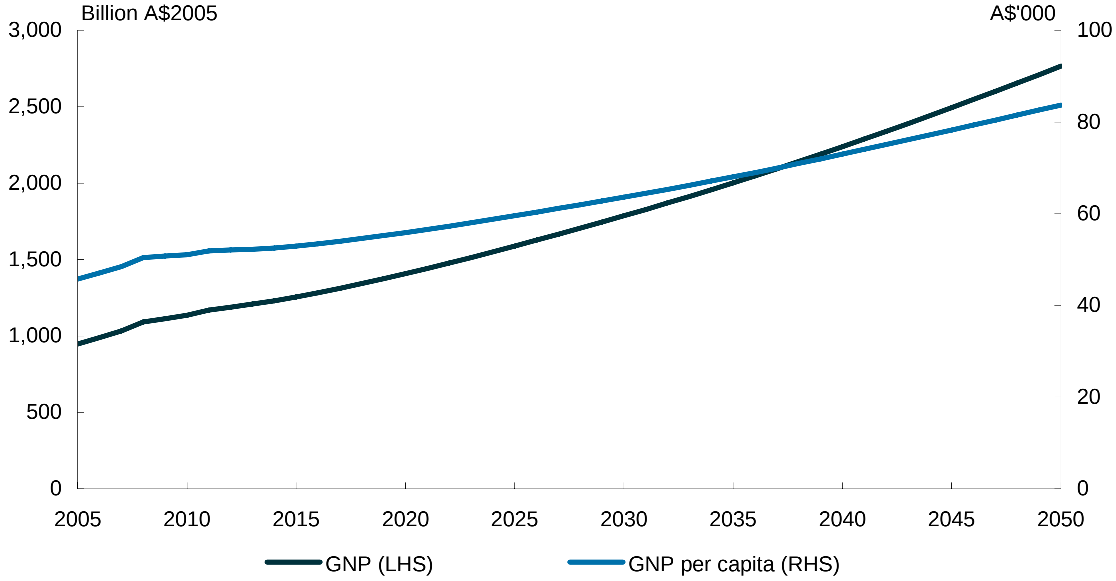
Consequently, by design, the G-Cubed reference scenario does not have any additional analytical use beyond the GTEM reference scenario. Effectively, the reference scenarios were aligned. As a result, G-Cubed specific results are not discussed in this chapter. This calibration exercise was conducted only for the reference scenario, and does not affect the modelling of the policy scenarios.

3.2 Australia

In Australia, population, participation and productivity growth boost Australia's GNP level by around 200 per cent between 2005 and 2050, and over 800 per cent to 2100. GNP growth gradually moderates to a long-term average of around 2 per cent per year, largely due to demographic trends, slowing population and labour force growth, despite modestly rising terms of trade — the price of exports relative to the price of imports. Over the next 100 years, Australia's population is projected to more than double, from 20 million in 2005 to 33 million in 2050 and nearly 47 million by 2100.

Australians are projected to be significantly richer in 2050 than today, with GNP per capita projected to increase from around $48,000 in 2007-08 to around $83,600 in 2050 (in 2005-06 dollars). Per capita GNP is expected to grow by 77 per cent between 2005 and 2050, slightly slower than the average from 1985 to 2005 (Chart 3.20).

Chart 3.20: Real GNP and real GNP per capita



Source: Treasury estimates from MMRF.

In Australia, both supply and demand-side factors drive sectoral trends. On the supply side, industry sectors are assumed to have different productivity growth rates. The dispersion of productivity growth rates across industry sectors is based upon historical estimates.

As a small open economy, Australia is strongly affected by global economic forces. Rising per capita incomes in developing economies are expected to result in more of the world's population spending a larger share of their income on more energy-intensive goods and higher-value food. These forces will create strong demand for Australia's commodity exports and substantially change its pattern of trade with other economies.

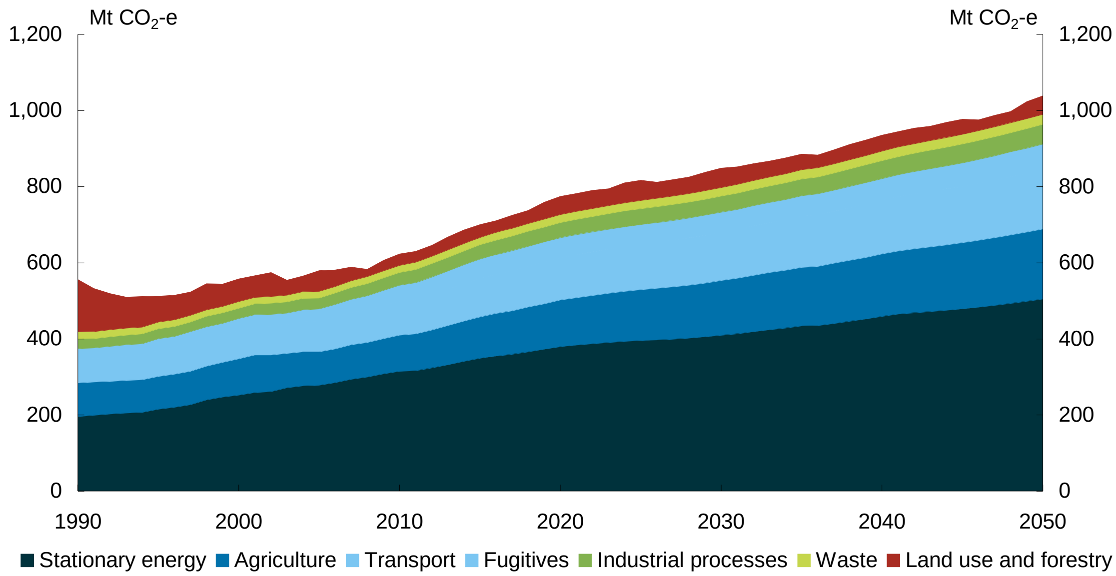
In recent years, these energy and emission-intensive industries have influenced Australian living standards more than their share of production implies. This reflects their high prices in world markets. Over the past three years, Australia's terms of trade have improved by 20 per cent, mainly owing to rising minerals prices. Real national income per capita grew at an average annual rate of 3.3 per cent, considerably faster than the 2.0 per cent growth in real GDP per capita.

Broadly, the historical pattern of growth across sectors is expected to continue. The services share of the economy continues to grow steadily, while the mining sector initially benefits from the current surge in world demand for commodities, before slowing in response to declining commodity prices and supply constraints in the oil and gas industries. The Australian manufacturing and agricultural sectors are expected to continue their historical trend decline.

3.2.1 Australian emissions

Australia's net greenhouse gas emissions were 576 Mt CO_2-e in 2006, up 4.2 per cent from 553 Mt in 1990 (Australian Government, 2008a). Australia's greenhouse gas emissions are expected to double by 2050, growing by 1.5 per cent per year from 2005 to 2050 (Chart 3.21).

Chart 3.21: Australian emissions



Source: Australian Government, 2008a; and Treasury estimate from MMRF.

Australia's emissions mainly flow from energy production, dominated by use of black and brown coal. Stationary energy is the largest source of emissions, at around half of total emissions, with electricity generation contributing more than two-thirds. Energy sector emissions grew by 40 per cent (114.8 Mt) from 1990 to 2006 and are expected to grow to 728 Mt CO_2-e by 2050. Stationary energy emissions comprise four sub-elements: electricity generation, other stationary energy, transport and fugitives. The strongest growth within this sector is from electricity generation, which is projected to increase by almost 200 Mt CO_2-e by 2050, as demand for electricity continues, as the population grows and reliance on black and brown coal continues (Table 3.8).

Table 3.8: Emissions by source

	2005		2020		2050		Growth rate	
	Mt CO_2-e	Per cent	Mt CO_2-e	Per cent	Mt CO_2-e	Per cent	2005-2020	2020-2050
Energy	390	67	544	70	728	70	2.2	1.0
Electicity generation	195	34	265	34	348	34	2.1	0.9
Other stationary energy	83	14	115	15	156	15	2.2	1.0
Transport	81	14	111	14	156	15	2.1	1.1
Fugitives	31	5	53	7	67	6	3.5	0.8
Agriculture	88	15	122	16	184	18	2.2	1.4
Industrial process	29	5	40	5	52	5	2.1	0.9
Land-use change	74	13	44	6	44	4	-3.4	0.0
Forestry	-20	-3	3	0.5	5	0.5	na	na
Waste	17	3	21	3	26	3	1.3	0.8
All sectors	579.1	100.0	774.2	100.0	1039.1	100.0	2.0	1.0

Source: Treasury estimates from MMRF.

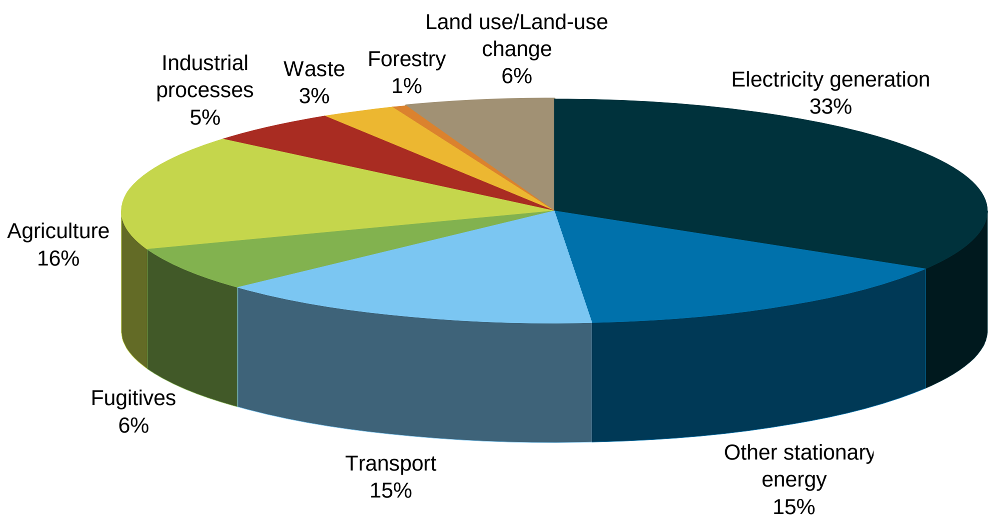
Agriculture and changes in land use, unlike in most OECD economies, contribute significantly to Australia's emissions. Emissions from agriculture are expected to grow broadly in line with growth in agricultural output as there are limited opportunities to reduce emission intensity without emission pricing. Output growth reflects ongoing productivity growth and strong world demand for Australian beef and lamb. By 2050, emissions from agriculture are projected to almost double to around 184 Mt CO_2-e.

From 1990 to 2006, emissions from land use, land-use change and forestry fall as state governments enacted policies to reduce deforestation. In the absence of new government policies, emissions from this sector are expected to remain stable to 2050.

Fugitive emissions include liberated gas previously trapped within coal seams, emissions released in producing and processing oil and gas, and gas leakage though transmission and distribution. Emissions from the fugitives sector grow strongly, around 1.7 per cent per year from 2005 to 2050, more than doubling to 67 Mt CO_2-e in 2050. Continued strong world demand for Australia's fossil fuels, namely coal and gas, drives this growth although it is partly offset by rising gas prices that encourage greater capture of methane emissions, which can be used for energy generation. This capture is also assumed to occur in the waste sector.

The cumulative amount of emissions released into the atmosphere determines possible climate change impacts, not emissions in any one year (Chart 3.22).

Chart 3.22: Share of cumulative emissions 2005 to 2050



Source: Treasury estimates from MMRF.

Emission intensity of energy-intensive industries is expected to fall slightly to 2050, largely reflecting continual assumed improvements in energy efficiency (Box 3.5). However, as the economy shifts towards the services sectors, the aggregate emission intensity of output is expected to fall (Chart 3.23).

Box 3.5: Energy efficiency

Energy efficiency occurs when less energy is used to make the bundle of goods and services we consume. This can occur through a number of mechanisms, including:

- firms substituting capital, labour and other inputs for energy;
- technologies improving so the same good is created using less energy; and
- consumers substituting away from energy-intensive goods.

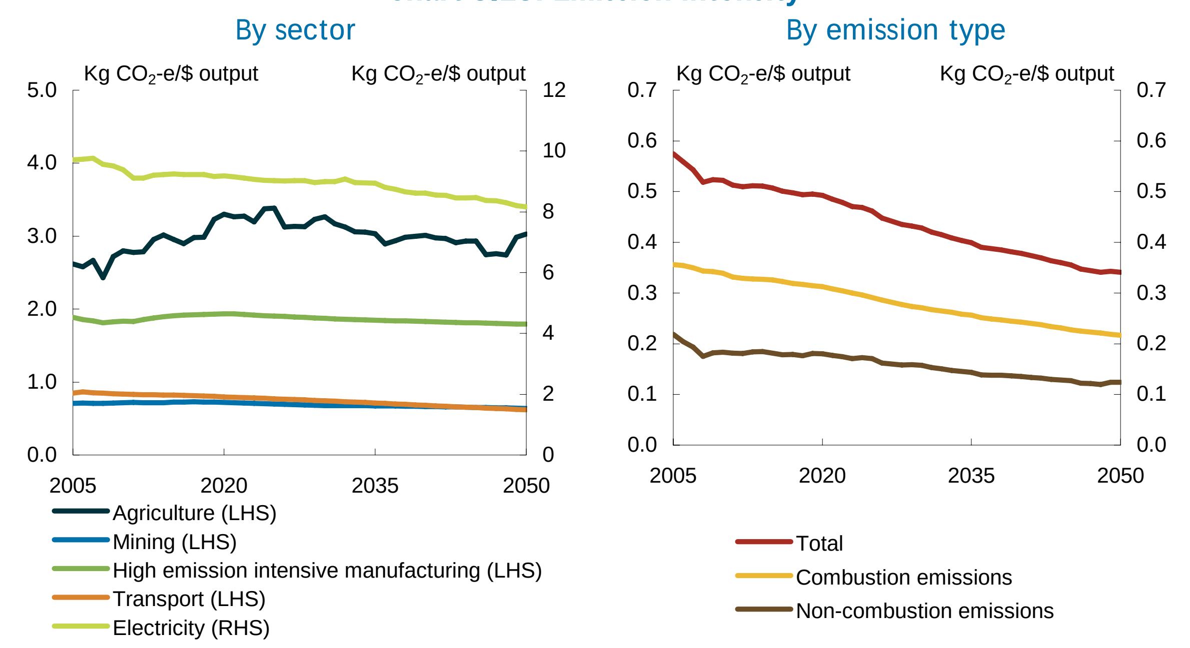
These mechanisms are all directly modelled within the CGE and bottom-up models used.

Additional technology and behavioural changes in sectors not modelled in detail are represented through an autonomous energy-efficiency improvement (AEEI) parameter.

The reference scenario for Australia assumes AEEI at the rate of 0.5 per cent per year for all sectors outside the electricity and transport sectors, reflecting available estimates of historical energy efficiency by Tedesco and Thorpe (2003), Cuevas-Cubria and Riwoe (2006) and the IEA (2004 and 2007c). For other regions, GTEM generally uses 0.5 per cent per year.

Arriving at estimates of future energy efficiency is difficult given uncertainty about how energy efficiency will evolve over long timeframes. A sensitivity scenario explored a higher energy-efficiency assumption in the reference scenario, with an additional 1 per cent per year from 2013 to 2030, an extra 0.5 per cent per year from 2031 to 2040, and no extra improvement thereafter assumed. Greater energy efficiency reduces emissions as demand for energy for a given level of economic activity falls. By 2050, global emissions were around 10 per cent lower than in the central reference scenario.

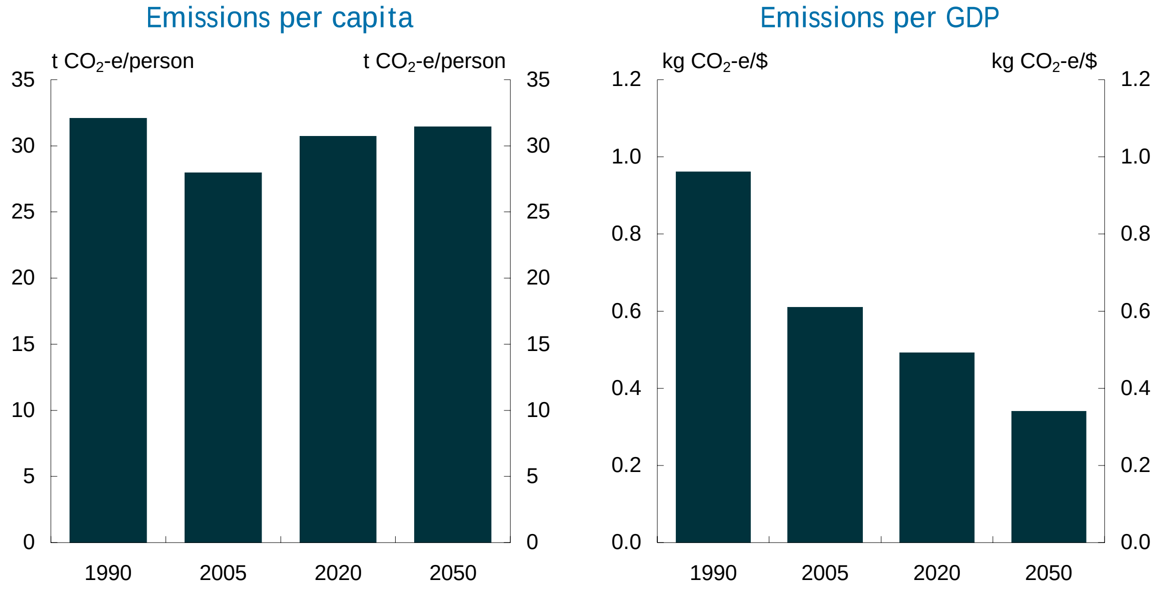
Chart 3.23: Emission intensity



Source: Treasury estimates from MMRF.

Australia's per capita greenhouse gas emissions are the highest in the OECD and among the highest in the world. However, they are broadly comparable to similar resource rich economies such as Canada. In 2006, Australia's per capita emissions were 27.7 t CO_2-e per person and are expected to remain broadly unchanged to 2050 (Chart 3.24).

Chart 3.24: Emissions in Australia



Note: Emission estimates vary from Table 3.2 due to database differences between the MMRF and GTEM models.
Source: Treasury estimates from MMRF.

In 2050, CO_2 is projected to remain the main contributing gas, accounting for around 77 per cent of emissions. Methane is second, with 17 per cent of emissions, largely from agriculture, then nitrous oxide with around 5 per cent of emissions.

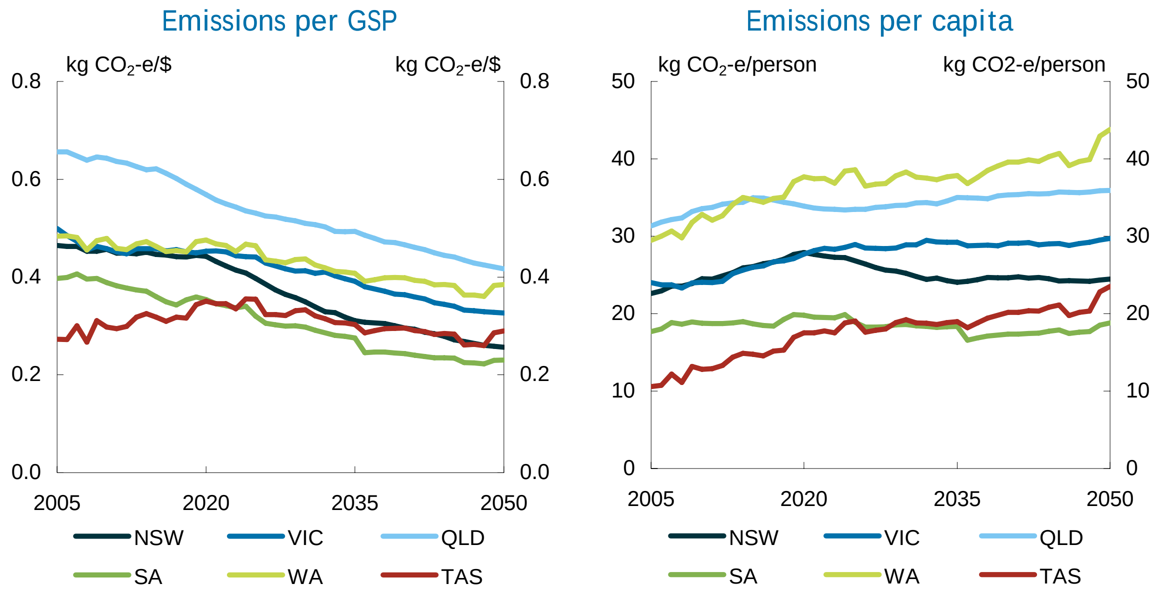
Emissions by state/territory

The level of emissions in each Australian state is determined by economic size and industrial composition. The emission intensity and emissions per capita show similar patterns for each state (Chart 3.25).

Emission intensity of output and per capita emissions are highest for Northern Territory, Western Australia and Queensland, reflecting specialisation in energy-intensive production for domestic and export markets.

The modest decline in emission intensities is due to the assumed known technological changes in the production processes.

Chart 3.25: Emissions by state/territory



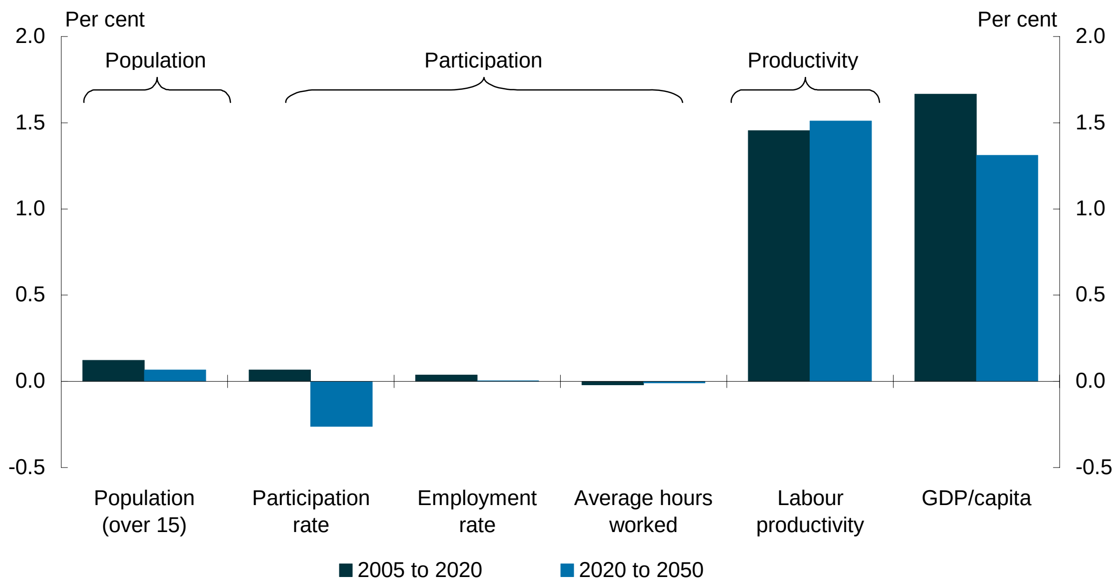
Source: Treasury estimates from MMRF.

3.2.2 The macroeconomy

Economic output

In the reference scenario, the pattern and rate of GDP growth is a function of assumptions on movements in population (the number of people of working age, 15 and over); changes in participation rates (which take into account labour force participation rates, the unemployment rate and hours of work); and the growth of productivity (the average output produced per hour worked) (Chart 3.26).

Chart 3.26: Decomposition of GDP growth



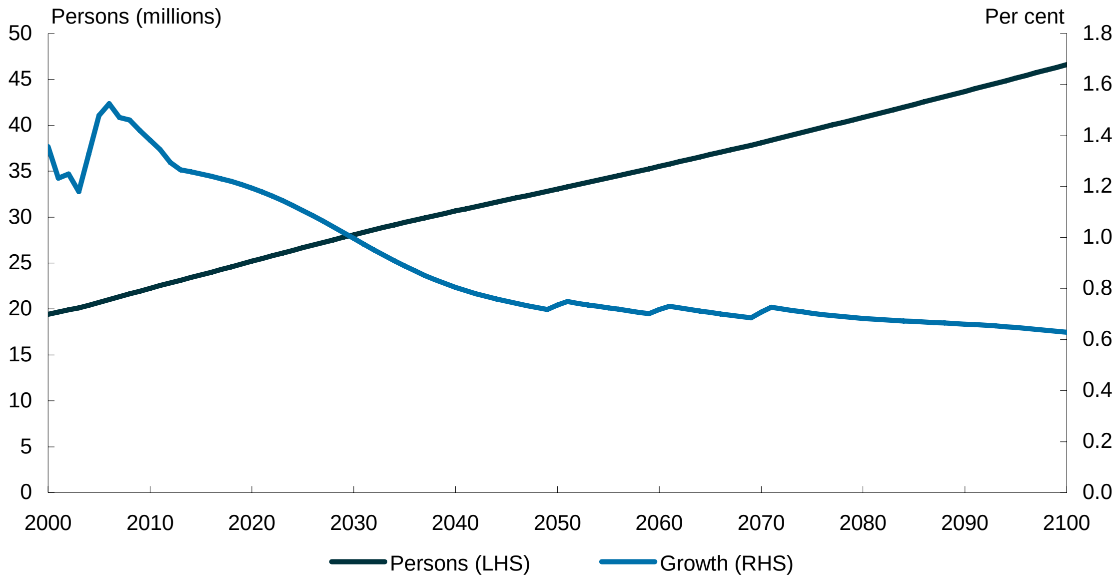
Source: Treasury estimates from MMRF.

Population

Australia's population is assumed to more than double, from 20.7 million in 2005 to 33 million in 2050, and is expected to reach nearly 47 million in 2100 (Chart 3.27). Australia's population growth moderates from around 1.5 per cent in 2005 to around 0.6 per cent after 2050 as fertility rates decline.

Australia's population estimates are based on Australian Bureau of Statistics (ABS) projections and the methodology of the Government's intergenerational report, revised in light of Treasury's most recent analysis of immigration trends. This sees net migration of 150,000 people per year until 2050, increasing to 200,000 people per year by 2070, then remaining constant to 2100.

Chart 3.27: Australian population



Source: ABS and Treasury.

The regional distribution of Australia's population shifts. Western Australia, the Northern Territory and Queensland capture a rising share; South Australia and Tasmania have a declining share (Table 3.9).

Table 3.9: Population growth by state/territory

Decade	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
2000s(a)	1.1	1.4	2.0	1.0	2.1	0.8	1.7	1.5
2010s	1.0	1.2	1.8	0.7	1.8	0.5	1.6	1.2
2020s	0.9	1.0	1.6	0.5	1.4	0.3	1.5	0.8
2030s	0.7	0.8	1.3	0.2	1.1	0.0	1.5	0.7
2040s	0.6	0.6	1.1	0.1	1.0	-0.2	1.4	0.6
2050s	0.7	0.6	1.0	0.1	0.9	-0.2	1.3	0.6
2060s	0.7	0.7	0.9	0.0	0.8	-0.1	1.0	0.7
2070s	0.7	0.7	0.8	0.0	0.8	0.0	0.8	0.7
2080s	0.7	0.7	0.7	0.0	0.7	0.0	0.7	0.7
2090s	0.7	0.7	0.7	0.0	0.7	0.0	0.7	0.7

(a) 2000s commence 2005-06, consistent with the base year in the MMRF model.
Source: ABS and Treasury analysis, MMRF.

Participation

Participation assumptions, including the labour supply and the proportion of Australia's population of working age, accord with the Government's intergenerational report (Australian

Government, 2007). Participation rates for each state and territory are assumed to follow the national pattern, with Australia's labour supply and employment assumed to grow at the same rate.

Productivity

Australian aggregate labour productivity is based upon Treasury forecasts and Budget projections until 2011-12 (Australian Government, 2008b). Beyond 2011-12, this rate is assumed to moderate from 1.75 per cent to 1.5 per cent per year over a ten-year period to the mid 2020s, as the Australian economy restructures towards lower productivity sectors, particularly services, reflecting the compositional shifts in consumer preferences as incomes rise.

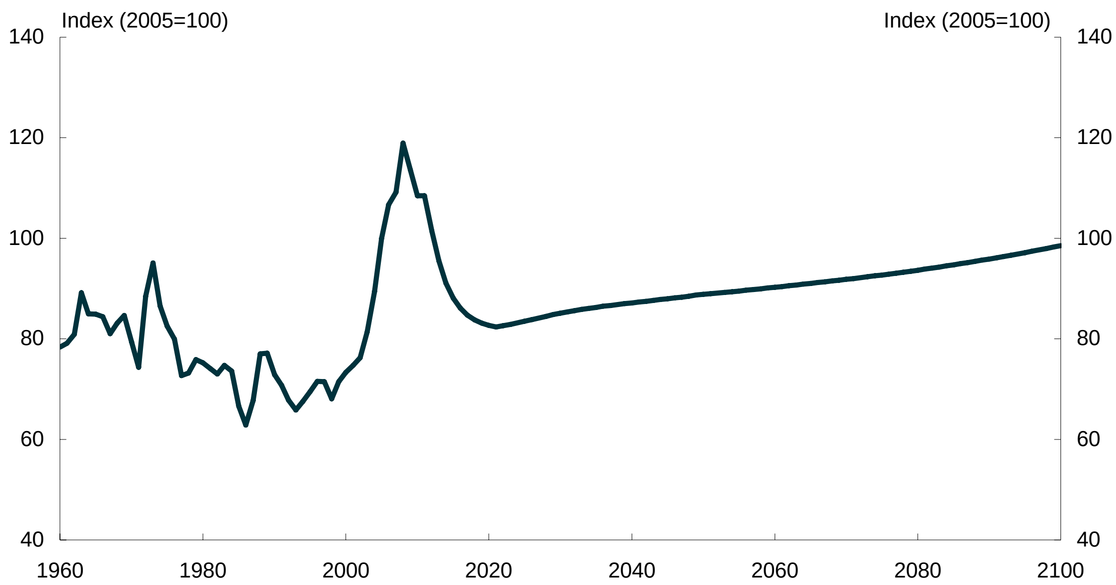
The dispersion of productivity growth across Australia's industry sectors is based on historical performance until 2020. After this, growth rates in market sector industries are assumed to converge, reflecting uncertainty about how persistent historical differences will be.

Terms of trade

Australia's terms of trade is expected to fall over the next 10 years from their current 50-year high as commodity producers around the world increase the supply of resources in response to the recent demand surge.

Beyond 2020, Australia's terms of trade is expected to gradually improve as export prices return to an upward trend and import prices remain modest, reflecting the likely pattern of global productivity growth. By 2050, Australia's terms of trade remain below the level reached in 2008, and returns to around the level of 2005 by 2100 (Chart 3.28).

Chart 3.28: Australia's terms of trade

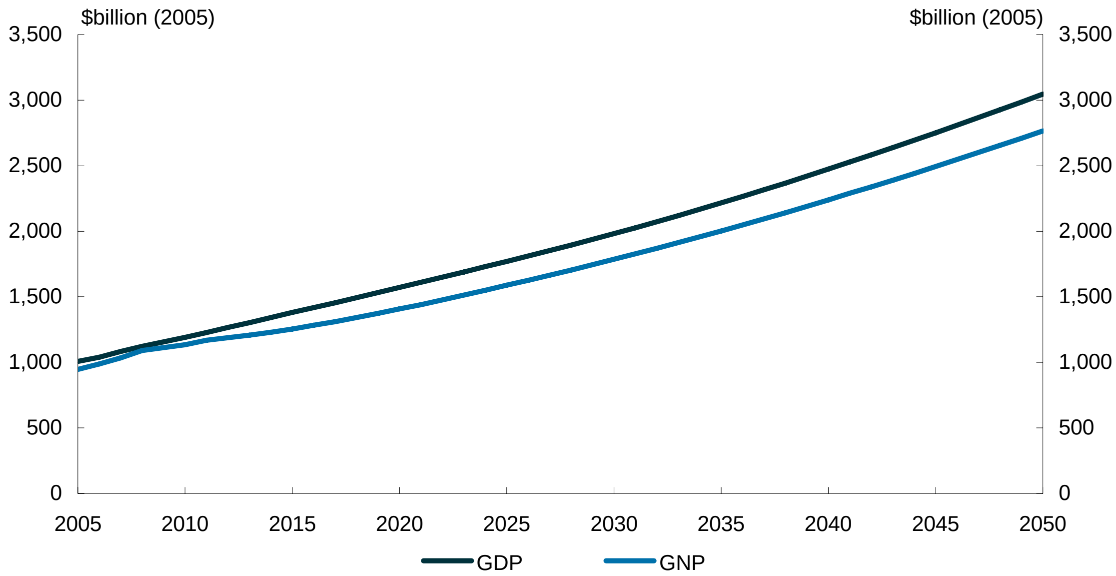


Source: Australian Government, 2008b; and Treasury estimates from MMRF and GTEM.

Gross national product

Movements in the terms of trade drive a wedge between GNP and GDP (Chart 3.29). GNP is a measure of welfare that captures current and future consumption, and indicates what a nation can afford to buy in addition to what it actually produces.

Chart 3.29: Australian GDP and GNP levels



Source: Australian Government, 2008b; and Treasury.

Consumption

Consumption remains broadly constant as a share of real GDP. Household incomes grow at an average rate of 2.3 per cent per year to 2050, and average household expenditure increases by more than 200 per cent from 2005 to 2050. As Australians' per capita income rises, the historical shifts in household preferences towards services and imported manufactures continue (Table 3.10).

Table 3.10: Consumption shares, 2020

Commodity	Per cent
Dwelling services	16.9
Other services	13.8
Public services	11.6
Other food, beverages and tobacco	10.6
Accomodation, hotels, cafes and restaurants	8.1
Transport services	5.5
Financial services	4.7
Communication services	4.0
Trade services	3.7
Textiles, clothing and footwear	3.3
Other manufacturing	2.6
Private electricity services	2.0
Chemicals	2.0
Air transport	1.8
Meat products	1.6
Private heating services	1.4
Other agriculture	1.3
Water transport	0.8
Printing	0.8
Road freight	0.6

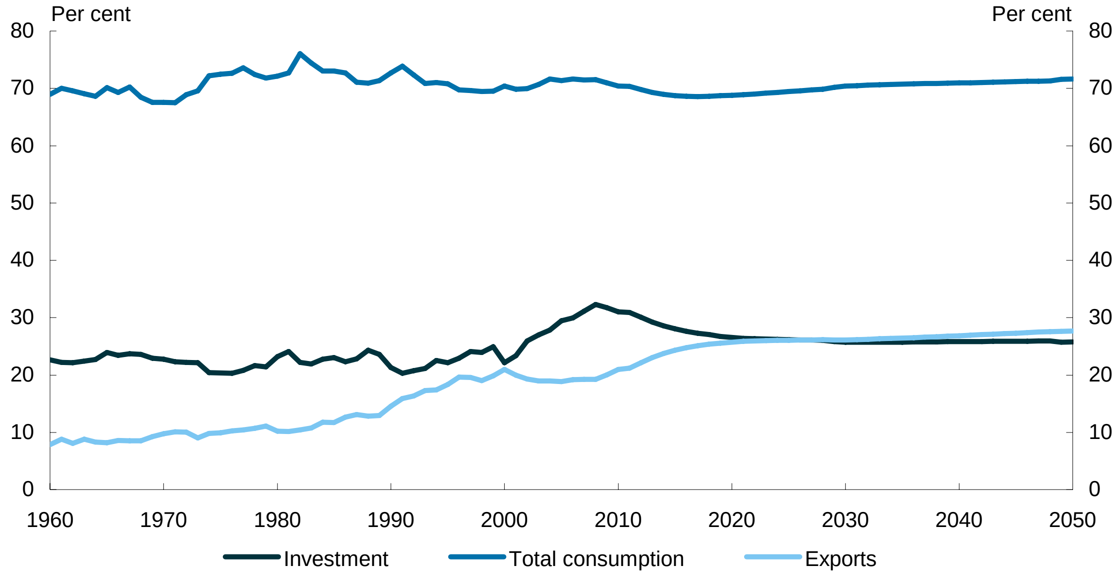
Source: Treasury estimates from MMRF.

Investment

Investment's share of real GDP is currently high as investment, particularly in mining, responded to demand from China and India for mining commodities. Investments' share of GDP falls over the decade to 2020, as the terms of trade declines and manufacturing's share of output continues to fall (Chart 3.30). Thereafter, it is assumed to remain broadly constant as a share of the real economy.

Investment rates are supported by ongoing trend declines in capital goods prices, reflecting productivity growth in world manufacturing. High levels of investment in mining are underpinned by rising marginal costs of extracting natural resources, as firms look to exploit lower quality ore deposits.

Chart 3.30: Consumption, investment and export shares of GDP



Source: Treasury estimates from MMRF.

Exports

With rising per capita incomes in developing economies, people will spend a larger share of their income on more energy-intensive goods and higher value food. These forces will create strong demand for Australia's commodity exports and substantially change Australia's pattern of trade.

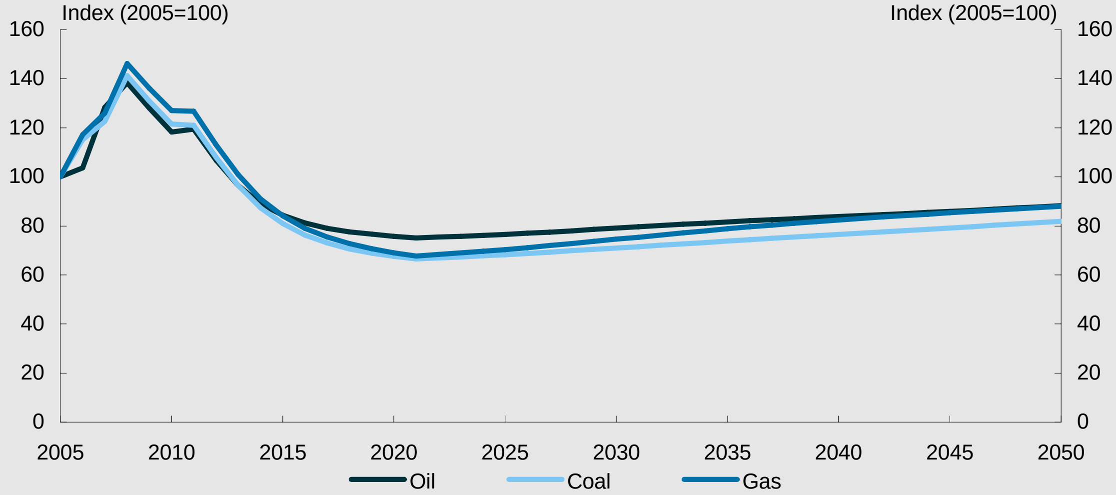
China, India and Indonesia are projected to be Australia's first, second and third largest export markets by 2050 – positions held by the European Union, Japan and the United States in 2005. The proportion of Australia's exports going to China, India and Indonesia increases from 14 per cent in 2005 to more than 35 per cent in 2050.

Export shares shift between sectors by 2050, with service exports, particularly tourism exports, becoming substantially more important (Chart 3.32). In line with these developments, the historical trend diversification of Australia's export shares is also expected to continue to 2050.

Box 3.6: Commodity prices

Global energy prices are assumed to rise gradually, as rising demand drives exploitation of more marginal resources. Movements in the international prices for key energy commodities, including oil, coal and gas, are assumed to broadly follow IEA projections (Chart 3.31).

Chart 3.31: Commodity price assumptions



Source: IEA, 2007b; and Treasury.

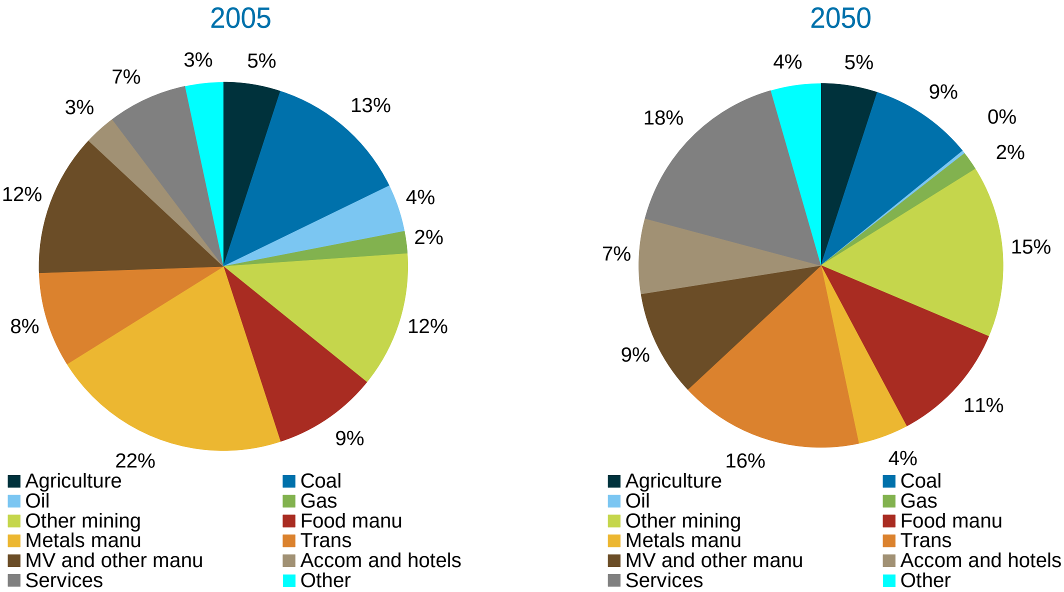
For Australian electricity generators, black coal prices are assumed to remain stable in the short term, reflecting existing contractual arrangements. However, as these contractual arrangements roll over, Australian prices begin to rise gradually in line with global trends. Australia does not export brown coal, so brown coal prices for electricity generators, notably in Victoria, are assumed to remain broadly flat, reflecting large reserves and limited alternative uses.

Australia's domestic gas market is highly regional; Western Australian prices are linked to international markets while prices in the eastern states market are not. Eastern seaboard gas prices for electricity generators are projected using a model of the gas market developed by McLennan Magasanik Associates (MMA). This model takes account of new and existing contracts, transmission costs and gas supply resources. East coast gas prices converge to world prices by around 2030, reflecting depletion of existing gas sources on the east coast over the next 20 years and links to world markets through liquefied natural gas (LNG) facility developments (Annex B).

While energy resources are not assumed to be depleted, given the uncertainty about future commodity prices, a sensitivity scenario examined the impact of energy extraction costs being 50 per cent higher than the standard assumptions. The higher extraction costs boosted oil prices, moderately increased gas prices and marginally increased coal prices, with impacts differing between regions. This results in substitution away from fossil fuels, but also a shift towards coal, the most emission-intensive fuel.

As a result, global emissions in this sensitivity scenario are around 5 per cent lower than the standard reference scenario at 2050, reflecting reduced energy demand due to higher energy prices. This means that the mitigation task would be less in the policy scenario. Compared with the Garnaut -10 scenario, GWP mitigation costs are around 10 per cent less in 2050 and 30 per cent less in 2100.

Chart 3.32: Export shares by key sectors



Source: Treasury estimates from MMRF.

Australia's exports are relatively emission intensive compared with total Australian production. The emission intensity of exports is expected to fall as productivity, including in energy use and other emission-intensive inputs, continues to improve and there is a compositional shift to relatively low-emission service exports.

3.2.3 State analysis

Differences in economic growth in each of the states and territories are a function of patterns of industrial production and population growth. Over time, South Australia and Tasmania diverge from the other states to a lower average gross state product (GSP) growth rate, largely reflecting lower assumed population growth. Queensland, Western Australia and the Northern Territory have rising shares of the national population, while South Australia, Tasmania and the Australian Capital Territory have falling national shares. Population shares for New South Wales and Victoria remain stable (Table 3.11).

Table 3.11: Gross state product
Annual average growth rates

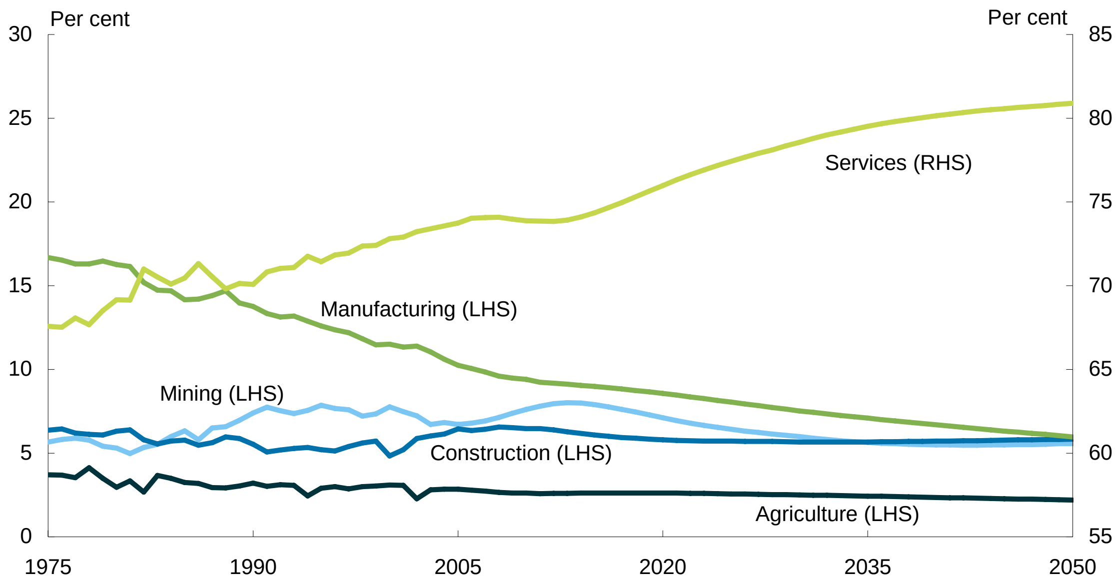
Decade	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
2000s(a)	3.0	3.2	3.8	2.7	4.6	2.9	4.3	2.9
2010s	2.6	2.8	3.2	2.2	3.2	2.0	2.8	2.6
2020s	2.3	2.3	2.7	1.6	2.4	1.7	2.3	2.2
2030s	2.2	2.1	2.6	1.6	2.4	1.7	2.6	2.1
2040s	2.0	2.0	2.4	1.4	2.3	1.5	2.7	1.9
2050s	2.0	2.0	2.3	1.4	2.3	1.5	2.7	1.9
2060s	2.1	2.1	2.3	1.5	2.3	1.6	2.6	2.1
2070s	2.2	2.1	2.2	1.5	2.3	1.6	2.5	2.2
2080s	2.1	2.1	2.2	1.4	2.3	1.6	2.4	2.1
2090s	2.1	2.0	2.2	1.4	2.2	1.6	2.4	2.1

(a) 2000s commence 2005-06, consistent with the base year in the MMRF model.
Source: Treasury estimates from MMRF.

3.2.4 Sectoral analysis

The sectoral composition of Australia's economy adjusts reflecting a continuation of historical trends. Both supply- and demand-side factors drive sectoral trends. On the supply side, industry sectors are assumed to have different rates of productivity growth. The sectoral differences assumed in the reference scenario are based on the historical dispersion of productivity growth across industry sectors. For instance, in Australia, productivity growth in the communications industry is expected to be almost twice the Australia-wide average, while productivity growth in service sectors such as public administration is expected to be below average. Over time, industry productivity growth assumptions in the market sector are assumed to converge, reflecting uncertainty about the persistence of historical differences over long timeframes.

Chart 3.33: Value added shares



Source: Treasury estimates from MMRF.

Overall, services are expected to grow at around 2.7 per cent per year to 2050, rising from around 73 per cent of real output in 2005 to almost 80 per cent in 2050. The service sectors that grow fastest include communications and property and business services.

While the service sectors provide the bulk of Australia's output, the Australian economy has a significant reliance on primary and related industries, such as agriculture, mining and mineral processing, reflecting Australia's abundance of natural resources. Over the next 50 years, all these sectors are expected to decline as a share of real GDP.

Agriculture is expected to grow more slowly, at around 1.9 per cent per year to 2050, largely reflecting land constraints. Agriculture's share of real GDP is projected to decline from around 3.2 per cent in 2005, to 2.5 per cent by 2050. However, increased world demand for agricultural products, and supply-side constraint, such as land availability, is expected to drive strong prices for agricultural commodities, and agriculture's share of nominal GDP is expected to increase to just over 5 per cent by 2050.

Initially, mining benefits from the recent surge in world demand for commodities before slowing in response to declining commodity prices and supply constraints in the oil and gas industries. Despite Australia possessing large reserves of (non-petroleum related) natural resources, as resource constraints start to affect underlying productivity in later decades, the mining sector is expected to grow by only slightly more than the national average, largely driven by strong growth in coal, iron ore and other metal ores. Overall the mining is assumed to grow at around 2.1 per cent per year to 2050.

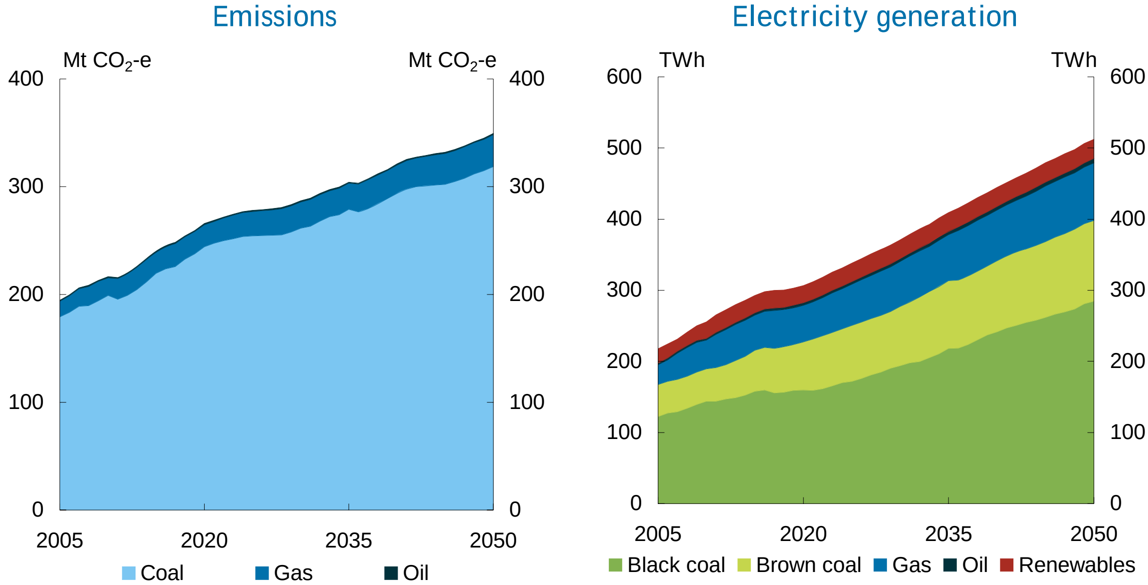
Australia's natural resource endowments provide an inexpensive and reliable supply of electricity. Access to low-cost energy provides a comparative advantage and contributes to the development of a range of energy-intensive manufacturing industries. Industries that benefit either directly (through their use of resources as material inputs) or indirectly (through their use of electricity) include mineral processing (iron and steel, non-ferrous metals), petroleum and chemicals, and wood and paper products. In 2005, together they accounted for 3.5 per cent of GDP; however, this is expected to fall to around 1.7 per cent by 2050 (Chart 3.33).

In aggregate, Australian manufacturing is expected to continue its historical decline. This decline is largely driven by strong productivity growth in global manufacturing, particularly in developing economies, resulting in a loss of competitiveness for Australian manufacturing. Overall, manufacturing is assumed to grow by 1.3 per cent per year to 2050. The contraction in manufacturing's share of the Australian economy is widespread across the sector, with metal-manufacturing industries such as steel and aluminium, textile, clothing and footwear, chemical manufacturing, and rubber and plastics industries all experiencing annual growth lower than the national average.

Electricity generation sector

Australian electricity generation is expected to more than double by 2050, growing from around 218 TWh in 2005 to around 512 TWh in 2050 (Chart 3.34). This reflects the economy's expansion and sustained growth in residential consumption and high electricity-use sectors, such as aluminium. Electricity generation grows less than output growth, reducing the electricity intensity of the economy.

Chart 3.34: Electricity sector



Source: Treasury estimates from MMRF and MMA (2008).

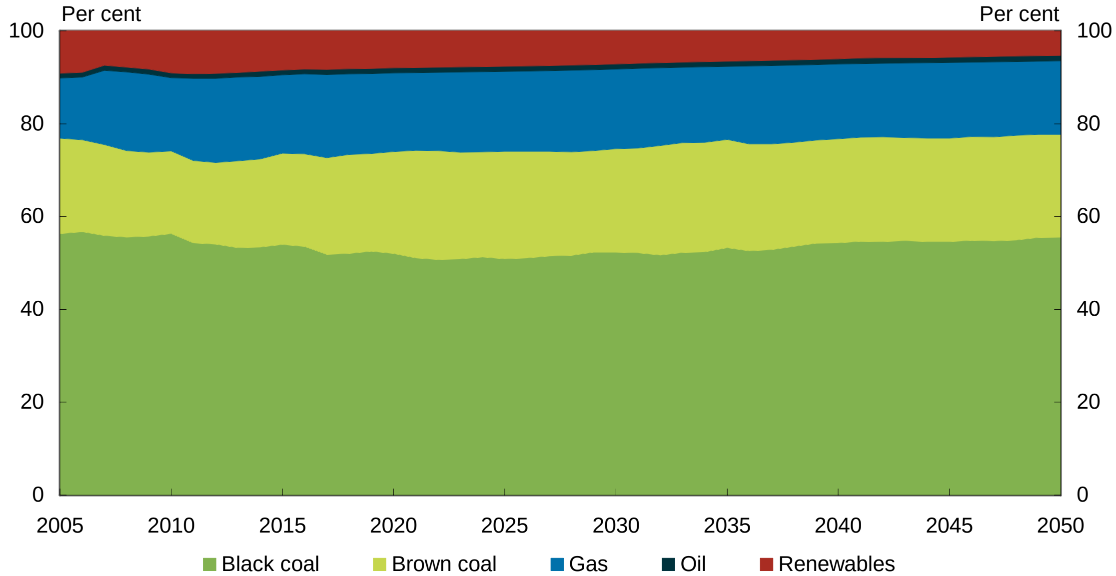
Australia has more than 100 years worth of reserves of black coal and 500 years of brown coal at 2005-06 rates of production (ABARE, 2008a). Coal accounts for around 75 per cent of Australia's electricity generation and 60 per cent of Australia's generation capacity by 2050.

The role of gas-fired electricity is projected to grow in the reference scenario, reflecting policies to encourage its take-up (such as the Queensland Government's gas scheme) and its capability to meet sudden 'peaks' in electricity demand (Chart 3.35). The ratio of peak-to-baseload electricity demand has been rising in recent years, including from the increasing penetration of air conditioners. This trend is assumed to continue until 2025 (MMA, 2008).

Gas-fired power plants rise from less than 20 per cent of Australia's current capacity to around 30 per cent by 2050, most of which is peaking plant. However, the role of gas is partly constrained by rising east coast gas prices, which reduce its competitiveness with respect to coal.

Renewable electricity sources continue to play a minor role in Australia's electricity sector. Hydroelectric capacity grows only marginally as most of Australia's hydroelectric potential is already exploited. Non-hydro renewables – particularly wind – increase their share of generation initially in response to incentives created under the pre-existing MRET scheme. However, without new policies, renewables comprise a declining share after 2020 owing to the cost advantage of fossil-fuel technology. Note that the reference scenario does not include the proposed expansion of the Renewable Energy Target scheme.

Chart 3.35: Australian electricity generation, technology shares



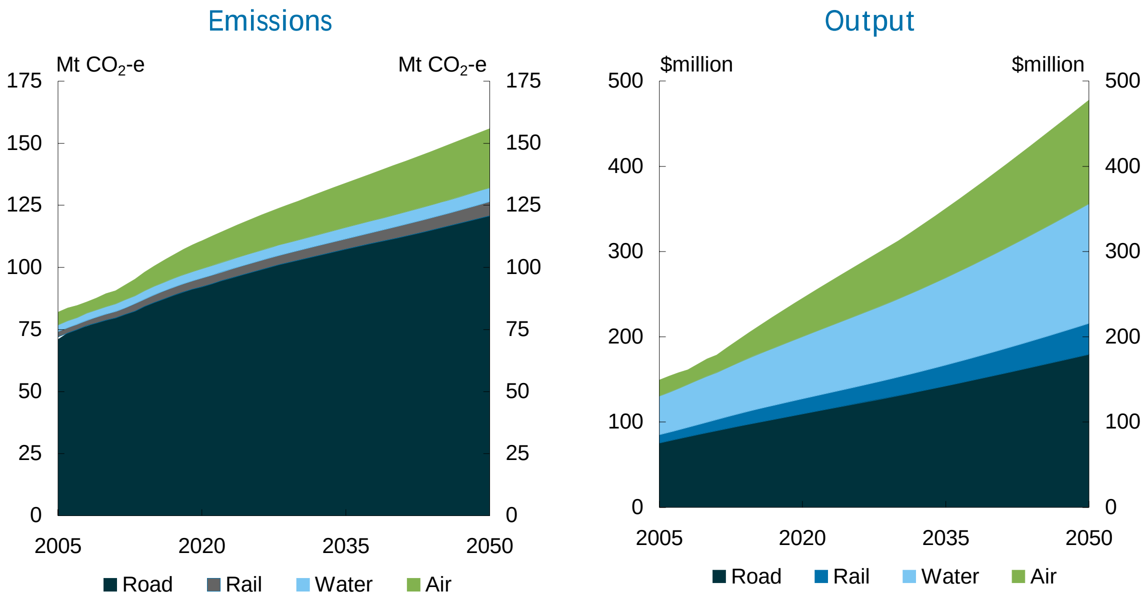
Source: MMA, 2008.

Electricity emissions in the reference scenario are projected to rise to around 348 Mt by 2050, 100 per cent more than 2000 levels of 175 Mt. The emission intensity of electricity generation remains broadly unchanged at around 0.8 tCO_2-e/MWh on average to 2050.

Transport

Output by the transport sectors (air, water, road, rail) is assumed to increase by around 2.6 times between 2005 and 2050 (Chart 3.36). This strong growth reflects the expansion of the economy and strong growth in air transport consistent with rising domestic and world incomes.

Chart 3.36: Transport sector



Source: Treasury; BITRE and CSIRO, 2008.

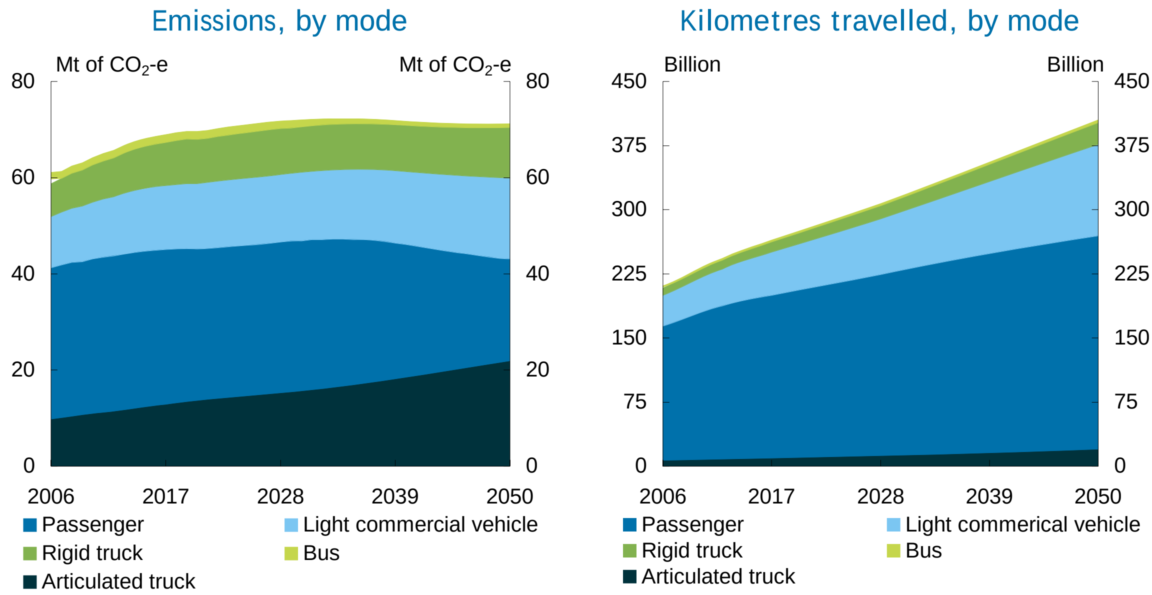
Australia's transport emissions increase modestly to 2050, with the share of total emissions relatively unchanged. Emissions growth primarily results from strong growth in the emission-intensive air transport sector, offset by moderate growth in passenger road transport emissions as demand is saturated (BITRE and CSIRO, 2008) and substitution occurs towards less fossil-fuel intensive vehicles as energy prices rise. Overall, emissions per unit of energy fall at an average annual rate of 0.1 per cent from 2005 to 2050.

Road transport

Road transport activity in Australia nearly doubles between 2006 and 2050 (Chart 3.37). Passenger transport is projected to reach a saturation point soon after 2010, whereby travel no longer increases with growth in incomes, reflecting consumer preferences to limit total time spent travelling. It then grows in line with population (BITRE and CSIRO, 2008). In contrast, freight activity continues to grow broadly in line with economic activity.

As a result, while passenger vehicles account for most of transport activity, their share falls from 75.6 to 63.5 per cent by 2050 and the share met by light commercial vehicles and trucks increases. The share of vehicle kilometres travelled met by buses remains below 1 per cent to 2050.

Chart 3.37: Road transport sector



Source: Treasury; BITRE and CSIRO, 2008.

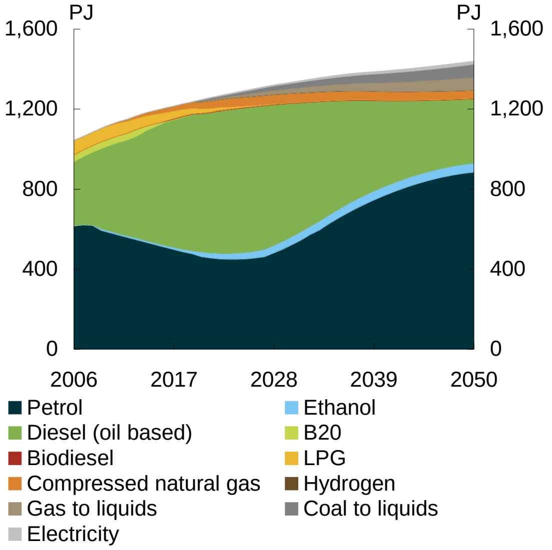
The mix of transport fuels changes over time. The changes reflect oil market conditions and technology assumptions, including the availability of fossil-fuel alternatives. Conventional fuels, such as petrol and diesel, still dominate in 2050 (Chart 3.38).

A major trend is diesel's share rises for the first 20 years, overtaking petrol as the dominant fuel, but then declines (BITRE and CSIRO, 2008). Diesel's increased share reflects the rising efficiency of diesel engines, making the fuel more attractive than petrol. Efficiency improvements are primarily due to the availability of European-designed diesel engines which until recently were not compatible with Australia's diesel fuel. Petrol regains a majority share by 2050, as the improved efficiency of hybrid engines makes them more cost-competitive than diesel.

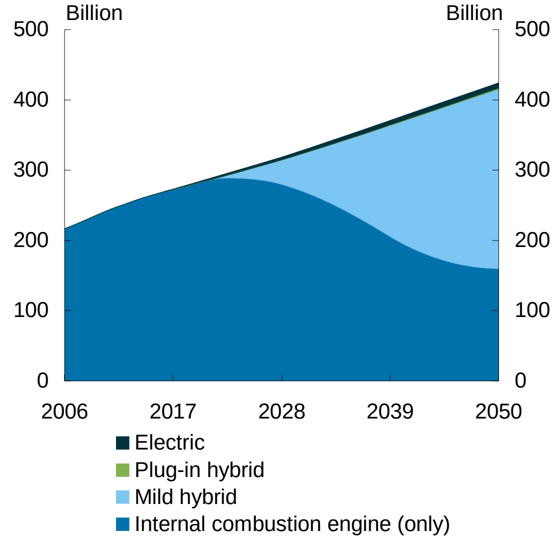
Another major trend is fuel diversification from around 2020, with ethanol, electricity and synthetic forms of diesel (such as gas and coal to liquid) (BITRE and CSIRO, 2008). The share of ethanol related fuels (E10 and E85) increases around 2020, as technology to extract ethanol from lignocellulose feedstocks is assumed to become cost effective. Production of synthetic diesel fuels is assumed to start in 2020 in response to rising oil prices. Electricity is consumed in the small number of fully electric and plug-in electric vehicles. By 2050, a total of 17 petajoules (PJ) of electricity is used in transport – around 5 TWh – which amounts to around 1 per cent of total Australian electricity production in 2050. Hydrogen technologies are not deployed.

Chart 3.38: Road transport sector

Fuel use



Kilometres travelled, by technology



Source: Treasury; BITRE and CSIRO, 2008.

These fuels use different engine technologies (Chart 3.38). Internal combustion engines and hybrid cars are the dominant technology, with few fully electric or plug-in electric cars. These more fuel efficient vehicles partly explain moderating emissions growth from the sector to 2050. In addition, growth in passenger kilometres slows due to a declining population growth rate and vehicle ownership saturation.

Reduction in energy use per vehicle kilometre, fuel switching and improvements in engine technology, slowing population, and improved engine technology drive a slowing in emissions. Emissions from road transport (including those from electricity used in transport) grow at an average annual rate of 1.2 per cent from 2006 to 2020, and an average annual rate of 0.8 per cent from 2006 to 2050.

Road freight emissions from rigid and articulated trucks and light commercial vehicles increase more strongly, in line with growth in mining and the economy as a whole.

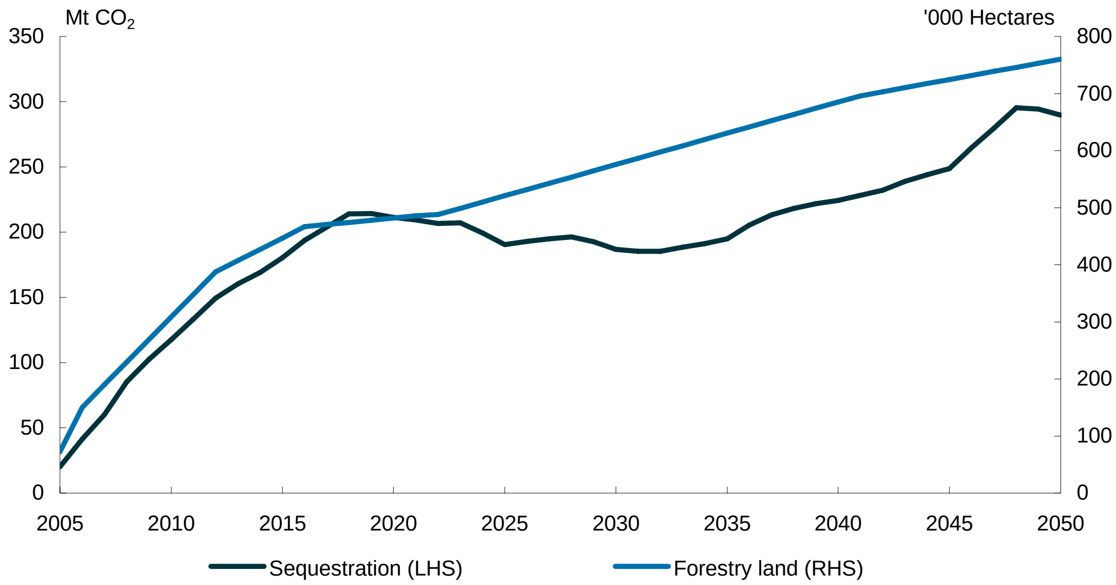
Land-use change and forestry

In Australia, more than 750 thousand hectares of new forestry plantations are projected to be established between 2005 and 2050. Western Australia is projected to have the largest uptake of new forestry plantations due to a significant increase in short rotation hardwood investments.

Annual expansion of plantations is projected to peak around 78,000 hectares in 2006 before trending down to an estimated 7,100 hectares per year by around 2040. No large scale deforestation is projected for Australia, as regulations prohibit clearing of native vegetation in all states and territories.

Forestry plantation and the corresponding emissions sequestered by the forestry sector grow steadily to 2050 (Chart 3.39). Sequestration rates vary, depending on the amount of land planted, growth rates, harvesting and other factors. From 2005 to 2050, forestry provides a cumulative net carbon sink of almost 300 Mt CO_2-e.

Chart 3.39: Australian land under forestry, and associated sequestration



Note: Land under forestry is cumulative since 2005.
Source: ABARE, 2008b and DCC, 2008.

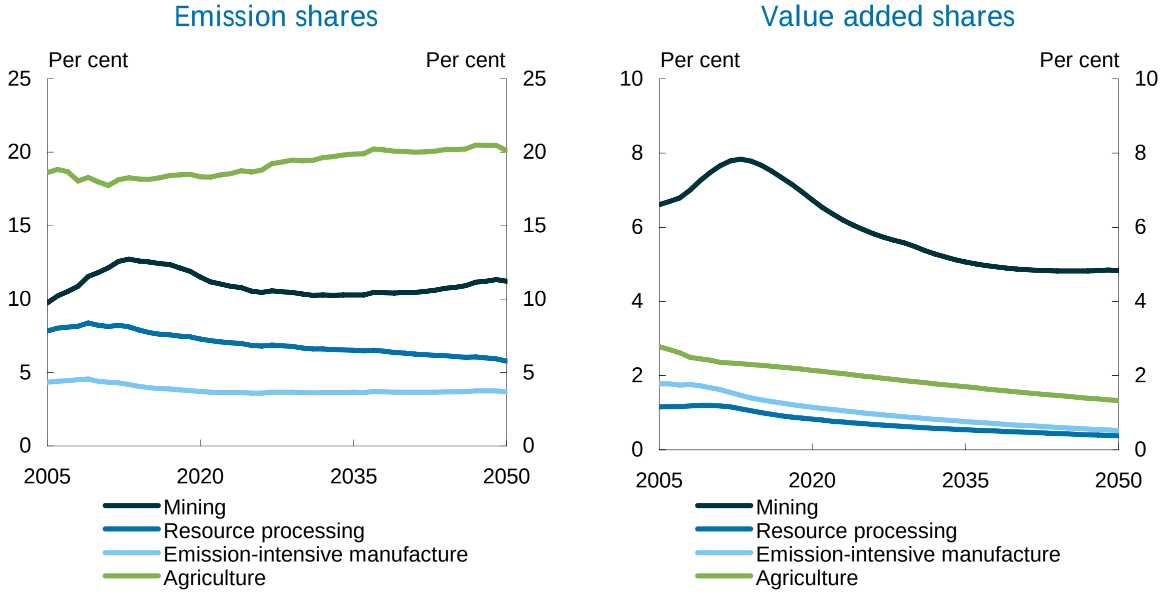
Emissions from land-use change in Australia continue at the rate of 44 Mt CO_2-e per year. This is based on a simple extrapolation from projections in the most recent national emission projections (DCC, 2008), and represents emissions from clearing of regrowth rather than any new deforestation.

Other emission-intensive industries

The other emission-intensive sectors comprise mining, resource processing, emission-intensive manufacturing and agriculture. These sectors comprise around 40 per cent of emissions and around 12 per cent of value added output. As the Australian economy becomes more service orientated, the share of output from these emission-intensive sectors falls, while their share of total emissions remains relatively constant (Chart 3.40).

These emission-intensive sectors comprise around 60 per cent of Australia's exports in 2005. This reflects Australia's rich endowment of natural resources, and access to low-cost sources of energy, a source of comparative advantage in international trade. The export share from these sectors falls to around 40 per cent by 2050, as world demand for resources slows after 2020.

Chart 3.40: Emission-intensive industries



Source: Treasury estimates from MMRF.

The resource-processing sector comprises steel, aluminium, alumina, refining and other metal-manufacturing industries. The share of output from this sector is projected to fall, as growth in output from the metal-manufacturing sectors (iron and steel, aluminium, alumina and other metal manufacturing) slows in response to slowing world demand, and higher electricity price, particularly for aluminium. Emissions from this sector are primarily from energy use (coal used in steel manufacture, and scope 2 emissions from electricity use within the aluminium sector) and industrial processes (such as PFCs generated and emitted during the production of aluminium).[5]

The emission-intensive manufacturing sector comprises paper products, chemicals, rubber/plastic, non-metal manufacturing and cement. Its falling share of output to 2050 largely reflects a loss of competitiveness because productivity growth remains strong in global manufacturing, particularly in developing economies. Emissions from this sector are largely industrial-process emissions, such as from calcification during cement manufacture releasing CO_2, and from the combustion of fossil fuels.

3.2.5 Households

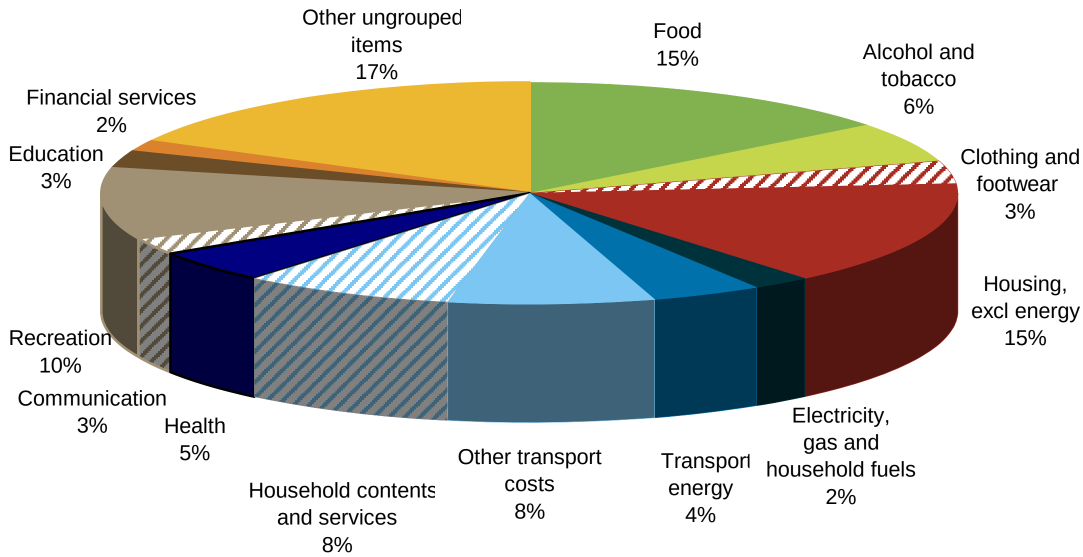
Household use of stationary and transport energy, including automotive fuel, residential electricity, gas and other energy sources, accounted for 36 per cent of energy consumption by volume in 2005-06. Transport energy spending is a large share of energy spending for most households. Total household spending on energy is around 6.3 per cent of household spending at the median, for those households that spend on energy, while spending on stationary energy is around 2.4 per cent of all spending at the median for those with spending on stationary energy.

Overall, households spend most on housing (15 per cent), food (15 per cent) and recreation (10 per cent) (Chart 3.41). Direct energy consumption represents around 6.6 per cent of all spending by Australian households, but households also consume energy indirectly, through the

5 Scope 2 emissions are indirect emissions from the generation of purchased electricity.

use of public transport, and embodied energy in household consumption, that is, the energy used in the manufacture, transportation and disposal of goods or services over the lifecycle.

Chart 3.41: Aggregate household spending
By category in 2010-11



Note: Shares of spending by category are based on aggregate spending for all households included in the HES survey sample.
Source: Treasury.

The pattern of spending by households is affected by income and other characteristics, including household composition and location.

Distributional analysis

Total household spending on energy varies across regions (Chart 3.42), possibly as a result of variation in available energy sources, prices and quantities consumed. There is also significant variation within regions as a result of transport and household consumption choices. Spending on energy by Hobart households, for example, ranges from around 5 per cent of spending at the 25th percentile to around 11 per cent of spending at the 75th percentile. Relatively low proportions of household spending on fuel in Brisbane and regional Queensland may be partly attributable to the Queensland Fuel Subsidy Scheme, which has provided a subsidy of around 8 cents per litre for Queensland motorists since July 2000.

Box 3.7: Methodology for household spending distributional analysis

In this section of the report, all distributional analysis is based on equivalised disposable household incomes. This enables comparison of income across households of different size and composition by scaling incomes back to a single person equivalent basis. Equivalised household incomes have been derived using the modified OECD equivalence scale, in which the first adult in the household is given a weight of 1.0, each subsequent person aged 15 years or more is given a weight of 0.5 and children aged less than 15 years are each given a weight of 0.3.

Incomes are generally represented in quintiles of household disposable income in the following analysis, with quintile cut-off points in 2010-11 dollar terms equivalised for a single adult as follows: $376 per week at the top of the first quintile, $5749 at the top of the second quintile, $773 at the top of the third quintile and $1043 at the top of the fourth quintile.

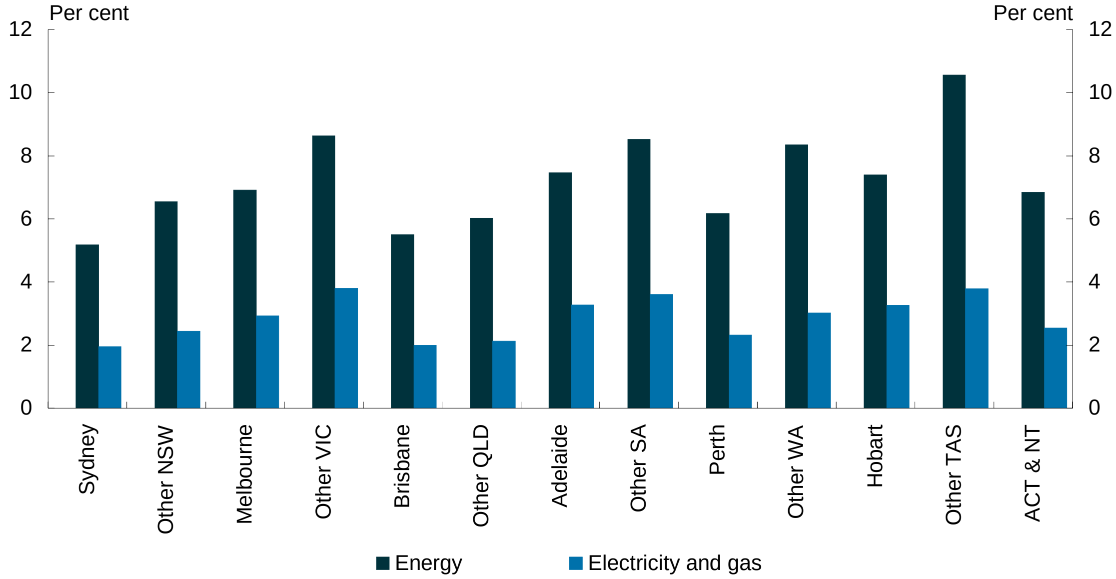
The PRISMOD.DIST model has been used for this analysis to ensure that results are consistent with the scenario results reported in Chapter 6 of this report. The model projects household spending for the 2010-11 year based on projected growth in prices for CPI expenditure classes, and projects incomes based on projected growth in wages and transfer payments and legislated tax rates and thresholds. Lump sum Government transfers of a one-off nature and other measures that are not legislated by 15 October 2008 to impact in the 2010-11 year are not modelled. The quantities of goods and services purchased by households are kept constant in the model, only prices vary over time.

Household spending on stationary and transport energy includes direct spending on electricity, mains gas, bottled gas, heating oil, wood for fuel, bottled gas for barbecues, kerosene, paraffin, petrol, diesel fuel, LPG, other gas fuels, other domestic fuel and holiday petrol. Where stationary fuel use is reported separately, petrol, diesel fuel, LPG, other gas fuels, other domestic fuel and holiday petrol are excluded.

Unless otherwise stated, households are only included in the analysis if they spend on energy and have positive disposable income. While the exclusion of households with negative or nil disposable income results in slightly fewer households in the lowest quintile being included in the analysis, it partially addresses ABS concerns that 'the (reported) income of many households in the lowest decile may not accurately reflect the level of their wellbeing'. Around 2.5 per cent of households with positive disposable income are excluded from the analysis because they report no direct spending on energy at all, while around 3.4 per cent of households with positive disposable income are excluded from analysis of spending on stationary energy because they report no spending on electricity, gas or household fuels.

Regional analysis of spending is limited to the broad areas identified in the ABS Household Expenditure Survey 2003-04 confidentialised unit record file. This particularly limits analysis for the Northern Territory and the Australian Capital Territory, which are treated as one area in the unit record file.

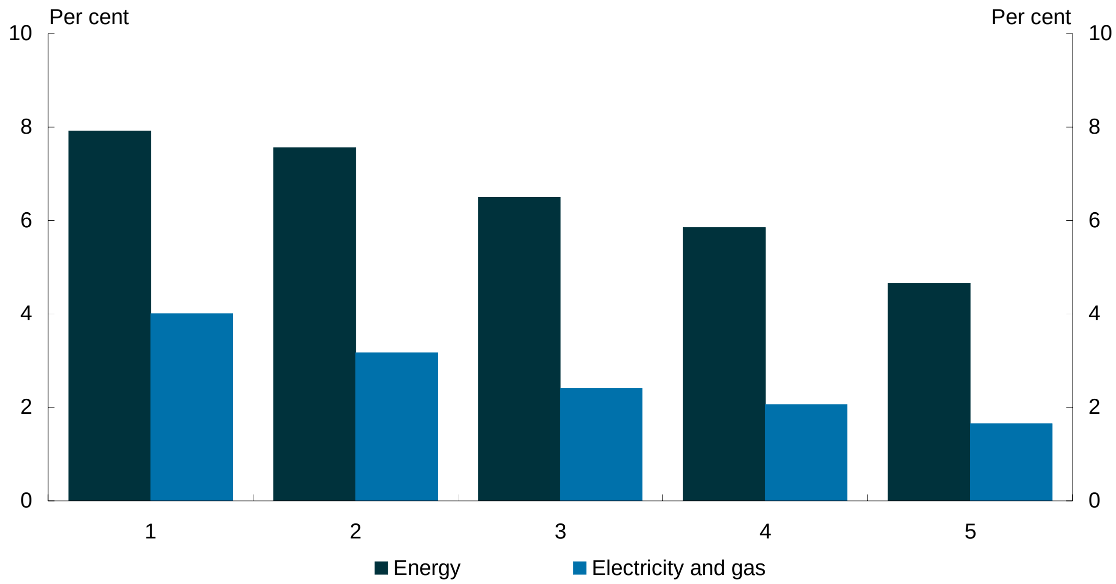
Chart 3.42: Spending on energy as a percentage of all spending
2010-11



Source: Treasury.

Spending on stationary and transport energy by low income households represents a higher proportion of total spending than for middle and higher income households (Chart 3.43). For households in the first income quintile, the median proportion of spending on energy is around 8 per cent, while the median proportion of spending on stationary energy is around 4 per cent of total spending.

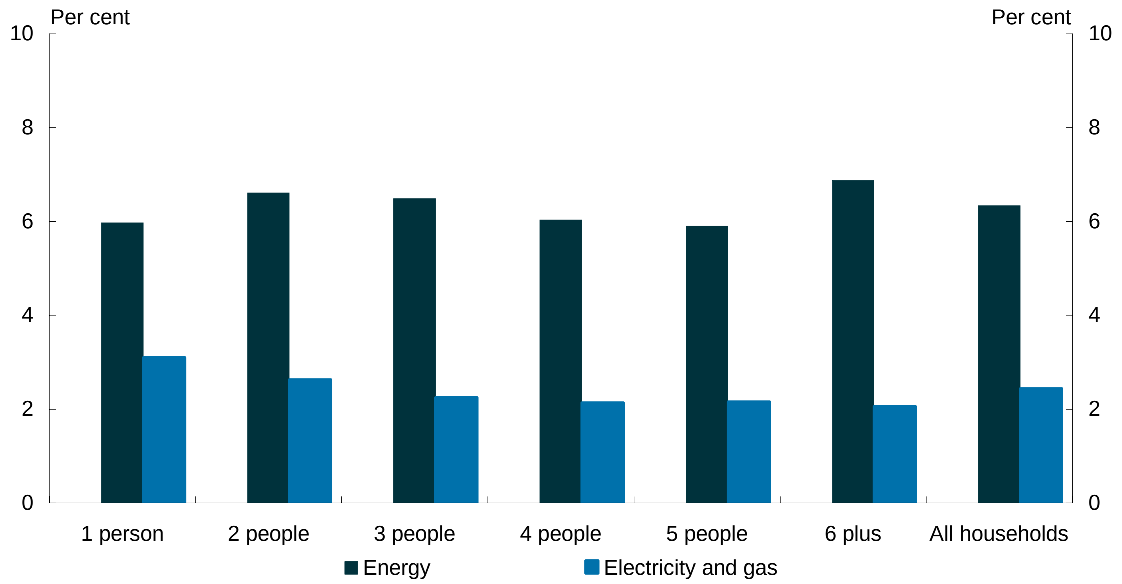
Chart 3.43: Spending on energy as a percentage of all spending
By equivalised disposable income quintile in 2010-11



Source: Treasury.

Spending on energy as a percentage of total household spending does not appear to vary markedly with household size, for households with more than two people. This may in part be due to economies of scale and government transfer payments supplementing the incomes of families with children. The picture for households with six or more people may not be consistent with the trend for smaller households, but it is difficult to draw conclusions about the spending patterns and circumstances of these households because of the relatively small number of them in the Household Expenditure Survey confidentialised unit record file. In all income quintiles except the highest, households with two people appear to spend a slightly higher proportion of their total spending on energy than households with one person. This effect is not observable for spending on stationary energy, which represents a higher proportion of the household budget for single-person households (Chart 3.44).

Chart 3.44: Spending on energy by household size
2010-11



Source: Treasury.

Households where Government transfer payments are the principal source of income spend a higher proportion of their budget on energy than other households (Table 3.12). This is also true for stationary energy alone. As suggested in the following table, the majority of these households are in the first and second equivalised income quintiles. Numbers above the third equivalised income quintile are too small to derive reliable estimates of spending patterns.

For households where Government transfer payments are the principal source of income, those in the lowest income quintiles spend a markedly higher proportion of their total budget on energy than those in the third income quintile. Households where Government transfer payments are the principal source of income in the first quintile include a high proportion of single pensioners, and the majority of couple allowees with and without children, and single allowees. In the second quintile, households where Government transfer payments are the principal source of income include more couple pensioners and Parenting Payment Single recipients.

Table 3.12: Spending on energy by principal source of household income, 2010-11

	Household income quintile				
	First	Second	Third	Fourth	Fifth
	Per cent	Per cent	Per cent	Per cent	Per cent
Spending on energy					
Households where government payments are the principal source of income	8.1	7.6	7.2	*	*
Other households	7.6	7.5	6.5	5.9	4.7
Spending on stationary energy					
Households where government payments are the principal source of income	4.1	3.5	2.6	*	*
Other households	3.4	2.8	2.4	2.1	1.7

* Sample size is too small to derive reliable estimates.
Source: Treasury.

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CHAPTER 4: DESCRIPTION OF POLICY SCENARIOS

Key points

The policy scenarios assume coordinated global action to reduce greenhouse gas emissions to a level that allows stabilisation of atmospheric concentrations around 2100.

- The Garnaut -10 and CPRS -5 scenarios are consistent with stabilisation at around 550 ppm CO_2-e in 2100.
- The CPRS -15 scenario is consistent with stabilisation at around 510 ppm CO_2-e in 2100.
- The Garnaut -25 scenario is consistent with stabilisation at around 450 ppm CO_2-e shortly after 2100, after an initial overshoot during which concentrations exceed 450 ppm.

The mitigation scenarios use global market-based policy mechanisms to reduce global emissions.

The Garnaut scenarios assume unified global action from 2013: all economies participate in a global emissions trading scheme that covers all sources of greenhouse gas emissions. These scenarios compare the relative mitigation costs of different stabilisation levels.

The Carbon Pollution Reduction Scheme (CPRS) scenarios assume multi-stage global action: economies gradually join a global emissions trading scheme from 2010 to 2025. These two scenarios incorporate information on the Government's preferred scheme design as outlined in the *Carbon Pollution Reduction Scheme Green Paper* (DCC, 2008).

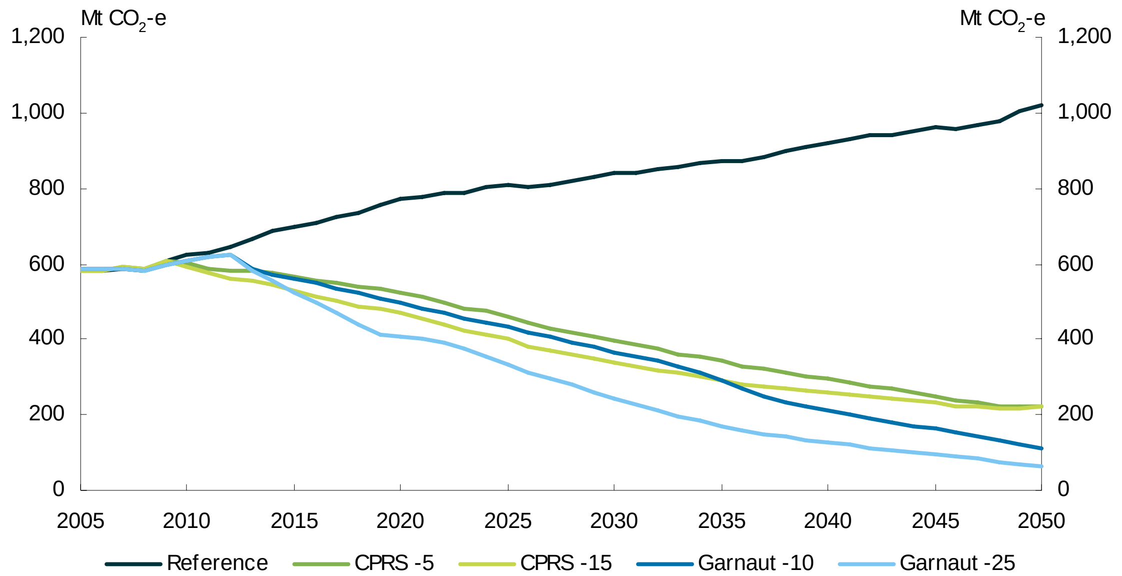
The reference scenario projects how Australia and the world could evolve if no new climate change mitigation policies are introduced. This chapter describes the mitigation policy scenarios, which assume global action to stabilise atmospheric concentrations of greenhouse gases. The assumptions described in this chapter are in addition to the assumptions in the reference scenario.

Four main policy scenarios were modelled. These were complemented with the modelling of several sensitivity scenarios to explore a range of uncertainties.

Two scenarios, Garnaut -10 and Garnaut -25, were modelled in conjunction with the Garnaut Climate Change Review. These scenarios form the basis of the Review's independent analysis of the costs and benefits of mitigation action. In this report, only the costs of mitigation action are considered. These scenarios involve stylised assumptions about global action to reduce emissions, with all economies assumed to join an emissions trading market covering all emission sources from 2013. Emission rights are shared between countries using a per capita allocation rule. For Australia, the Garnaut Climate Change Review scenarios correspond to emissions reductions targets in 2020 of 10 per cent and 25 per cent below 2000 levels for the Garnaut -10 and Garnaut -25.

Two scenarios, CPRS -5 and CPRS -15, model the Government's 2050 emissions reduction target, the design features are as outlined in the *Carbon Pollution Reduction Scheme Green Paper*, and a multi-stage approach to international emissions trading. Developed countries act first, and developing countries join over time. National emission targets gradually diverge from reference scenario trends for each country. The CPRS scenarios begin in 2010. Two illustrative medium-term targets have been modelled: 5 per cent and 15 per cent below 2000 levels by 2020 for the CPRS -5 and CPRS -15 scenarios (Chart 4.1 and Table 4.1).

Chart 4.1: Australian emission allocations



Source: Treasury estimates from MMRF.

Table 4.1: Summary of emission trajectories

	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
World				
Atmospheric stabilisation goal, CO_2-e ppm	550	510	550	450
Emission allocation, change from 2001 levels, per cent				
2020	32	24	40	29
2050	-9	-18	-13	-50
Emission allocation, per capita, change from 2001 levels				
2020	7	0	14	4
2050	-38	-44	-41	-66
Australia				
Emission allocation, change from 2000 levels, per cent				
2020	-5	-15	-10	-25
2050	-60	-60	-80	-90
Emission allocation, per capita, change from 2000 levels, per cent				
2020	-27	-34	-31	-44
2050	-77	-77	-88	-93

Note: International emissions data has been sourced from the GTEM model, whose database is from 2001.
Source: Treasury estimates from GTEM and MMRF.

Box 4.1: Climate change projections: stabilisation at 450 and 550 ppm

Stabilisation of atmospheric concentrations requires significant cuts in global greenhouse gas emissions. The stabilisation level depends on how soon emissions peak and how quickly they decline. Lower stabilisation levels require global emissions to peak within the coming decade and fall well below current levels by 2050 (IPCC, 2007a).

The global average surface temperature has risen around 0.8°C since 1850, and will rise further in the coming decades as a result of emissions that have already occurred.

Global mitigation action to achieve stabilisation at 450 ppm CO_2-e is associated with a 50 per cent chance of limiting global average warming to around 2°C above pre-industrial levels. This is the temperature threshold most frequently spoken of in the scientific literature as representing the limit beyond which 'dangerous' climate change may occur (for example, Hansen et al., 2007). Risks associated with this level of warming vary from region to region. For Australia, this is likely to involve substantial environmental change. Natural and agricultural production systems face significant change due to the combined effects of higher temperatures and a general reduction in rainfall across much of the nation. Risks from bushfires and other extreme weather increase, particularly in coastal and rural regions (Pearman, 2008).

Global mitigation action to achieve stabilisation at 550 ppm CO_2-e is associated with a 50 per cent chance of limiting global average warming to around 3°C above pre-industrial levels. Changes projected under a 450 ppm scenario are likely to occur sooner and become more severe under a 550 ppm world. Between 20 and 30 per cent of all species are projected to face a 50 per cent likelihood of extinction under this scenario (IPCC, 2007b). This would involve the total realignment of ecosystems across Australia. Coastal communities, agriculture and infrastructure would all face significant risks of adverse impacts. These include frequent or permanent coastal inundation for parts of the Australian coastline, a substantial increase in extreme weather across the nation, and substantial restructuring of the rural sector (Pearman, 2008).

4.1 Global emissions reductions

The policy scenarios examined assume coordinated global action to reduce greenhouse gas emissions to a level that allows stabilisation of greenhouse gas concentrations in the atmosphere. Concentration levels are a convenient measure of the scale of global mitigation effort, as they involve a single measure linked to human activities (via emissions) and environmental risks (via the relationship between concentration and temperature change) (Box 4.2). The target stabilisation levels examined vary within the range 450 to 550 ppm.

Box 4.2: Alternative specifications of targets

Strategies to address anthropogenic climate change are usually formulated as scenarios designed to meet a certain greenhouse gas emission-related target. Various targets are used in modelling exercises, each with advantages and disadvantages (Table 4.2).

Table 4.2: Advantages and disadvantages of different climate change targets

Target	Advantages	Disadvantages
Maximum tolerable level of impacts (for example, no more than a doubling of the current population under water stress)	Is linked directly to the consequences to avoid.	Has scientific, economic and ethical difficulties in defining important impacts and level of change tolerated. Is uncertain in linking avoidance of a specific impact to human action. Success cannot be measured until too late to take further action.
Global mean warming (above a baseline)	Can be linked to impacts, although somewhat uncertain. Has one quantifiable variable.	Has uncertainties in linking goal with specific human actions. Cannot show lags in time between temperature changes and human influence, so difficult to measure success of human actions in moving towards the goal.
Concentration(s) of greenhouse gases (or radiative forcing)	Has one quantifiable variable. Can be linked to human actions, although somewhat uncertain. Succeeds in moving towards the goal measurably and quickly.	Is uncertain about the magnitude of the avoided impacts.
Cumulative emissions for greenhouse gases (over a given period)	Has one quantifiable variable. Is directly linked to human actions. Succeeds in moving towards the goal measurably and quickly.	Is uncertain about the magnitude of the avoided impacts.
Reduction in annual emissions by a specific date	Has one quantifiable variable. Succeeds in moving towards the goal measurably and quickly.	Is uncertain about the magnitude of the avoided impacts. Does not address the problem that impacts are a function of stocks, not flows. May limit 'what, where, when' flexibility and so push up costs.

Source: Stern, 2007.

Many possible global emissions pathways could achieve a given stabilisation goal. Each pathway implies a different allocation of mitigation effort over time, with implications for economic costs, intergenerational equity and the preservation of options to change emission budgets and stabilisation goals in light of future information.

A 'Hotelling rule' is used to construct a global emissions pathway for each scenario within the global models (GTEM and G-Cubed). The emission price grows from a specified starting level at the real interest rate, assumed to be 4 per cent per year, which represents the rate of increase in comparable financial assets[1]. Other recent climate modelling exercises use similar levels.[2]

This approach mimics the expected behaviour of an efficient global emission market that allows banking and borrowing of permits over time, and draws on similarities between mitigation policy and management of finite resources (Box 4.3). Irrespective of the initial allocation of permits, market participants would form views regarding the future emission price in light of the

1 This rate of return embodies the commercial risks of holding permits and investing in emissions-related activities. The 4 per cent rate embodies a risk-free real rate of 2 per cent and a risk premium in markets for permits of 2 per cent.

2 For example, see CCSP, 2007, p 89.

environmental objective, overall emission budget, and expected future social, economic and technological conditions.

If market participants expect the emission price to grow faster than the value of other comparable financial assets, they would 'bank' permits now for use later (to capture this higher return) and the current emission price would rise. Conversely, if market participants expect the emission price to grow more slowly than other comparable assets, they would sell banked permits (or 'borrow' future permits if required) for use now, and the current emission price would fall. The emission price derived in the models mimics the price expected in the market, given the assumptions made in each scenario. Restrictions on borrowing are assumed in the CPRS scenarios, but given the assumptions made in the models this is not enough to move the price away from the 'Hotelling path', as the pressure in the market would only be towards banking. This reflects the equilibrium nature of the models (Chapter 2), which eliminates short-term market fluctuations.

Box 4.3: Depletion of natural resources

The concept of a resource price rising with the interest rate comes from resource economics. Hotelling (1931) and Solow (1974) observed finite resources are stored for consumption in future periods if the expected growth in price is greater than the required return for an asset in an equivalent risk class. If the expected growth in price is less than the required return, the asset is sold and the proceeds invested in an equivalent risk class asset. As a result, return from the optimal extraction of a finite mineral resource will increase over time at the rate of interest.

Stabilisation of greenhouse gas concentrations in the atmosphere requires limits on total emissions over time, not emissions in any particular year. Thus the optimal release of greenhouse gases into the atmosphere over time is a problem similar to the optimal extraction of a finite resource (Peck and Wan, 1996).

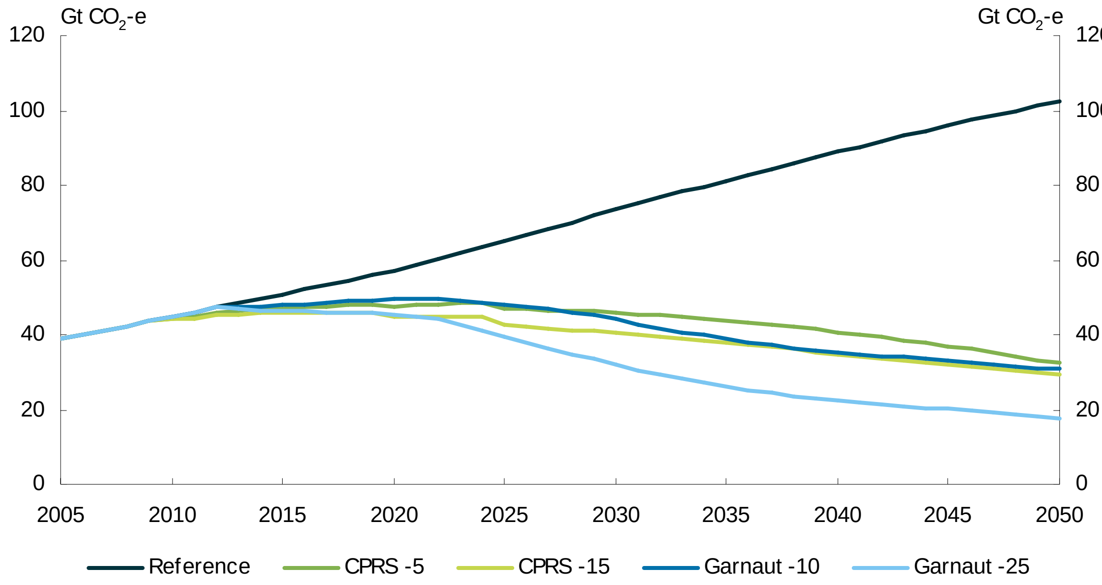
In an emissions trading scheme, emission permits encourage the efficient intertemporal allocation of mitigation effort by allowing use of a permit at any time (referred to as 'banking and borrowing'). Under these conditions, emission permits share characteristics of finite resources, as the total quantity is fixed, while their use varies over time.

A constant risk premium is applied to permits over time. Policy settings, such as the extent and credibility of future emission targets, disclosure rules for market-relevant information, and the legal nature of permits, may affect the risk premium applied in the market, and vary across economies and over time.

Different emission price paths, all growing at 4 per cent, but starting at different levels, were explored to produce an emission price path consistent with the stabilisation goal. The resulting emissions pathway is consistent with an efficient mitigation effort over time for a fixed emission budget and stabilisation target. The simple climate model MAGICC confirms that the resulting global emissions pathways are consistent with the stabilisation objective (Wigley, 2008).

In the Garnaut -10 and CPRS -5 scenarios, global emissions fall to levels consistent with achieving stabilisation at 550 ppm by 2100 (Table 4.1 and Chart 4.2). Global emissions in the CPRS -15 scenario follow a path consistent with stabilisation at around 510 ppm by 2100, and in the Garnaut -25 scenario, concentrations peak at 520 ppm in 2050, then could fall to 450 ppm just beyond 2100.

Chart 4.2: Global emissions and allocations

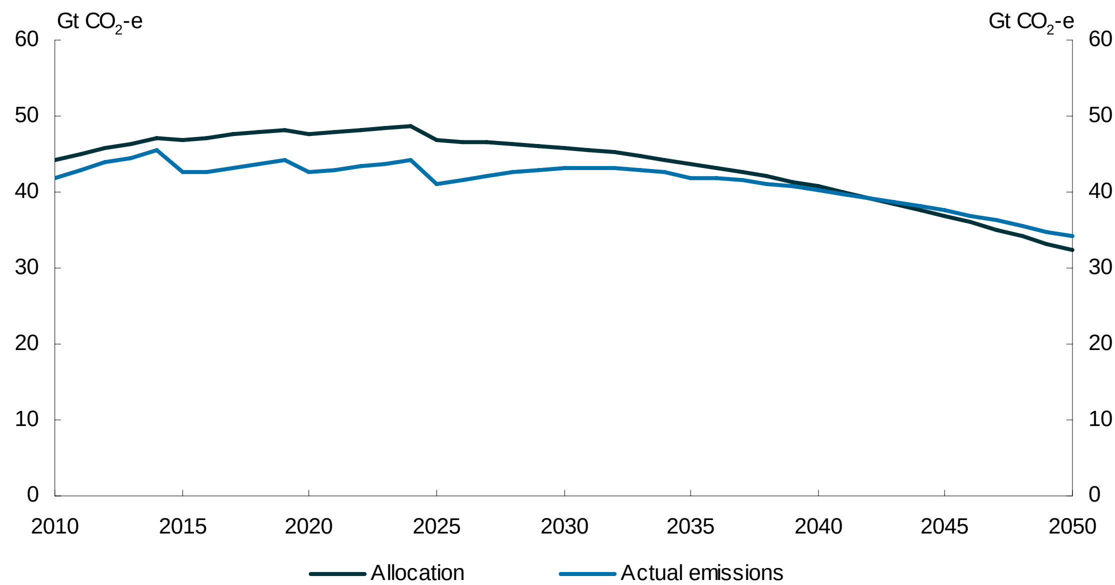


Note: Reference scenario emissions and assumed emission allocations for the policy scenarios are shown.
Source: Treasury estimates from GTEM.

Conceptually, permit banking plays an important role in the mitigation policy scenarios, particularly the CPRS scenarios. In these scenarios, national emission allocations gradually diverge from the reference scenario emission levels towards long-term emission reduction targets. However, the actual emissions in the models fall initially, in response to the introduction of an emission price at the level determined by the Hotelling rule. As a result, some allocated permits are banked for future use (Chart 4.3). The gap between allocations and actual emissions represents the permits that are banked. After 2040, actual emissions are higher than allocations, reflecting the use of previously banked permits.

Chart 4.3: Global emissions pathway and allocation

CPRS -5 scenario



Source: Treasury estimates from GTEM.

If the scenarios did not assume permits could be banked, the global emission price in all scenarios would start much lower, and accelerate much faster than 4 per cent per year. For example, if banking was not permitted in the CPRS -5 scenario, the emission price could start as low as around A$2 and grow at an annual average rate of over 20 per cent from 2010 to 2020.[3] While the emission price could be volatile when the CPRS is first introduced, banking helps ensure the price does not rise at rapid rates. Banking also allows for the efficient allocation of mitigation effort across time (Box 4.3).

The emission prices derived in the models do not incorporate the 'option' value associated with future changes to the emission budget and stabilisation target. Stochastic models that explicitly model uncertainty better suit option analysis than CGE models. In general, the starting price could be expected to rise where the market anticipates lower future stabilisation levels or emission budgets, and fall where the market anticipates higher future levels or budgets.

Emission pathways are expressed in CO_2-e emissions, calculated from the emissions of the six gases covered under the Kyoto Protocol, and combined using the 100-year global warming potentials applied under the Protocol. While the global warming potential concept is subject to continuous scientific debate, it is a convenient and widely used measure in policy analysis (IPCC, 2007c). Global warming potentials are embedded in the structure of the models used in this report.

Box 4.4: Emission targets, mitigation and trade

The Government's long-term target is to reduce Australia's net emissions by 60 per cent below 2000 levels by 2050.

Emissions generated in Australia may exceed or fall short of the national target in any particular year owing to Australia's participation in international emissions trading (DCC, 2008). Australia's target represents its contribution to the global mitigation effort. Emission trading is a mechanism to reduce the cost of Australia's contribution, and the global cost of achieving stabilisation, as emissions are reduced where it is cheapest. If Australia's emissions were higher (or lower) than its target, it would buy (or sell) permits accordingly.

In modelling reports, the gap between emissions in the reference scenario and policy scenarios over time often is characterised as the 'abatement task'. In this study, the gap between the reference scenario emissions and the Government's target in 2050 is about 800 Mt CO_2-e. This represents the difference between two alternative development pathways. The difference arises through incremental changes in the economy over time; it does not represent the actual mitigation task Australia faces in 2050. The sectoral and technological composition of the Australian economy in the reference scenario and policy scenarios gradually evolves, so the actual task Australia faces each year is a small additional mitigation effort compared to the previous year.

3 This is an approximation, as this sensitivity did not update for exogenous land-use and forestry sequestration assumptions. If these sequestration assumptions were updated, the annual average growth in the emission price could be even greater.

4.2 INTERNATIONAL ALLOCATION

'International allocation' refers to the division of emission rights and mitigation effort among economies. National contributions to the global mitigation effort are the subject of current international negotiations. While several principles guide these negotiations, national interests loom large, and the nature and timing of outcomes are difficult to predict.

Simplifying assumptions about the relative contribution of Australia and other nations are made in this report. While stylised, these assumptions provide a basis for exploring the relative costs of different stabilisation levels; give a sense of the scale of transition required; highlight differences in economic impacts across regions; and help identify which sectors are likely to be most affected.

The international allocation assumptions significantly affect Australia's mitigation costs. These assumptions determine the timing and level of Australia's contribution to the global mitigation effort. They determine the pattern of mitigation action by other economies which affect Australia through impacts on world trade and the extent of permit trade among economies. Trade in emission permits results in income or wealth transfers across economies.

The literature discusses different allocation frameworks (den Elzen et al., 2005; Rose et al., 1998; Cazorla and Toman, 2000). This report explores two approaches, 'multi-stage' and 'contraction and convergence'. These approaches differ structurally.

In the multi-stage approach, the number of economies participating in global mitigation gradually expands. National targets are based on an allocation of mitigation effort ('burden sharing'). Each country gradually diverges from its reference scenario emissions. This approach is based on responsibility and capability principles: the greater the contribution to the problem and the greater the capacity to act, the greater the share in the mitigation burden.

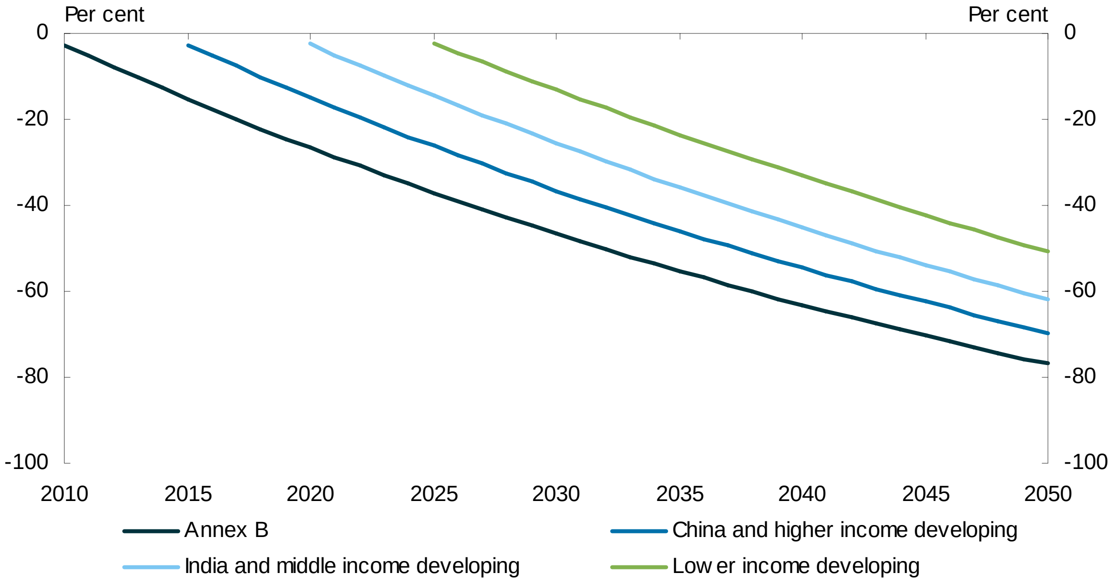
In contrast, in the contraction and convergence approach, economies participate and allocate emissions rights ('resource sharing') from the start. National targets are based on a per capita allocation rule. This approach balances egalitarian and sovereignty principles: all humans have equal rights to use the atmosphere, and current emissions constitute a 'status quo right' of economies.

The CPRS scenarios assume a multi-stage approach. Australia's level of mitigation effort is taken as the starting point. Developed economies take comparable action, and developing economies join the scheme over the period 2015 to 2025.

All economies follow their reference scenario emissions until 2009. Starting in 2010, they are then divided into different groups and assumed to take on emission targets that gradually diverge from reference scenario emission levels towards long term reductions. Economies listed in Annex B to the Kyoto Protocol are assumed to act in concert with Australia from 2010.[4] China and higher income developing economies take on targets in 2015. India and middle income developing economies take on targets in 2020, and lower income economies take on targets in 2025 (Chart 4.4).

4 This provides a simple proxy for existing and proposed mitigation policies in these countries. These policies were not included in the reference scenario.

Chart 4.4: Multi-stage emission allocations: relative to reference scenario
CPRS -5 scenario



Note: Allocations applied in the modelling diverge slightly from this chart owing to assumptions about the creation of offset credits in developing economies.
Source: Treasury.

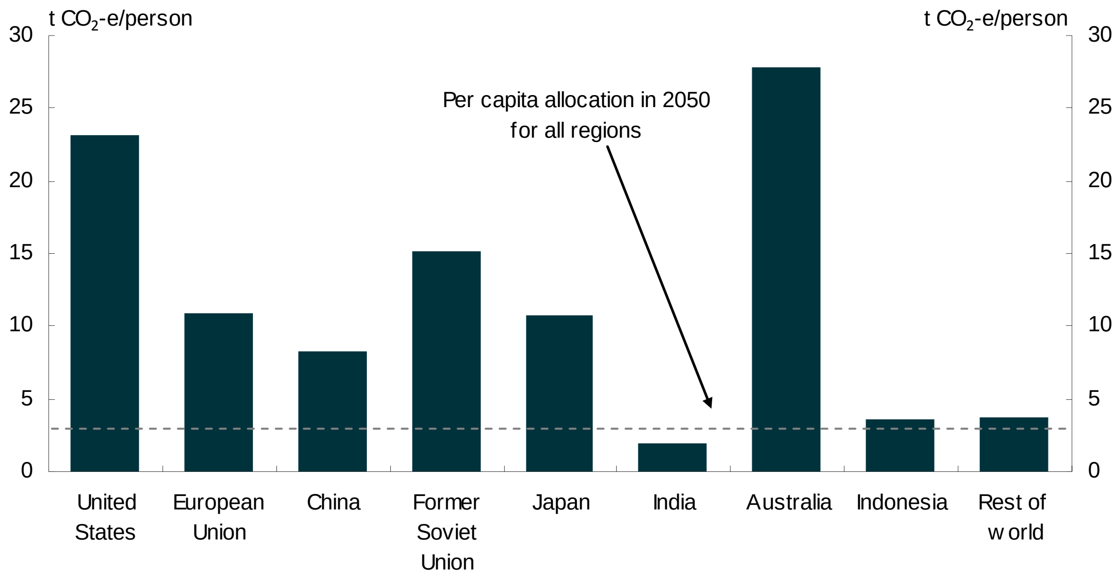
Australia's allocation under the CPRS scenarios is 60 per cent below 2000 levels by 2050, equal to about an 80 per cent reduction relative to the reference scenario. All Annex B economies diverge from their reference scenario emissions at the same rate, reflecting the principle of comparable effort.

Before taking on emission reduction targets, non-Annex B economies are assumed to generate a modest volume of offset credits (such as credits generated through projects under the Kyoto Protocol's Clean Development Mechanism) for sale to Annex B economies. In the medium term, developing economies take on targets that gradually reduce emission rights, and diverge strongly from reference scenario levels by 2050. For example, China's allocation is roughly treble 2000 levels in 2030, but falls to less than double 2000 levels by 2050. This is equal to a 70 per cent reduction from China's reference scenario emission levels.

The Garnaut scenarios assume a 'contraction and convergence' approach originally developed by the UK-based Global Commons Institute, with refinements developed by the Garnaut Climate Change Review (Garnaut, 2008). Features of this approach include:

- Initial national allocations reflect actual emission levels at the start of the scheme, but over time, they converge and by 2050, rights are allocated on an equal per capita basis (Chart 4.5).
- Allocations for fast growing developing economies increase at half their rate of economic growth until their per capita allocation reaches the level of the European Union and Japan.

Chart 4.5: Contraction and convergence approach
Per capita emissions in 2012, Garnaut -10 scenario



Source: Treasury and Garnaut, 2008.

Australia currently has relatively high per capita emission levels, and so the contraction and convergence approach implies significant reduction targets for Australia over the long term: 80 per cent reductions from 2000 levels by 2050 for Garnaut -10 and 90 per cent reductions for Garnaut -25.

Nevertheless, Australia may benefit more from approaches which take into account per capita emission levels than approaches which only focus on reducing absolute emissions levels relative to an historical baseline. This is because Australia's population is projected to grow more strongly than most developed economies in the coming decades. Population is an important driver of greenhouse gas emissions growth, and so (all else being equal) Australia's emissions are likely to grow faster than other developed economies' emissions. As a result, a fixed reduction in absolute emission levels relative to an historical baseline probably will cost Australia more than other developed economies.

An advantage of contraction and convergence is that it adjusts for the effect of population growth over time, so Australia is allocated a growing share of the global carbon budget relative to countries with lower population growth.

The allocation approaches examined are based on production emissions from producing goods and services within the economy. This is the standard accounting framework applied under current international climate change agreements. Alternative allocation rules could be based on where goods containing emissions are consumed. Australia has a comparative advantage in emission-intensive industries. Allocations based on production are likely to result in higher welfare costs for Australia than allocations based on consumption.

The notions of comparable effort and common, but differentiated, responsibilities will be central in reaching a post-2012 agreement accepted as 'fair'. Negotiations are unlikely to follow any single rule or formula, and all economies will emphasise factors that bear on their own national circumstances. The challenge is to identify principles that can harness broad support, and which will accelerate progress towards an effective international framework (Garnaut, 2008).

4.3 POLICIES TO REDUCE EMISSIONS

A wide range of policies currently used in Australia support mitigation goals, including energy efficiency incentives and standards, support for research and development into low-emission technologies, targets for renewable energy deployment, and controls on land use. A wider range of policies apply across the world, including emission taxes and emission trading schemes.

For the Garnaut scenarios, a single policy measure — a global emissions trading scheme covering all economies and all gases starting in 2013 — was used to drive emission reductions across the global economy. This stylised global policy framework allows the greatest flexibility to find and exploit the cheapest mitigation opportunities, rather than prescribe the regions and sectors in which emission reductions should occur. The international emissions trading system modelled in these policy scenarios is a simplified proxy for the range of mechanisms — from the flexibility mechanisms under the Kyoto Protocol to multilateral technology funds to voluntary emission markets — which constitute the global mitigation framework.

Similarly, in this analysis each economy or region in the model has an annual national emissions target, which forms the basis of its participation in the global emissions trading scheme. This target represents each economy or region's contribution to the global mitigation effort. The target is a simplified proxy for the range of policies and measures — from domestic emission trading schemes to bilateral cooperation on deforestation to regional technology partnerships — which constitute a national climate change response.

The emissions trading schemes modelled in the CPRS scenarios are based on the preferred policy positions as outlined in the *Carbon Pollution Reduction Scheme Green Paper* (DCC, 2008). This scheme's coverage and operation is assumed to evolve, initially offsetting some impacts of emission prices, limiting international trade, and shielding emission-intensive trade-exposed sectors ahead of full global participation (Table 4.3). Economies that participate in the global emissions trading scheme are assumed to follow similar policies to Australia.

In the CPRS scenarios, emission trading occurs between economies that have emission reduction targets. International permit trade is constrained until 2020 to reflect the Kyoto Protocol principle of supplementarity, which mandates flexibility mechanisms such as international emissions trading supplement (not replace) domestic mitigation effort. For the purposes of the modelling, constraints are calculated as half of the implicit 'mitigation effort' (that is, half of the gap between reference scenario emissions and allocations).

Developing economies, which initially remain outside the scheme, are assumed to be able to generate credits for sale into the global market ahead of taking on national emission caps, through schemes such as the Clean Development Mechanism. These parallel schemes help reduce global mitigation costs by creating access to low-cost mitigation in all economies, and help reduce global emissions by shifting developing economies onto lower emission development pathways including through the transfer of low-emission technologies.

Table 4.3: Summary of policy mechanisms

	CPRS -5 and CPRS -15	Garnaut -10 and Garnaut -25
Australia's emissions trading scheme	Starts in 2010. Based broadly on the *Carbon Pollution Reduction Scheme Green Paper*. Provides unlimited banking of permits. Excludes agriculture until 2015. Offsets impact on household fuel costs through fuel excise changes until 2013. Shields emission-intensive trade-exposed sectors until 2020 through providing free permits. Limits international trade in permits until 2020. Returns residual revenue to households as a lump-sum income transfer each year.	Starts in 2013. Covers all emissions in all sectors. Does not constrain international trade in permits. Does not shield emission-intensive trade-exposed sectors (as economies take on emissions reductions simultaneously). Returns all revenue to households as a lump-sum income transfer each year.
Other Australian mitigation policies	Includes expanded Renewable Energy Target (RET) of 45,000 GWh per year by 2020. Victorian RET and NSW and ACT Greenhouse Gas Reduction Scheme cease. Queensland 15 per cent Gas scheme remains operational.	The expanded RET and state and territory schemes cease when emissions trading starts.
International action	Multi-stage approach. Annex B economies have targets and participate in international emissions trading from 2010. Developing economies gradually join the scheme (China in 2015, India in 2020, and complete coverage from 2025). National emission targets are based on a gradual divergence from reference scenario emission levels. Scheme participants are assumed to have similar emissions trading scheme policy settings to Australia.	Contraction and convergence approach. All economies adopt targets and participate in international emissions trading from 2013. National emission allocations start at current levels and converge to equal per capita rights by 2050.

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CHAPTER 5: MITIGATION SCENARIOS — INTERNATIONAL RESULTS

Key points

Stabilisation is only possible with action by all major emitters.

Stabilisation at 450-550 ppm CO_2-e requires a fundamental shift in global emission trends. Once that occurs, the differences – in terms of aggregate economic impacts – are relatively small.

Global mitigation effort is an important factor in the economic impact of mitigation policies on Australia.

Australia and global economies could maintain strong long-term economic growth while cutting emissions to achieve stabilisation. Even ambitious goals have little impact on global and national economic growth.

Strong global coordinated action accelerates cost reductions in low-emission technologies, prevents lock-in of more emission-intensive industry and infrastructure, and minimises distortions in trade-exposed sectors.

There are advantages to early action if emission pricing expands gradually across the world. Economies that defer action face higher long-term costs, as more emission-intensive infrastructure is locked in place and global investment is redirected to early movers.

In the face of uncertainty, strong coordinated global action has an insurance benefit: it keeps open the option of pursuing lower stabilisation levels in the future. Weaker global action may prove more costly in the longer term.

Australia's mitigation costs are higher than most developed economies due to its large share of emission-intensive industries. Differentiating the national emission reduction targets of developed economies could help reduce differences in mitigation costs.

International trade can reduce the cost of achieving emission reduction targets, because it allows mitigation to occur wherever it is cheapest.

It is not possible to accurately predict which mitigation opportunities will prove most cost effective. Broadly-based market-oriented policies allow the market to respond as new information becomes available.

Progress in developing low-emission technologies is important for reducing global and Australian mitigation costs. Australia's costs will be particularly affected by progress in carbon capture and storage, which will affect future demand for Australia's coal resources.

Whatever action Australia takes, the international context is important in determining the impact on Australia's productivity, industries, regions and households. Both the stabilisation target and the international mitigation framework will influence Australia's emissions pathway in a low-emission world.

The global analysis shows that the link between global economic growth and emissions growth can be broken by pricing emissions. In all scenarios modelled, economic growth is sustained.

To stabilise at 550 ppm CO_2-e by 2100, global emissions must peak within the next 20 years, fall to below current levels by 2050, and fall further after 2050 (IPCC, 2007).

Although the global mix of mitigation activity is far from certain, united global action to achieve stabilisation slows average annual global growth by around 0.1 per cent per year from 2010 to 2050, from 3.5 per cent per year in the reference scenario to 3.3-3.4 per cent per year. As a result, per capita gross world product (GWP) is 42-46 per cent above current levels by 2020, compared with 47 per cent in the reference scenario and is 215-219 per cent above by 2050, compared with 228 per cent in the reference scenario. This suggests global economic mitigation costs are equivalent to delaying global growth by about one year.

Multi-stage action influences the regional distribution of costs, bringing benefits to economies that act early and higher costs to those that delay. Economies that defer emission pricing become more emission intensive, so that when pricing is eventually introduced, the costs of adjusting to a low-emission economy are greater

If stabilisation levels are lower, global emissions must be cut faster; stabilisation at 450 ppm roughly doubles initial costs compared with 550 ppm. The cost gap narrows over time to around one-half higher by 2050. This is equivalent to delaying global growth by no more than two years.

The structure of the global approach to mitigation and determination of targets and trajectories is the subject of current international negotiations on the post-2012 global framework. National emission targets after 2012 should ensure comparability of effort among developed economies, taking account of differences in national circumstances (UNFCCC, 2007, p 3).

In assessing comparability of effort, relative mitigation costs across economies are important. Australia is likely to face higher mitigation costs (in terms of reduced GNP) than many other developed economies. This is because emission-intensive industries comprise a larger share of its economy and exports. Similarly, Canada, Russia and the transition economies are likely to face higher costs. Differentiation of national emission reduction targets — particularly during the initial transitional period — could help reduce cost disparities.

The post-2012 policy framework will affect Australia's costs. Australia's marginal cost of mitigation is relatively high. Expanding access to international mitigation through market-based mechanisms, such as international emission trading and the clean development mechanism, will help reduce the cost of achieving any given national emission trajectory. As a small open economy, Australia faces relatively higher costs from any contraction of global activity. It therefore has a strong economic interest in encouraging the creation of an efficient global scheme that uses all opportunities for cost-effective mitigation by covering all economies, sectors, gases, and emission sources and sinks.

The economic costs to Australia will be significantly influenced by the likely developments in the global economy. Lower stabilisation levels require faster emission reductions, leading to higher costs. With Australia's higher marginal cost of mitigation, participation in the global emissions trading market is important to access all possible ways to reduce mitigation costs. Other factors significant to Australia include the global emission price, timing of global action and the rate of progress in low-emission technologies. More generally, global mitigation effort will create both costs and benefits.

The impact of a global emission price will differ significantly across economies. This is as a result of differing consumer preferences, industrial structures, resource endowments and application of technologies. Chapter 5 explores the impact of the policy scenarios on the global economy and draws on both GTEM and G-Cubed.

5.1 GLOBAL EMISSION ALLOCATIONS

The international climate change policy framework determines the overall environmental outcome, and timing and contribution of different economies to the global mitigation effort. While some principles guide international discussions, national interests loom large, and the outcomes are impossible to predict. This report uses simplified assumptions on the relative contributions of Australia and other economies.

Mitigation costs vary, depending on the nature, horizon and stringency of the stabilisation goal, and the trajectory to it. Lower stabilisation levels require faster cuts in global emissions, and higher emission prices, which tend to increase mitigation costs for all regions.

The global emission pathway determines the overall global cap on emissions (Chart 5.1). This cap is then allocated across nations using the different approaches outlined in Chapter 4. Nations can trade emissions up to their cap to achieve their targets at least cost. Under all policy scenarios, global emission pathways are dramatically lower than the reference scenario; they are 13-23 per cent below the reference scenario in 2020 and 68-83 per cent below by 2050 (Table 5.1).[1] In 2020, global allocations are lower in the CPRS -5 scenario than in the Garnaut -10 scenario, despite many developing regions remaining outside the scheme, reflecting the earlier start for participating economies.

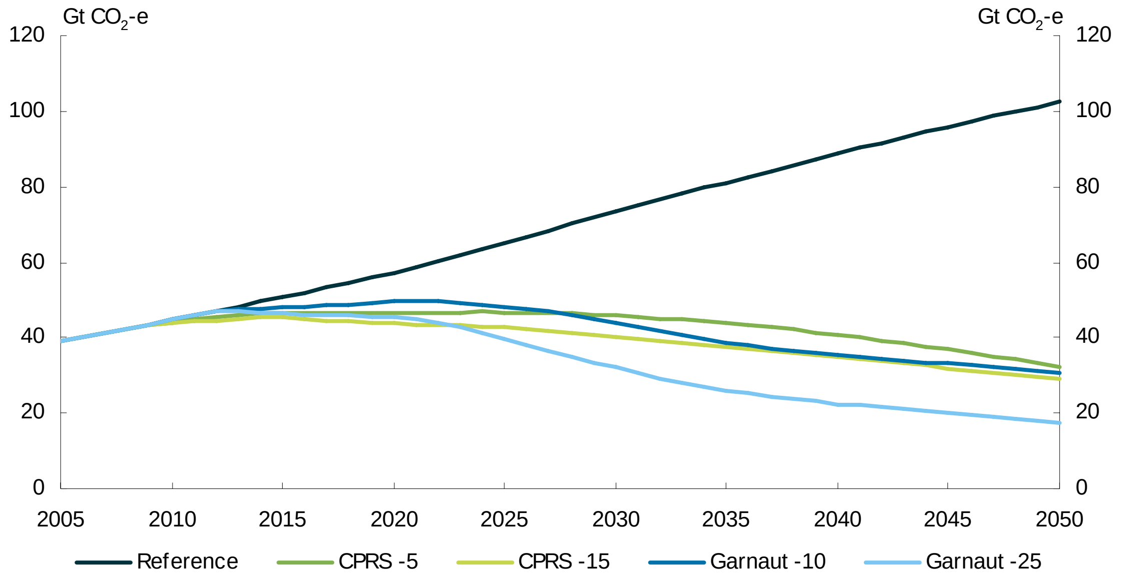
Table 5.1: Global emission allocations

	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
Greenhouse gas stabilisation goal ppm CO_2-e	550	510	550	450
Global, per cent change from 2001				
2020	32	24	40	29
2050	-9	-18	-13	-50
Per capita, per cent change from 2001				
2020	7	0	14	4
2050	-38	-44	-41	-66
Global, per cent change from reference scenario				
2020	-19	-23	-13	-20
2050	-68	-72	-70	-83
Year in which global emission allocations peak	2024	2014	2021	2012

Note: Allocations in G-Cubed are calculated using the same policy rules, but some differences arise owing to differences in the database used in the model. GTEM's emissions database is from 2001.
Source: Treasury estimates from GTEM.

1 In the CPRS scenarios, the rest of world region does not take on emission targets and thus does not have a national allocation until after 2020. In 2020, global emission allocations are reported as the sum of the emission allocations to participants and the reference scenario emissions for the rest of world.

Chart 5.1: Global emission allocations



Note: In the CPRS scenarios, global emissions are not restricted until 2025. Before 2025, global emission allocations are the sum of the allocations to participants and the reference scenario emissions of non-participants.
Source: Treasury estimates from GTEM.

The CPRS scenarios assume a multi-stage approach, under which national emission targets gradually diverge from reference scenario emission levels. The Garnaut scenarios assume a more stylised global framework, with national emission allocations based on a per capita approach (Garnaut, 2008).

Initially, allocations across all participating regions in the CPRS -5 scenario are lower than in the Garnaut -10 scenario. However, towards 2050, allocations in the CPRS -5 scenario are higher than in the Garnaut -10 scenario.

Regions with high initial per capita emissions receive larger allocations under the multi-staged approach (CPRS -5 scenario) than the contraction and convergence approach (Garnaut -10 scenario). Both scenarios achieve the same environmental objective (Table 5.2). The multi-stage approach places more weight on pre-existing emission levels and emission growth trends than the contraction and convergence framework. For example, Canada's allocations in 2050 are 9 per cent below 2001 levels in the CPRS -5 scenario, compared with 33 per cent below in the Garnaut -10 scenario, yet both scenarios stabilise at 550 ppm by 2050. In contrast, regions with low per capita emissions, such as the European Union, Japan, India, Indonesia and the rest of world, receive smaller allocations under the multi-stage approach in the long term.

Table 5.2: National emission allocations

Region	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent change from 2001 levels							
United States	-19	-28	-12	-28	-69	-69	-81	-89
EU-25	-23	-32	-14	-30	-75	-75	-69	-82
China	172	155	210	195	88	71	-4	-45
Russia + CIS(a)	14	2	13	-8	-58	-58	-73	-85
Japan	-29	-37	-27	-41	-81	-81	-75	-86
India	99	97	98	97	152	119	230	90
Canada	-9	-19	-33	-45	-63	-63	-80	-89
Australia	-5	-15	-10	-25	-60	-60	-80	-90
Indonesia	0	-2	0	-1	-14	-26	6	-39
South Africa	56	46	79	45	2	-7	-48	-70
Other South and East Asia	-15	-16	10	9	-34	-43	-11	-49
OPEC	50	40	67	67	11	1	-19	-54
Rest of w orld	47	47	40	39	48	26	94	11
World	32	24	40	29	-9	-18	-13	-50

Note: (a) Commonwealth of Independent States
Source: Treasury estimates from GTEM.

5.1.1 Global emission price

To achieve the desired greenhouse gas concentration stabilisation level, the policy scenarios use different starting emission prices, which then grow at around 4 per cent per year (Chart 5.2). The lower the stabilisation level, the higher the starting emission price. The required starting price to achieve a 550 ppm stabilisation level is around US$23 in 2010 and US$27 (Table 5.3) if the starting year is 2013, in nominal terms. A slightly higher starting price of US$32 in 2010 achieves 510 ppm stabilisation and US$47 in 2013 achieves 450 ppm stabilisation, in nominal terms. Deeper emission reductions require regions to take more mitigation action.

Banking of permits ensures that the global price path satisfies the inter-temporal arbitrage condition (Hotelling price path).[2]

The emission price in the CPRS -5 scenario tracks closely the emission price trajectory of the Garnaut -10 scenario. Despite starting three years earlier, the CPRS -5 scenario assumes that all economies and emissions are not immediately affected by the emission price. These two factors broadly offset each other to result in a similar emission price path.

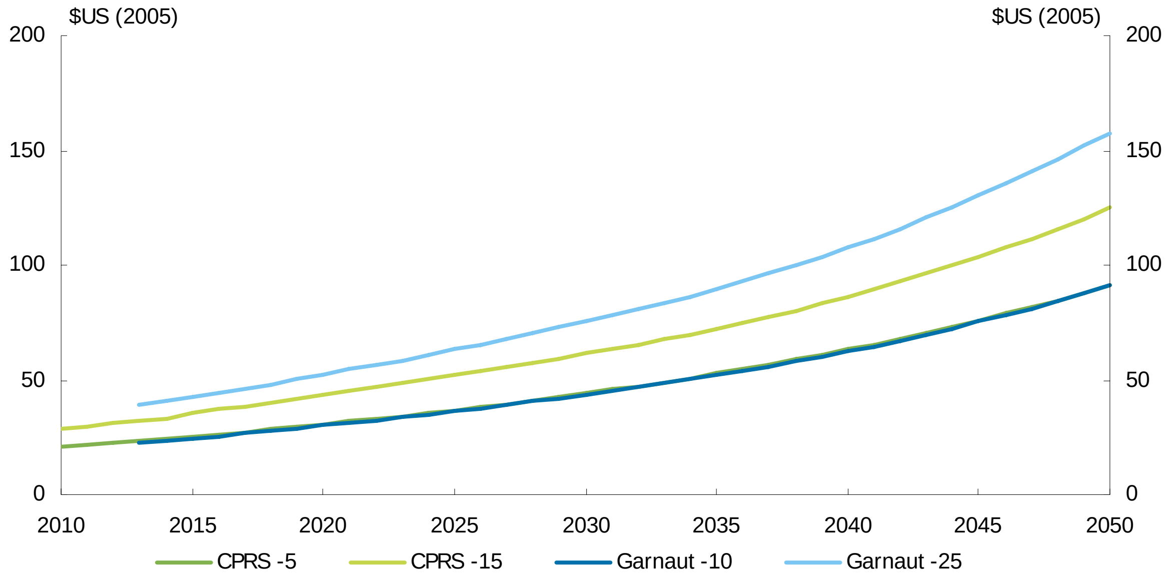
Table 5.3: Global emission prices

	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
First year, US$ nominal	23	32	27	47
First year, US$ 2005 prices	21	29	23	39
2020, US$ 2005 prices	31	43	30	52
2050, US$ prices	91	125	91	158

Note: CPRS scenarios start in 2010. Garnaut scenarios start in 2013.
Source: Treasury estimates from GTEM.

2 Actual emissions in the CPRS scenarios keep the global permit price on the Hotelling price path. This will occur where the global emissions trading scheme allows full banking and borrowing, or where the allocation scheme is such that borrowing is never required.

Chart 5.2: Global emission prices



Source: Treasury estimates from GTEM.

The projected emission prices are lower than prices currently observed in some emission markets, particularly the European Union Emission Trading Scheme. Higher prices in the EU market reflect its more limited coverage and restricted access to international trade. The scenarios in this report assume broader coverage of regions and sectors, allowing far more low-cost mitigation opportunities to be captured.

If sources of emissions from a global trading scheme are excluded, emission prices and costs of stabilisation objectives will rise. For example, land-use change and forestry account for a significant share of the global mitigation effort, around 10 per cent in 2050 in both the Garnaut scenarios. If this sector is not included in the global trading scheme, the same overall reduction target would need to be achieved from a smaller set of mitigation options. That would raise emission prices by around 25 per cent and 30 per cent in 2050 for the global economy in the Garnaut scenarios. This would increase the mitigation costs, in terms of global GDP in 2050, by around 20 per cent and 25 per cent.

5.1.2 Global emissions

The ability to bank permits in the early years of the scheme for use later leads to actual global emissions and emission allocations being different.

Initially, actual global emissions are lower than the allocations in all four policy scenarios, resulting in 5-20 per cent of permits being banked in the first 10 years. Banking occurs initially to maintain the Hotelling price path, and is accentuated by the step-down in global emissions after emission pricing is introduced. The step-down reflects the equilibrium nature of the GTEM model: the economy moves immediately to its new equilibrium.

Box 5.1: The emission price in G-Cubed

The G-Cubed model has a different theoretical structure and data set from the other two CGE models. It therefore uses a different emission price path to meet environmental and permit banking constraints. The G-Cubed global emission price path is considerably lower than in GTEM and MMRF (Table 5.4). This difference highlights the uncertainty around emission prices.

Table 5.4: Emission prices (US$/t$CO_2$-e, nominal) first year of scheme

	GTEM	G-Cubed
	nominal US$/t$CO_2$-e	nominal US$/t$CO_2$-e
CPRS -5	23	9.3
CPRS -15	32	11.3
Garnaut -10	27	8.9
Garnaut -25	47	13.1

Source: Treasury estimates from GTEM and G-Cubed.

While G-Cubed suggests that a lower emission price might achieve the same stabilisation level, the economic costs are comparable as G-Cubed suggests higher per dollar mitigation costs. This highlights that emission prices, considered in isolation, do not provide a good measure of the macroeconomic costs of mitigation policy (Barker et al, 2006).

Emission prices are lower in G-Cubed for several reasons. G-Cubed is a forward-looking model, which brings forward some technological substitution, lowering the transition costs and hence reducing the required emission price (Migone, 2008). G-Cubed is more flexible, requiring lower emission prices to transform the economy. Finally, G-Cubed lacks technological detail and allows a (theoretically) infinite range of options for the electricity and transport sectors, ensuring a greater response to emission prices.

The G-Cubed emission price path deviates from a Hotelling path for the CPRS scenarios as constraints on international permit trade are binding. As economies exhaust the permits available from trading and banking in 2010 to 2019, their domestic emission prices move higher than the global traded price.

The restriction on international permit trade raises the overall economic cost of the CPRS scenarios for some economies, such as Australia, where the limits bind. If the limits on international permit trade are lifted, the fall in GWP in 2019 is reduced from 2.9 per cent to 2.5 per cent. The improvement is found in economies which have the largest price increase, Europe and the former Soviet Union, but even the relatively small change for Australia means that Australian GNP is around 0.25 per cent higher in 2019 with unconstrained international trading. Most of these differences do not persist beyond 2020, as the forward-looking agents invest with the expectation that trade becomes unconstrained.

By 2050, actual global emissions in the CPRS -5, Garnaut scenarios are higher than the allocations, resulting in a draw-down on the global bank of permits. Net cumulative banked permits, however, remain in 2050 for most regions. In the CPRS -15 scenario, however, global emissions remain lower than the allocations to 2050, resulting in the accumulation of banked permits to 2050.

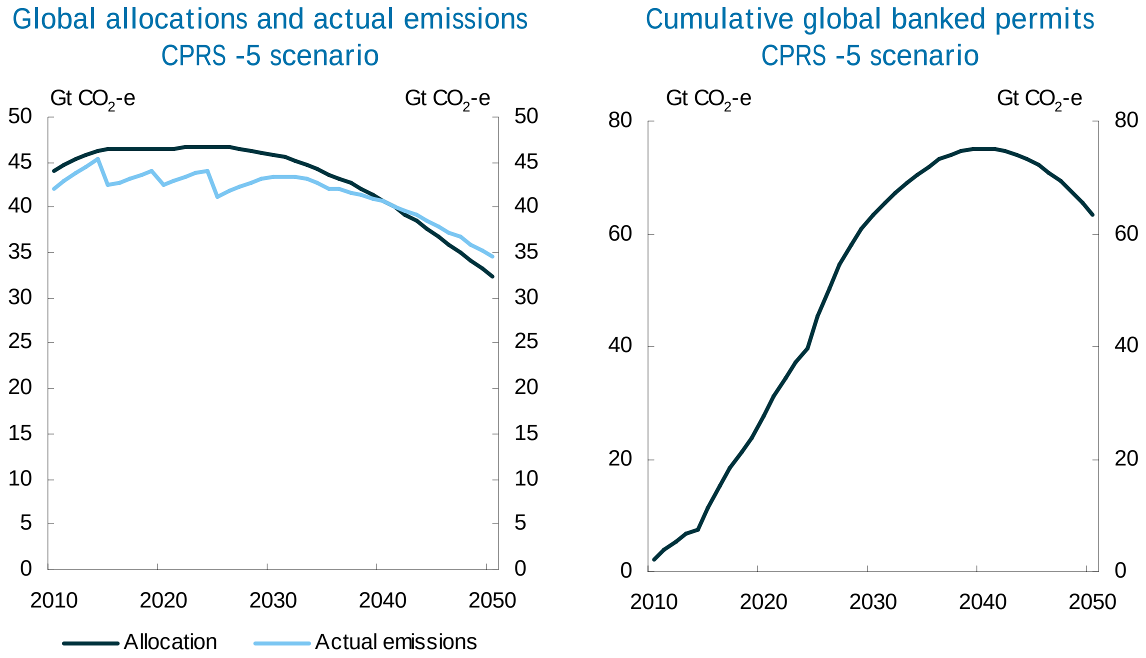
Table 5.5: Global allocations, emissions and banked permits

CPRS -5 scenario

	Allocation	Emissions	Banked permits	Net permits in the bank
	Gt CO_2-e	Gt CO_2-e	Gt CO_2-e	Gt CO_2-e
2020				
CPRS -5	46.5	42.6	3.9	27.5
CPRS -15	43.8	39.5	4.3	30.1
Garnaut -10	49.5	40.5	9.0	73.4
Garnaut -25	45.6	33.9	11.7	100.8
2050				
CPRS -5	32.3	34.7	-2.4	63.3
CPRS -15	29.1	27.4	1.7	79.8
Garnaut -10	30.7	35.9	-5.3	5.1
Garnaut -25	17.6	21.6	-4.0	22.6

Note: The difference between cumulative emissions and allocations is cumulative permits banked.
Source: Treasury estimates from GTEM.

Chart 5.3: Emissions, allocations and cumulative banked permits



Source: Treasury estimates from GTEM.

Emissions by gas

Reducing emissions from fossil fuel combustion account for most of the mitigation effort to 2050 (Chart 5.4).

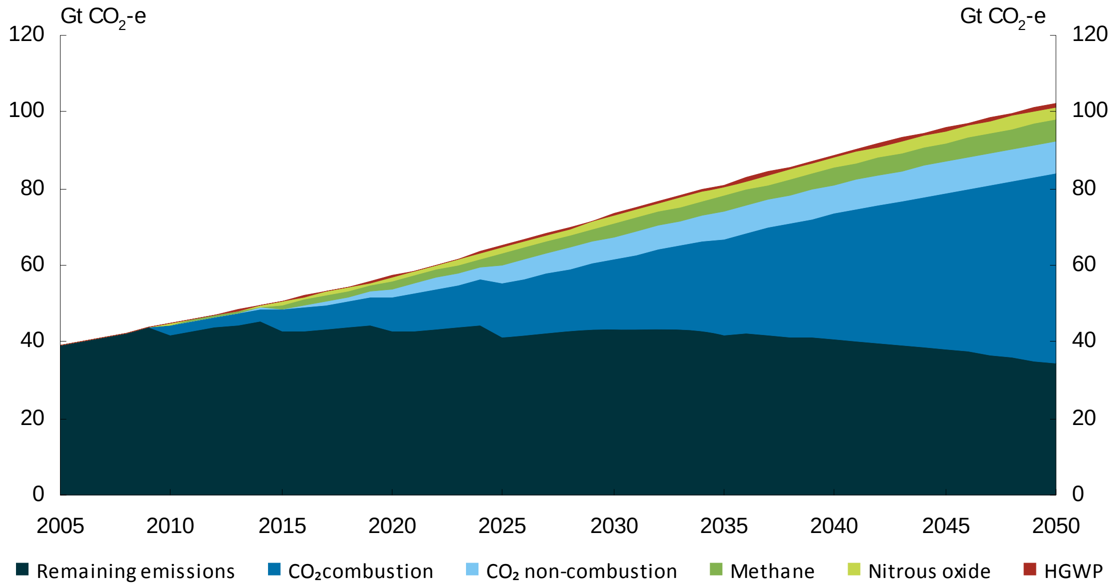
Forestry sinks across most regions provide substantial emission sequestration, wholly offsetting non-combustion CO_2 emissions from all sources by 2020. Non-combustion CO_2 emissions are negative for most of the projection period as reafforestation continues.

Current estimates of mitigation potential suggest that reducing methane and nitrous oxide emissions require higher emission prices than CO_2 emissions; consequently, these sources contribute less to global mitigation. As a share of total global emissions, methane increases from 13 per cent in 2005 to 15 per cent in 2050 and 37 per cent by 2100; nitrous oxide increases remains around 6 per cent. Other recent multi-gas studies show methane and nitrous oxide comprising a rising share of total emissions, reflecting their relatively higher mitigation costs (CCSP, 2007).

Emissions of the other gases (SF_6, HFCs and PFCs) are largely eliminated through changes to industrial processes, and comprise less than 1 per cent of total emissions in 2100.

Chart 5.4: Decomposition of global mitigation by gas

CPRS -5 scenario



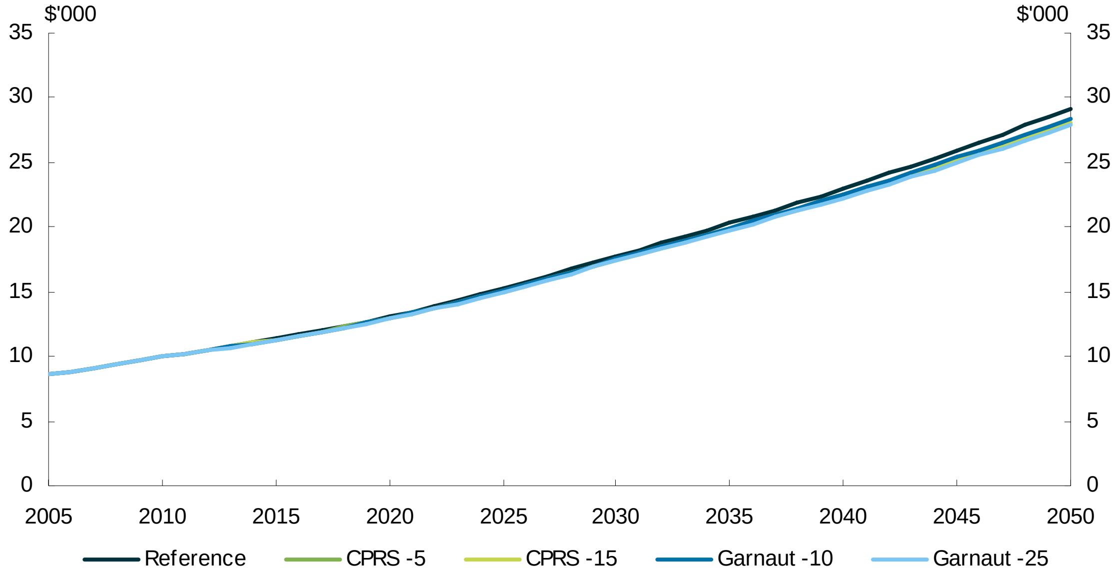
Note: HGWP: High-global-warming-potential gases, including SF_6, HFcs and PFCs.
Source: Treasury estimates from GTEM.

5.2 GLOBAL MITIGATION COSTS

Under all mitigation scenarios, the global economy continues to grow steadily; growth slows only slightly relative to the reference scenario. Introduction of a global price on emissions results in a substitution towards cleaner but more expensive technologies, and in an adjustment in industry structure that is generally less efficient than in the reference scenario (given that climate change impacts are not included). This means that global income and production decline compared with the reference scenario. The decline in income leads to lower global investment and lower global capital stocks, which further reduces global income and production.

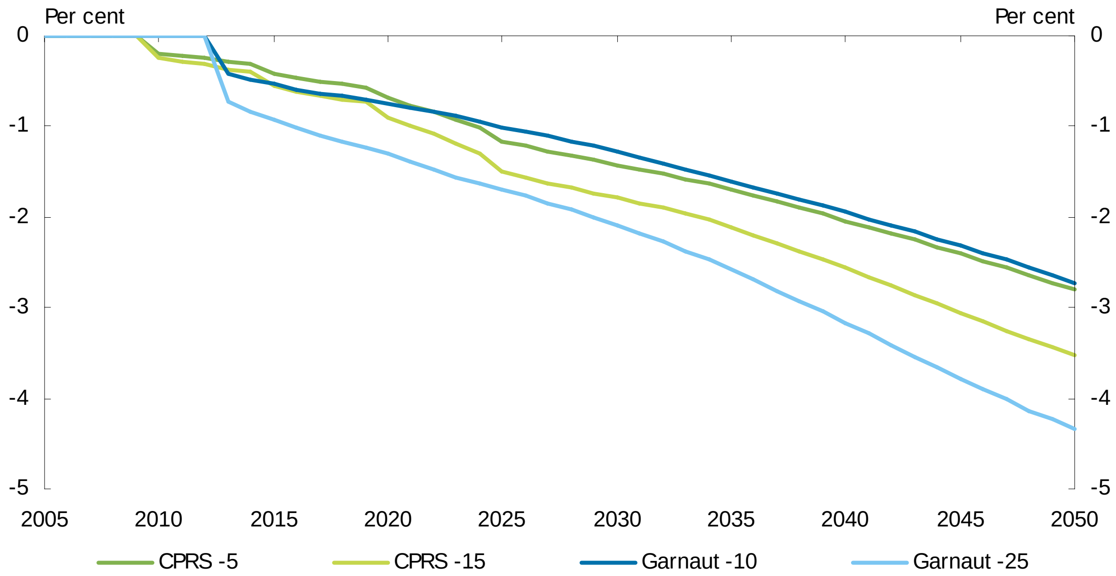
Average annual global growth slows by around 0.1 per cent per year from 2010 to 2050, from 3.5 per cent per year in the reference scenario to 3.3-3.4 per cent per year. As a result, per capita GWP is delayed by about one year (Chart 5.5).

Chart 5.5: GTEM: Gross world product per capita



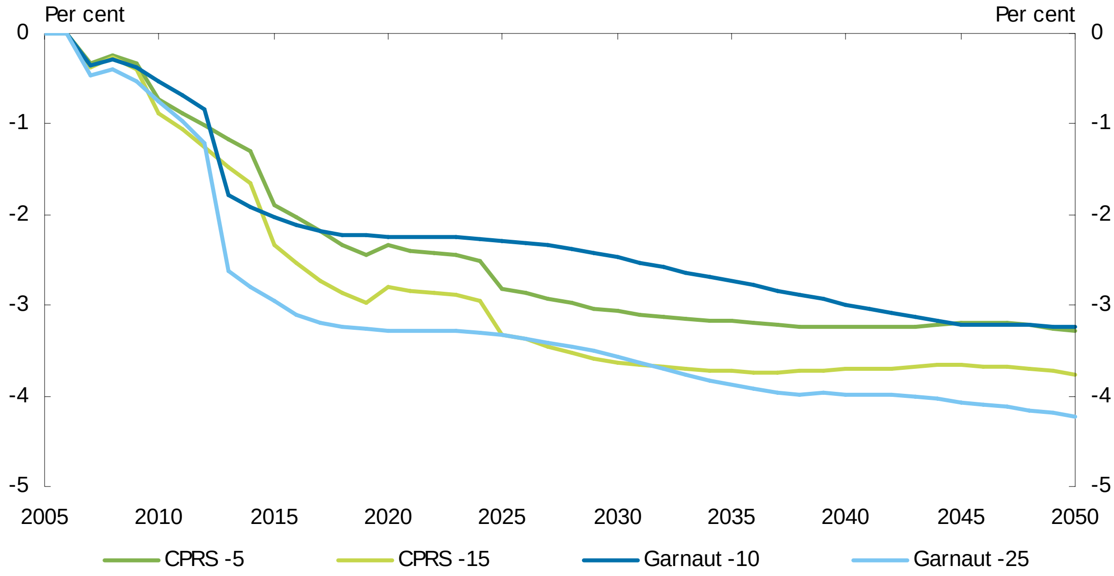
Note: Values are in US$ trillion, 2005 purchasing power parity weights.
Source: Treasury estimates from GTEM.

Chart 5.6: GTEM: Gross world product
Change from reference scenario



Source: Treasury estimates from GTEM.

Chart 5.7: G-Cubed: Gross world product
Change from reference scenario



Source: Treasury estimates from G-Cubed.

Table 5.6: Gross world product, change from reference scenario

	2020		2030		2040		2050	
	GTEM	G-Cubed	GTEM	G-Cubed	GTEM	G-Cubed	GTEM	G-Cubed
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
CPRS -5	-0.7	-2.3	-1.4	-3.1	-2.0	-3.2	-2.8	-3.3
CPRS -15	-0.9	-2.8	-1.8	-3.6	-2.6	-3.7	-3.5	-3.8
Garnaut -10	-0.7	-2.2	-1.3	-2.5	-1.9	-3.0	-2.7	-3.2
Garnaut -25	-1.3	-3.3	-2.1	-3.6	-3.2	-4.0	-4.3	-4.2

Source: Treasury estimates from GTEM and G-Cubed.

Average annual growth in global output declines slightly across all the policy scenarios. For example, average annual growth of GWP over the 2010-2050 period slows from 3.45 per cent per year from 2010 to 2050 in the reference scenario to 3.34 per cent per year for the Garnaut -25 scenario, generally the highest cost scenario and to 3.38 per cent per year for the Garnaut -10 scenario, generally the lowest cost scenario. This represents 15-25 months of growth. As a result of the mitigation policy, the global output level expected for January 2050 in the reference scenario is deferred until April 2051 to February 2052 in the policy scenarios.

Table 5.7: Gross world product, average annual growth rates

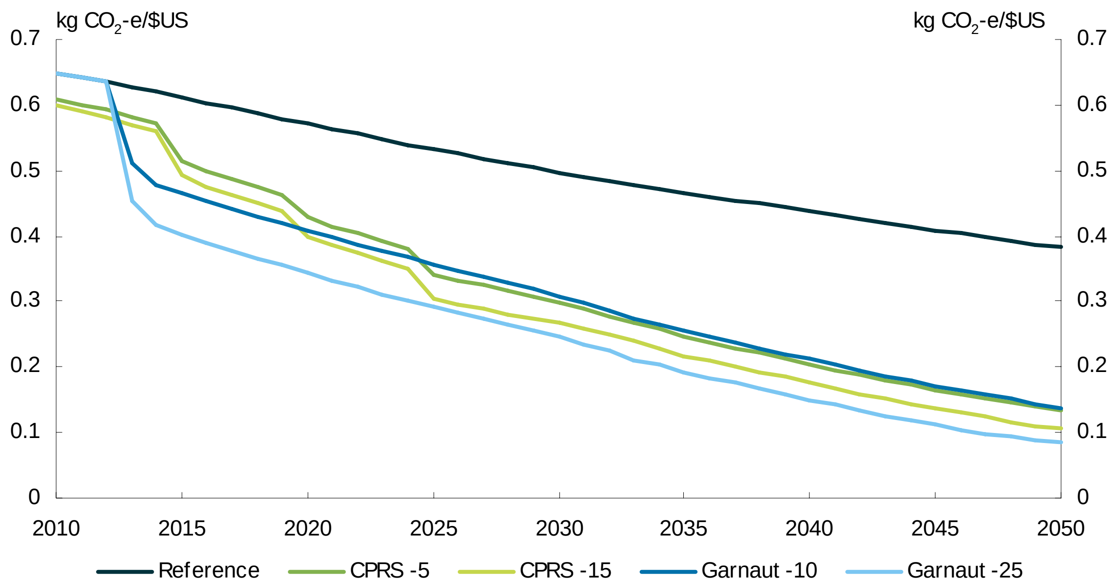
	2010 to 2050		2010 to 2020		2020 to 2030		2030 to 2040		2040 to 2050	
	GTEM	G-Cubed	GTEM	G-Cubed	GTEM	G-Cubed	GTEM	G-Cubed	GTEM	G-Cubed
	Per cent		Per cent		Per cent		Per cent		Per cent	
Reference scenario	3.5		3.8		4.0		3.2		2.8	
CPRS -5	3.4	3.4	3.8	3.6	3.9	3.9	3.2	3.2	2.7	2.8
CPRS -15	3.4	3.4	3.7	3.6	3.9	3.9	3.2	3.2	2.7	2.8
Garnaut -10	3.4	3.4	3.7	3.6	3.9	3.9	3.2	3.2	2.7	2.8
Garnaut -25	3.3	3.4	3.7	3.5	3.9	3.9	3.1	3.2	2.7	2.8

Source: Treasury estimates from GTEM and G-Cubed.

While the two global models indicate similar overall costs of mitigation policy, the time profiles differ (Charts 5.6 and 5.7). In GTEM, the costs increase steadily over time; in G-Cubed, the costs increase rapidly in early years, before stabilising. In contrast to GTEM, G-Cubed has elements of forward-looking agents, and includes capital adjustment costs. As a result, consumers and businesses plan for the higher emission prices, and their reactions raise the initial adjustment costs earlier (Box 5.3). In the CPRS scenarios, GWP costs fall slightly in 2020, when international permit trade restrictions are removed, followed by a small increase in GWP costs in 2025, when the rest of the world joins the emission trading scheme.

The emission intensity of GWP falls sharply in response to emission pricing, allowing strong growth to continue as emissions fall (Chart 5.8). Some 94-96 per cent of global mitigation across all scenarios comes through breaking the link between economic growth and emissions. The emission intensity of GWP declines from 0.7 kg of CO_2-e per US$ in 2005 to less than 0.13 kg of CO_2-e per US$ in 2050 across the scenarios. This compares with the reference scenario emission intensity of 0.4 kg of CO_2-e per US$ in 2050. The decline in emission intensity increases as the emission price grows.

Chart 5.8: Emission intensity of gross world product



Note: Weighted using US dollar 2005 purchasing power parity.
Source: Treasury estimates from GTEM.

Box 5.2: How do mitigation costs arise?

Gross world product and regional GDP are affected by changes in allocative efficiency, factor supply and productivity. Regional GNP impacts are affected by changes in GDP and international income transfers.

Introduction of emission pricing reallocates resources away from the 'optimal' allocation in the reference scenario, including triggering substitution towards cleaner but more expensive technologies. The associated loss in allocative efficiency reduces production and income. Efficiency losses are greatest in regions where emission-intensive production comprises a larger share of the economy.

Pre-existing distortionary taxes and subsidies in the economy (those that do not correct market failures) influence the size of the efficiency losses. Imposing emission pricing on top of a pre-existing tax on fossil fuel will increase the efficiency loss, as it magnifies the existing distortion. Imposing emission pricing on top of a fossil fuel subsidy may result in only a small efficiency loss and potentially even an efficiency gain, as the emission price offsets the existing distortion created by the subsidy. Similarly, if the emission price evens up the taxes applied across all goods in the economy, the emission price will offset distortions created by pre-existing taxes, creating an efficiency gain and increasing GDP. In most regions, however, this does not occur and emission prices cause a global allocative efficiency loss.

The global allocative efficiency loss has a second-round impact on regional incomes through global investment and capital stock. At an aggregate level, income losses reduce savings (if regional savings rates remain a fixed proportion of household income), resulting in fewer overall global funds for investment and a decline in the global capital stock.

The magnitude of this effect varies across regions as the relative rates of return change. In fossil fuel producing regions, reduced demand for fossil fuels drives a reallocation of capital from mining (which is capital intensive) to less productive sectors. This reduces the return to capital in these regions, making these regions less attractive to global investment, and generates a relatively greater decline in the capital stock than the global average decline. At the same time, other regions' rate of return improves, and becomes relatively more attractive for investment, attracting a larger share of global investment relative to the global average. If the increases in the relative rates of return for such regions are large, they attract more investment and capital stock relative to the reference scenario, despite the overall decline in global investment.

In addition, as natural resource demand declines, demand for fossil fuels falls. Output contracts, particularly in fossil fuel producing regions. In GTEM and G-Cubed, labour and land supply are fixed outside the models and do not change in response to the policy. Changes to the size of sectors within an economy will change aggregate productivity, as historically sectors have experienced different levels of productivity.

Regional GNP impacts are affected by changes in income transfers between regions. Income transfers are affected by changes in terms of trade, international emission permit sales and foreign interest payments. Emission pricing tends to reduce the terms of trade in fossil fuel exporting regions, as demand for fossil fuel falls. The sale of emission permits affects GNP positively by generating income.

Box 5.3: Forward-looking behaviour and early action

Backward-looking models such as GTEM and MMRF implicitly assume businesses and consumers in the model only learn about the emission price at the start of each year. In contrast, some businesses and consumers in G-Cubed know the future of the emission price with perfect foresight.

In G-Cubed, consumers and businesses first learn about the emission trading scheme in 2007. They can then respond immediately, even though the emission price is not introduced until 2010 or 2013.

The forward-looking consumers and businesses respond early, and because they can see the emission price path, the adjustment to a new economic structure happens more rapidly than in a backward-looking model.

Some businesses look at the likely future value of the capital they want to install. With the introduction of emission pricing, the value of capital falls, as future economic growth slows and more constraints are applied. As a result, businesses start to lower their level of capital investment immediately.

Forward-looking consumers look at their expected level of future wealth, taking into account future wages, changes in stock market value, property values and overseas assets. In most regions, wealth falls initially, so forward-looking consumers reduce their consumption immediately.

However, not all consumers are forward looking. G-Cubed assumes most (70 per cent) consumers are myopic, looking only at their current income. Current income in 2007 and other years before the introduction of emission pricing is higher than in the reference scenario, owing to the lower investment levels. Lower investment means firms make greater current profits, raising household income through dividends.

5.2.1 The cost of delaying global action

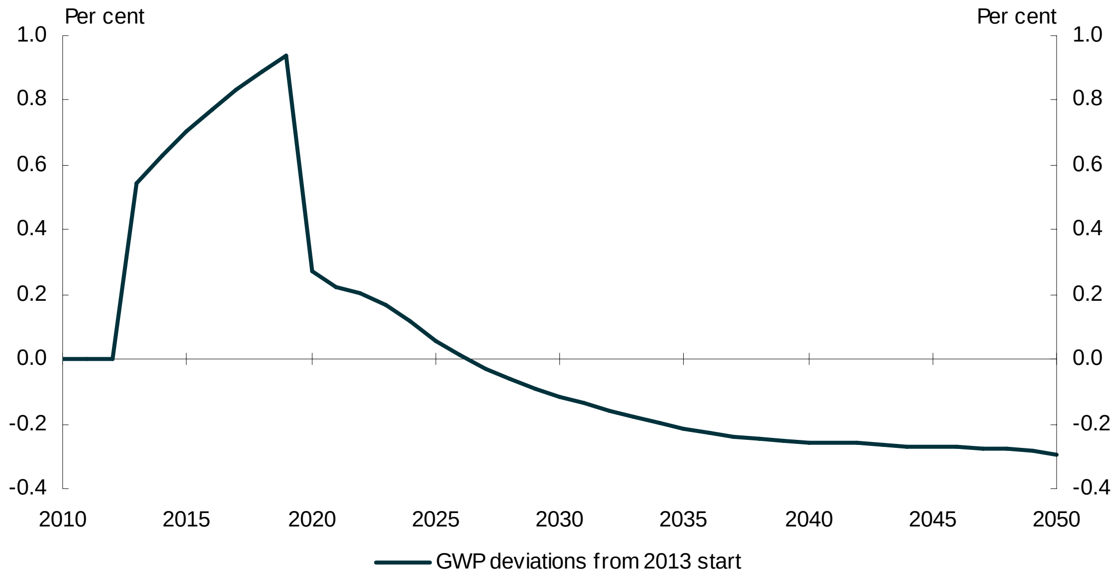
Delaying mitigation action in the global economy will increase climate change risks, lock in more emission-intensive industry and infrastructure, and defer cost reductions in low-emission technologies. This will increase the cost of achieving environmental goals.

A sensitivity analysis examined the effect of delaying global mitigation action by seven years, but still stabilising at 550 ppm CO_2-e by 2100 (Chart 5.9). The initial benefits of delay arise when emissions are not priced. However, once global mitigation action begins, GWP levels are lower than if the mitigation had begun earlier. The higher costs come from the need for greater emission reductions in less time to achieve the same environmental outcome, and the high cost of low-emission technology options that have not benefited from reductions in capital costs. As a result, global costs (as a share of GWP) are about 10 per cent higher in 2050, and remain higher to 2100.

If the net cost or benefit is calculated from 2013 to 2050, the delay represents a net cost to the world at a discount rate of 3 per cent or below. The time distribution of these costs and benefits raises the issue of how much future income is discounted and how far into the future benefits or costs are examined. The higher the discount rate used to discount future income, the less weight given to future income relative to current income.

Chart 5.9: Cost of global mitigation policy delay

Change from Garnaut -10 scenario



Note: GWP level change from the Garnaut -10 scenario and a sensitivity where global action is delayed from 2013 to 2020, but achieves the same 550 ppm CO_2-e concentration level by 2100.
Source: Treasury estimates from GTEM.

A gradually evolving global mitigation framework is likely to make costs higher than a coordinated introduction of emission pricing across all regions.

Multi-stage action influences the regional distribution of costs, bringing benefits to economies that act early and higher costs to those that delay. Economies that defer emission pricing become more emission intensive, so that when pricing is eventually introduced, the costs of adjusting to a low-emission economy are greater (Box 5.4).

Unified global action is more attractive because of its environmental and economic benefits. Coordinated global action minimises competitiveness distortions. Extended delay could make stabilisation at low levels impossible. For example, if Annex B nations reduce their emissions to zero by 2050 and non-Annex B nations follow reference scenario levels, then greenhouse gas concentrations would be over 650 ppm by 2050, and rising.

Box 5.4: Impact of a multi-stage global framework

In the CPRS -5 scenario, economies' enter the global trading scheme in stages, developed nations acting first, in 2010, and developing economies taking on emission reductions and emission prices 5-15 years later. This delayed entry raises long-term mitigation costs for developing economies.

Initially, remaining outside a global trading scheme developing economies continue to grow in on an emission-intensive pathway, with resources shifting to emission-intensive sectors.

Subsequently, when these developing economies join the global emissions trading scheme, their mitigation costs are higher than if they had joined earlier. A larger part of the economy now has to adjust to the emission price, resulting in larger distortions or allocative efficiency losses in the economy and larger declines in returns to capital.

In contrast, those that join the global trading scheme at or near the beginning receive a relative benefit once all regions join. As a result of the larger declines in returns to capital experienced in delayed-entry economies, early-entry economies receive relatively more investment, leading to higher levels of capital stock.

Comparisons of the GDP impacts in CPRS -5 and Garnaut -10 scenarios show this (Table 5.8). Regions that start in 2010 and 2015 have lower GDP costs under the CPRS -5 scenario, compared with the Garnaut -10 scenario. Regions that enter the scheme in 2020 and 2025 have higher costs in the CPRS -5 scenario, compared with the Garnaut -10 scenario. The emission price in 2050 in both scenarios is around US$91 per tonne of CO_2-e, in 2005 prices.

Table 5.8: Regional GDP costs in 2050

	GDP cost(b)		Is the GDP
Regional group(a)	CPRS -5	Garnaut -10	decline greater
	Per cent	Per cent	in the CPRS - 5?
Enter in 2010	-1.4	-1.6	no
Enter in 2015	-3.9	-4.2	no
Enter in 2020	-3.9	-3.4	yes
Enter in 2025	-2.4	-2.0	yes

(a) Regions aggregated by the time of entry in the CPRS -5 scenario.
(b) GDP costs expressed as the percentage change from the reference scenario.
Source: Treasury estimates from GTEM.

5.2.2 Cost of uncertainty

Stabilisation targets may rise or fall in the future. Stronger mitigation action initially could preserve the option of pursuing lower stabilisation levels and be a cost-effective strategy in the face of uncertainty (Box 5.5).

Stronger mitigation action accelerates cost reductions in low-emission technologies, which help reduce future costs, even where, in the future, stabilisation goals are relaxed. In contrast, weaker mitigation action results in higher initial emissions, which means that faster emission reductions then are required if stabilisation goals are strengthened. Economic benefits may come from setting precautionary goals at the global level, as weaker global action may prove costly in the longer term. This result accords with previous studies of the 'option value' of stronger mitigation action (Yohe et al., 2004).

Box 5.5: Implications of revising stabilisation goals

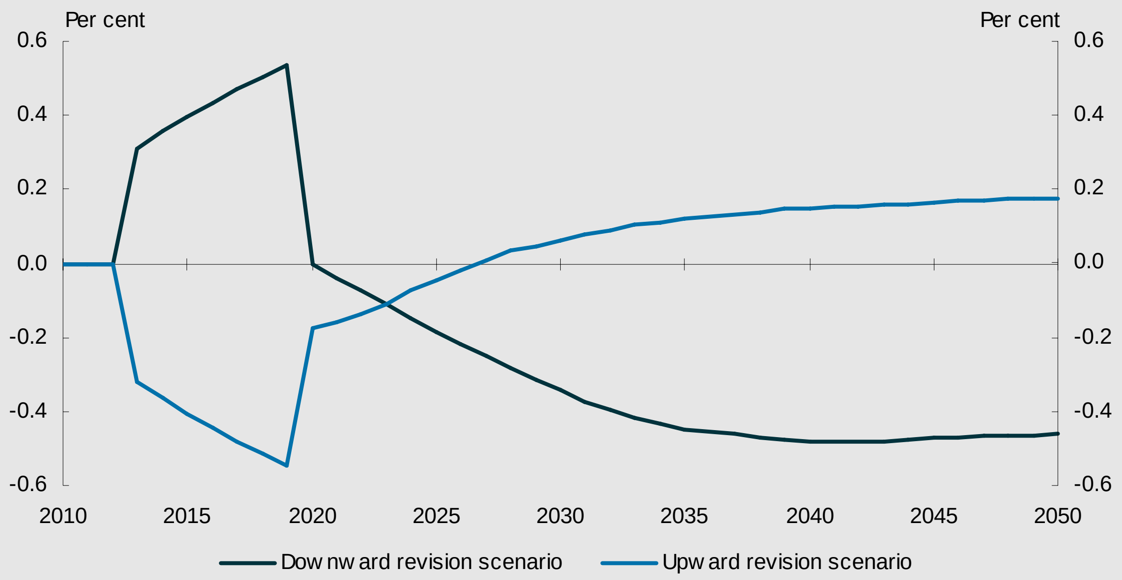
To explore the possibility of upwards or downwards revision of the future stabilisation goal, sensitivity simulations were conducted in GTEM. Revising stabilisation targets is not without costs, especially when the move is from a higher to a lower goal.

- Upwards sensitivity: in 2013, the global emissions trajectory is set to achieve a 450 ppm of CO_2-e level by 2100. Then, in 2020, the trajectory is changed to achieve a stabilisation level of 550 ppm by 2100 (light blue line on Chart 5.10). The cost is compared with the Garnaut -10 scenario.

- Downwards sensitivity: in 2013, the global emissions trajectory is set to achieve a 550 ppm of CO_2-e level by 2100. Then, in 2020, the trajectory is changed to achieve a stabilisation level of 450 ppm by 2100 (dark blue line on Chart 5.10). The cost is compared with the Garnaut -25 scenario.

Chart 5.10: Gross world product

Compared with corresponding stabilisation scenario



Source: Treasury estimates from GTEM.

Initially, GWP in the upwards revision scenario is lower, as the trajectory is tighter than subsequently needed. Aiming for a lower stabilisation target raises the emission price and mitigation costs. Costs are quite symmetrical across the two cases.

After 2020, cost differences become asymmetric.

When the target is revised down, global emissions must fall sharply in a short time. Undertaking faster reductions costs more after 2020 as the economy has not benefited from improved low-emission technologies before 2020. The changed goal results in an under-investment in low-emission technologies, raising mitigation costs.

Box 5.5 Implications of revising stabilisation goals (continued)

In the downwards revision scenario, the same technological effect works in reverse. The greater mitigation effort before 2020 results in an over-investment in low-emission technologies, lowering the mitigation costs for the remaining period. While forward-looking behaviour from firms, individuals, and investors may reduce the size of this effect, this will depend heavily on expectations regarding future mitigation policy.

The costs and benefits of revising the stabilisation level are not evenly distributed, raising the issue of how to discount the costs. The net present value from 2013 to 2050 of the data in Chart 5.10 is discounted by a range of discount rates (Table 5.9). The net present values of the downwards revision scenario are negative across all discount rates, suggesting erring on the side of lower stabilisation targets is better. These modelling results imply that, at a discount rate of 4 per cent, the world could pay US$5.3 trillion today to avoid having to revise the target down at a later date.

Table 5.9: Net present value of GWP

Discount rate, per cent per year	10	8	6	4	2
Upward revision, $US billion	-$180	-$170	-$1,450	-$850	$400
Downward revision, $US billion	-$150	-$1,100	-$2,650	-$5,340	-$10,050

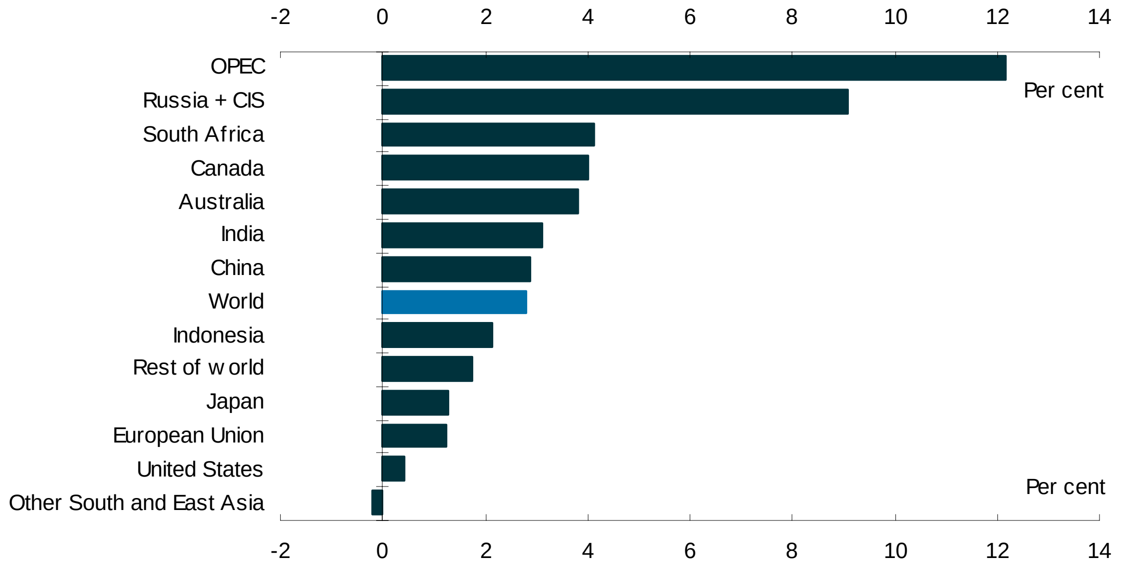
Note: Rounded to nearest 50 billion.
Source: Treasury estimates from GTEM.

5.3 Regional mitigation costs

Mitigation costs vary significantly across regions, reflecting differences in natural resource endowments, industrial structures, existing taxation arrangements and the allocation approach (Box 5.2 and Chart 5.11). Australia’s GNP loss is higher than the world average for most scenarios and higher than most other developed regions (except for Canada).[3] Other South and East Asia experiences an increase in GNP in all policy scenarios in 2050 compared with the reference scenario, as it benefits significantly from the sale of forestry sequestration credits.

3 Gross national product (GNP) is a high-level measure of economic welfare impact. GNP reflects changes in GDP and international income transfers. Reducing greenhouse gas emissions cost efficiently may involve transfers of income between economies and influence economies’ terms of trade. In that context, GNP is a better measure of welfare as it excludes income accruing to overseas residents, thereby better depicting the current and future consumption possibilities available to Australians.

Chart 5.11: GNP mitigation costs across regions
Change from reference scenario, CPRS -5 scenario in 2050



Source: Treasury estimates from GTEM.

5.3.1 Gross national product

Regional GNP impacts are affected by changes in GDP and international income transfers.

Pricing global emissions tends to reduce GDP more in developing economies, compared with developed economies, as developing economies tend to have a higher emission intensity of economic output (Table 5.11). Agriculture, natural resource extraction and manufacturing are all relatively emission intensive and account for a higher share of activity in developing economies. A given proportion of mitigation affects GDP more when the emission intensity of output is higher, as it leads to a greater reallocation of resources and more negatively affects capital rates of return and foreign investment. The United States, Japan and Europe experience the smallest GDP reductions as their economies are service-based.

Although developing economies have larger declines in GDP than developed economies, they benefit from income transfers through emission permit sales, partially offsetting the negative GDP effects in these regions (Chart 5.13). Permit sales help India, Indonesia, other South and East Asia, South Africa and the rest of world. The developed economies and OPEC purchase emission permits, leading to greater GNP declines than GDP.

Box 5.6: Comparison with other mitigation cost studies

Mitigation cost estimates in this report are within the range of other studies. The wide range from published studies indicates the uncertainty in estimated mitigation costs (Table 5.10).

Comparisons across mitigation studies are imprecise owing to different inputs and policy assumptions, model parameters, mitigation opportunities and requirements, and different methods for aggregating results.

Table 5.10: Gross world product mitigation cost estimates

Change from reference scenario

Scenario/source	Reduction at 2030 Per cent Median	Per cent Range	Reduction at 2050 Per cent Median	Per cent Range	Mitigation at 2050 (Gt CO2e)
Weighted using purchasing power parity					
GTEM CPRS -5, Garnaut -10	1.4	1.3-1.4	2.8	2.7-2.8	67-68
GTEM CPRS -15	1.8		3.5		75
GTEM Garnaut -25	2.1		4.3		81
G-Cubed Garnaut -10	2.5		3.2		67
G-Cubed CPRS -5	3.1		3.3		38
OECD 550 ('All 2008')	0.8		0.9		38
Weighted using market exchange rates					
GTEM CPRS -5, Garnaut -10	0.9	0.8-1	2.2	2-2.3	67-68
GTEM CPRS -15	1.3			2.8	75
GTEM Garnaut -25	1.5			3.5	81
G-Cubed Garnaut -10	1.9		2.9		67
G-Cubed CPRS -5	2.5		3.3		38
CCSP 530		0.6- 3		1.9-5.4	31-56
IPCC 4AR 535-590	0.6	0.2-2.5	1.3	Slightly negative to 4	
Stern 550 (Chapters 8 and 10)			1	-6	50
den Elzen et al 550	0.4	0.2-1.4	1.1	0.5-2	

Source: Treasury estimates from GTEM and G-Cubed; OECD, 2008; IPCC, 2007; CCSP, 2007; Stern, 2007; den Elzen et al., 2007.

This report provides aggregated cost estimates using purchasing power parity weights. This increases the weight given to developing regions relative to using market exchange rate weights. By 2050, developing economies (including India, Indonesia and China) experience the largest national GDP costs, while developed economies (such as the United States, the European Union and Japan) experience the smallest GDP costs. In market exchange rate terms, the mitigation costs estimates are closer to the median estimate of other studies, many of which report results in market exchange rate terms.[4]

The level of emissions in the reference scenario determines the scale of the mitigation effort; and costs increase as the scale of the effort increases (den Elzen et al., 2007). The reference scenario is significantly higher than many reference scenarios in the literature, so greater economic adjustment is required to stabilise at low concentrations.

4 Of the studies listed in Table 5.10, the Climate Change Science Project (CCSP) results are aggregated using market exchange rate weights. The IPCC and Stern estimates are based on literature reviews, so are likely to include some studies that use market exchange rates and others that use purchasing power parity weights.

Table 5.11: Emission Intensity of GDP

Kg of CO_2-e per US$ (2005 PPP)	2005	2050	2050			
			CPRS	CPRS	Garnaut	Garnaut
	Reference scenario		-5	-15	-10	-25
United States	0.55	0.29	0.08	0.06	0.08	0.04
European Union	0.37	0.22	0.11	0.09	0.11	0.08
China	1.38	0.57	0.17	0.16	0.18	0.14
Russia + CIS	1.49	0.72	0.19	0.10	0.20	0.07
Japan	0.33	0.22	0.13	0.11	0.14	0.10
India	0.81	0.34	0.12	0.10	0.13	0.08
Canada	0.64	0.44	0.18	0.13	0.18	0.11
Australia	0.80	0.43	0.15	0.07	0.16	0.06
Indonesia	1.17	0.35	0.11	0.07	0.13	0.06
South Africa	1.27	0.61	0.18	0.13	0.18	0.08
Other South and East Asia	0.69	0.29	0.01	-0.06	0.04	-0.07
OPEC	0.86	0.48	0.29	0.24	0.27	0.15
Rest of w orld	0.90	0.31	0.13	0.10	0.14	0.09
World	0.70	0.38	0.13	0.11	0.14	0.08

Source: Treasury estimates from GTEM.

How emission intensity of output falls in response to emission pricing varies across regions. In most cases, emission intensity falls more in economies with a low marginal cost of mitigation as they undertake a greater proportion of mitigation in a global trading environment. Japan experiences the smallest proportion of reductions in emission intensity as it is a service-based economy with high marginal costs of mitigation. OPEC, however, experiences low proportional reductions in emission intensity across the scenarios, despite being highly emission intensive. This is because demand for petroleum, a primary source of emissions, remains the dominant fuel source for global transport to 2050.

Aggregate costs and marginal costs have different determinants. Aggregate costs largely depend on the share of energy- and emission-intensive industries in the economy (as this determines the extent of economic restructuring required), while marginal costs depend on the nature of opportunities to reduce emissions within the economy. Some economies, such as Japan, have relatively low aggregate costs but high marginal costs, while others, such as China, have relatively high aggregate costs but low marginal costs. Australia's costs, both aggregate and marginal, are relatively high.

The marginal cost of mitigation tends to be lower in developing economies, compared with developed economies, as developed economies already tend to use more low-cost clean technologies than developing economies because of higher energy costs and higher energy-efficiency standards.

Table 5.12: Regional GNP costs

Change from reference scenario, GTEM

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent				Per cent			
United States	-0.3	-0.4	-0.4	-0.6	-0.4	-0.1	-0.9	-0.8
European Union	-0.4	-0.6	-0.2	-0.4	-1.2	-1.4	-1.1	-1.7
China	-1.2	-1.5	-1.6	-2.7	-2.9	-4.6	-5.9	-9.8
Russia + CIS(a)	-3.6	-5.3	-3.5	-6.0	-9.1	-9.5	-10.7	-13.2
Japan	-0.2	-0.4	-0.2	-0.4	-1.3	-1.7	-1.1	-2.0
India	0.0	0.6	-0.6	-1.4	-3.1	-3.7	-0.8	-2.3
Canada	-1.1	-1.5	-1.4	-2.3	-4.0	-4.7	-4.8	-6.5
Australia	-1.1	-1.6	-1.3	-2.1	-3.8	-3.2	-4.8	-5.2
Indonesia	-0.8	-0.5	-0.7	-0.9	-2.1	-2.0	0.5	0.2
South Africa	-0.8	-1.2	-1.4	-2.5	-4.1	-4.5	-6.7	-8.1
Other South and East Asia	-0.2	0.0	0.1	0.6	0.2	1.4	1.3	3.6
OPEC	-2.4	-3.4	-2.3	-4.5	-12.2	-15.8	-12.6	-18.1
Rest of world	0.3	0.5	0.6	1.0	-1.7	-2.5	0.0	-1.4
World	-0.7	-0.9	-0.7	-1.3	-2.8	-3.5	-2.7	-4.3

Change from reference scenario, G-Cubed

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent				Per cent			
United States	-1.2	-1.5	-1.2	-1.7	-2.2	-2.3	-2.1	-2.3
Japan	-1.2	-1.5	-1.0	-1.6	-4.9	-5.4	-4.8	-5.8
Australia	-1.9	-2.5	-1.7	-2.6	-4.2	-4.7	-3.8	-4.8
Europe	-1.4	-1.9	-1.0	-1.5	-4.4	-5.1	-3.6	-5.1
Other OECD	-2.3	-2.9	-2.1	-3.0	-4.7	-4.8	-4.3	-4.4
China	-4.4	-5.0	-1.7	-2.1	3.7	4.2	0.0	1.3
Rest of world	-0.7	-0.9	-1.9	-2.9	-3.3	-4.0	-2.2	-3.4
Former Soviet Union	-1.7	-2.1	-1.6	-2.4	-4.6	-5.1	-4.3	-6.0
OPEC	-9.3	-11.1	-8.0	-11.8	-9.8	-11.6	-9.8	-13.5
World	-2.3	-2.8	-2.2	-3.3	-3.3	-3.8	-3.2	-4.2

Note: (a) Commonwealth of Independent States.
Source: Treasury estimates from GTEM and G-Cubed.

Another way to explore cost differences is to examine the implied additional time each region takes to reach the January 2050 level of GNP per capita in the reference scenario (Table 5.13). The delay for all scenarios, in all models and across all regions, is from minus 18 months (that is, growth accelerates in the policy scenario) to just under 10 years.

Table 5.13: Delay in growth, GNP per capita

	GTEM				G-Cubed			
	CPRS -5 Months	CPRS -15 Months	Garnaut -10 Months	Garnaut -25 Months	CPRS -5 Months	CPRS -15 Months	Garnaut -10 Months	Garnaut -25 Months
United States	3	1	7	6	18	18	17	18
European Union(a)	10	11	9	14	35	41	29	41
China	19	31	40	68	-24	-27	0	-8
Russia + CIS(a)	64	67	76	94	41	46	39	54
Japan	11	15	10	17	44	49	43	53
India(b)	11	14	3	8				
Canada(c)	33	38	39	54	38	39	35	36
Australia	36	30	45	49	39	44	36	46
Indonesia(b)	9	8	-2	-1				
South Africa(b)	21	23	35	42				
Other South and East Asia(b)	-1	-7	-6	-17				
OPEC	73	97	76	112	45	54	46	64
Rest of world(d)	7	10	0	5	13	16	9	14

(a) Economy coverage differs between GTEM and G-Cubed.
(b) GTEM only.
(c) Includes New Zealand for G-Cubed.
(d) Includes India, South Africa, other South and East Asia in G-Cubed.
Source: Treasury estimates from G-Cubed and GTEM.

The G-Cubed model offers a contrasting view, owing to differences in the economic structure and underlying data compared with GTEM. G-Cubed's pattern of regional impacts for the developed regions is somewhat different. G-Cubed has less sectoral detail than GTEM, particularly in terms of the electricity sector and the combustion of coal. G-Cubed allows businesses and consumers to substitute more readily between industries and intermediate inputs of production in response to relative price changes. This greater production flexibility allows the electricity and transport sectors to substitute almost entirely away from coal relatively cheaply. In particular, the dirtier the coal (for instance, a high share of brown coal), the cheaper the mitigation will be. G-Cubed does not include detailed technology structures in other sectors, which means mitigation in agriculture or industrial processes is virtually impossible, other than to reduce consumption. G-Cubed has no carbon capture and storage technology, so combustion emissions only decline by reducing fossil fuel consumption.

Table 5.14: Regional GDP costs

Change from reference scenario, GTEM

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent				Per cent			
United States	-0.2	-0.3	0.0	-0.1	-0.3	-0.3	-0.6	-0.7
EU-25	-0.2	-0.2	0.1	0.1	-0.3	-0.4	-0.5	-1.0
China	-1.6	-2.1	-1.7	-3.0	-2.8	-3.7	-3.1	-5.1
Russia + CIS(a)	-3.1	-4.4	-3.3	-5.7	-9.7	-12.8	-9.9	-15.5
Japan	0.1	0.1	0.3	0.4	0.4	0.3	0.2	0.0
India	-0.7	-0.7	-1.4	-2.4	-4.6	-5.2	-4.2	-5.8
Canada	-0.5	-0.8	-0.4	-0.7	-2.3	-3.1	-2.7	-4.5
Australia	-0.9	-1.2	-0.8	-1.4	-2.9	-3.5	-3.2	-4.6
Indonesia	-1.0	-1.2	-2.0	-3.6	-3.7	-4.6	-2.6	-4.9
South Africa	-1.5	-2.1	-1.6	-2.8	-5.4	-6.5	-5.7	-8.0
Other South and East Asia	-0.3	-0.3	-0.2	-0.4	-2.1	-2.6	-1.6	-2.6
OPEC	-1.9	-2.6	-1.9	-3.4	-8.2	-11.4	-8.6	-14.4
Rest of w orld	-0.2	-0.1	-0.4	-0.7	-2.4	-2.9	-2.0	-3.3
World	-0.7	-0.9	-0.7	-1.3	-2.8	-3.5	-2.7	-4.3

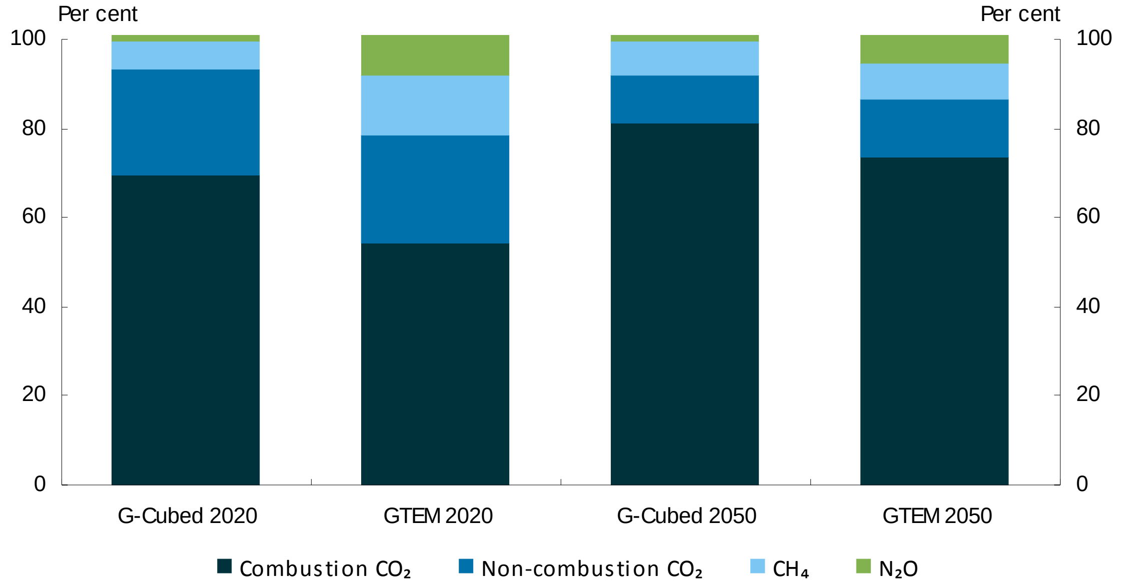
Change from reference scenario, G-Cubed

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent				Per cent			
United States	-1.0	-1.2	-1.0	-1.4	-1.4	-1.3	-1.8	-1.8
Japan	-0.9	-1.1	-0.6	-0.9	-2.9	-3.1	-3.0	-3.1
Australia	-2.2	-2.8	-1.8	-2.6	-5.3	-6.3	-3.9	-5.5
Europe	-1.4	-1.8	-0.9	-1.3	-3.5	-4.2	-2.8	-4.2
Other OECD	-2.7	-3.3	-2.2	-3.2	-7.0	-7.6	-5.3	-5.8
China	-4.8	-5.5	-3.3	-4.6	-1.6	-1.4	-2.8	-2.3
Rest of w orld	-0.8	-1.0	-2.1	-3.1	-3.2	-3.8	-2.3	-3.4
Former Soviet Union	-1.9	-2.3	-1.3	-2.0	-5.3	-6.4	-3.7	-5.4
OPEC	-10.5	-12.6	-9.1	-13.5	-9.1	-10.6	-11.3	-16.2
World	-2.3	-2.8	-2.2	-3.3	-3.3	-3.8	-3.2	-4.2

Note: (a) Commonwealth of Independent States.
Source: Treasury estimates from GTEM and G-Cubed.

As a result, mitigation of non-CO_2 gases is more expensive in G-Cubed than in GTEM. In G-Cubed, nitrous oxide emissions are barely mitigated compared with GTEM (Chart 5.12). CO_2 contributes a much greater share of emissions mitigation in G-Cubed than in GTEM. As a result, G-Cubed suggests the United States will experience relatively lower mitigation costs than Japan, Europe and Australia. Australia's mitigation costs in early years are high, but diminish over time, as mitigation lowers Australia's current account and net foreign debt.

Chart 5.12: Mitigation by gas
Garnaut -25 scenario



Source: Treasury estimates from GTEM and G-Cubed.

The approach adopted for allocating global emissions among economies can significantly alter a country's GNP mitigation costs through changing income transfers between economies. For example, in the CPRS -5 scenario, GNP costs in 2050 for India are almost four times higher than in the Garnaut -10 scenario, even though the two scenarios have very similar emission prices and GDP impacts (Table 5.12).

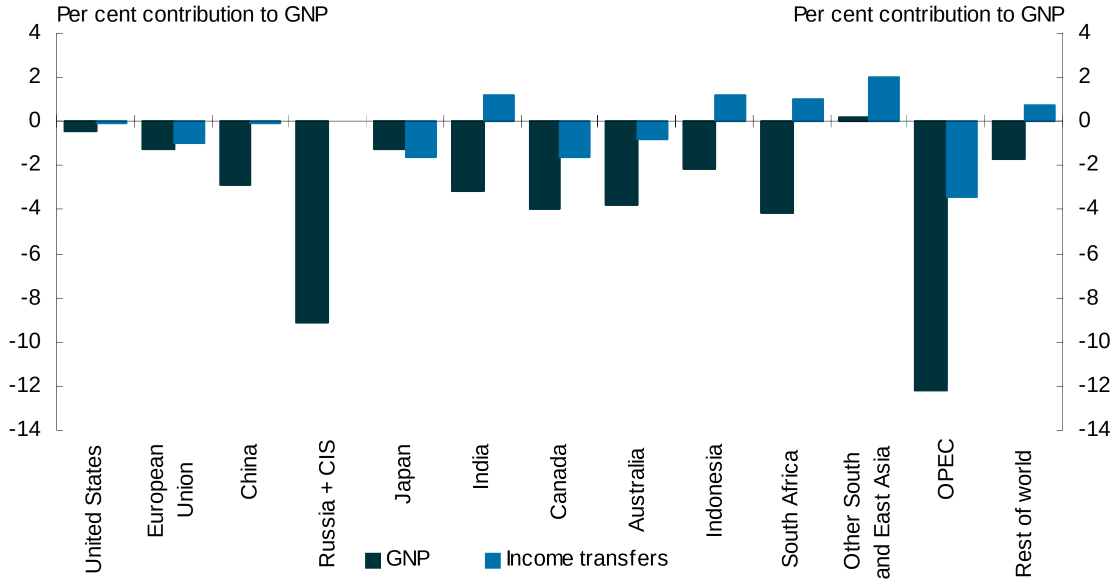
5.3.2 International income transfers

Income transfers between regions occur because of changes in the terms of trade, the sale (purchase) of emission permits and changes in foreign interest payments.

Net income transfers have a positive impact upon GNP in regions with low mitigation costs as they can sell emission permits. The sale of large numbers of permits tends to cause the exchange rate to appreciate, positively affecting net foreign interest payments and further boosting net income transfers.

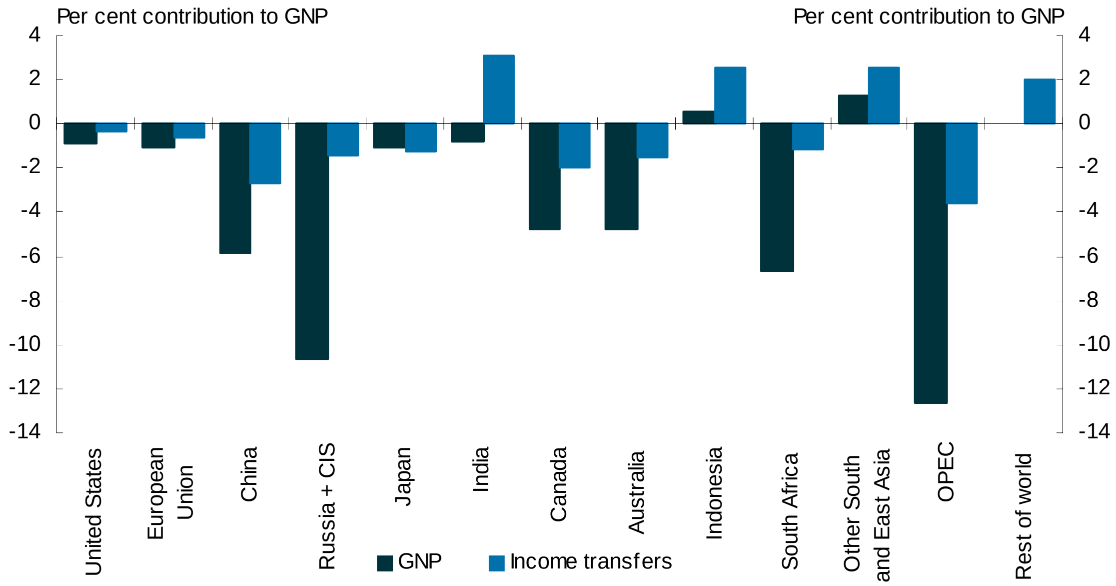
All developed economies buy permits in the Garnaut -10 and CPRS -5 scenarios, raising GNP mitigation costs (Chart 5.13 and 5.14). For some regions (such as China and India) income transfers differ significantly depending on the emission allocation approach.

Chart 5.13: Contribution of international income transfers to GNP
CPRS -5 scenario in 2050



Note: The difference between GNP and income transfers is the GDP impact.
Source: Treasury estimates from GTEM.

Chart 5.14: Contribution of international income transfers to GNP
Garnaut -10 scenario in 2050



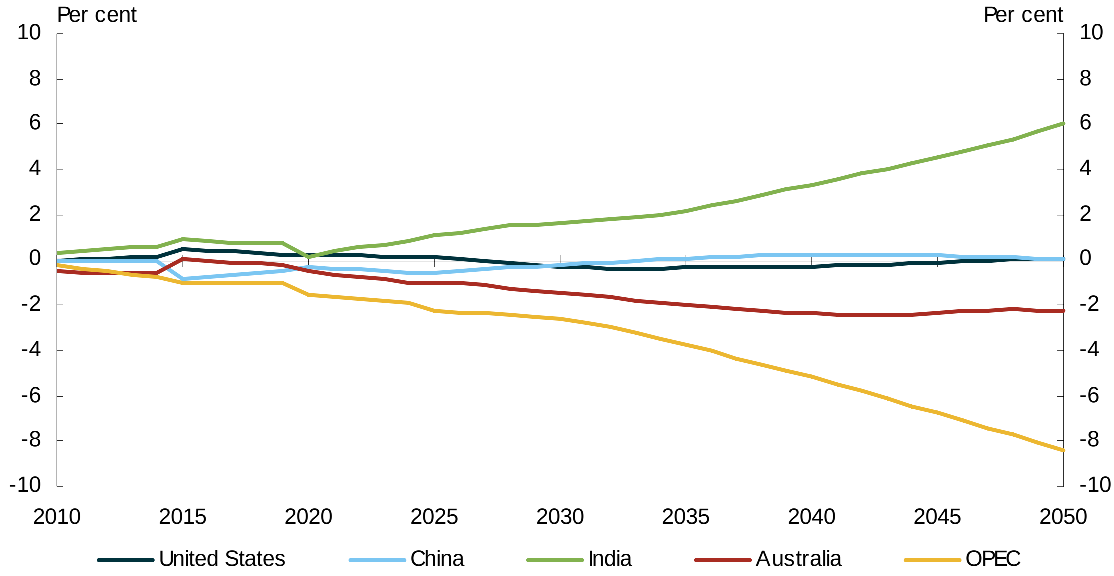
Note: The difference between GNP and income transfers is the GDP impact.
Source: Treasury estimates from GTEM.

Terms of trade

A change in an economy's terms of trade allows it to buy more or fewer imports for a given quantity of exports. As demand for fossil fuels falls, fossil fuel exporting regions tend to experience a fall in their terms of trade under the mitigation scenarios (Chart 5.15 and Table 5.15). This effect is most significant for OPEC and Australia. Most regions that are net importers of fossil fuels experience negligible or small positive impacts in their terms of trade. India experiences the largest increase in terms of trade, as oil and petrol contribute a large share to its overall imports in the reference scenario.

Chart 5.15: Terms of trade

Change from reference scenario, CPRS -5 scenario



Source: Treasury estimates from GTEM.

Table 5.15: Terms of trade impacts

Change from reference scenario

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent				Per cent			
United States	0.2	0.3	-0.1	-0.2	0.1	0.6	-0.4	0.2
European Union	0.1	0.1	0.1	0.2	-0.2	-0.1	-0.1	0.1
China	-0.3	-0.3	-0.7	-1.0	0.0	-0.7	-1.4	-2.8
Russia + CIS(a)	-0.5	-0.7	0.1	0.2	-0.5	1.6	-1.1	1.2
Japan	0.4	0.3	0.8	1.0	-0.5	-0.9	-0.2	-1.2
India	0.2	0.5	1.0	1.1	6.0	6.7	8.3	9.4
Canada	-0.5	-0.7	-0.5	-0.7	-3.2	-3.2	-3.3	-3.5
Australia	-0.5	-0.7	-0.5	-1.0	-2.2	-0.6	-2.7	-1.3
Indonesia	-0.6	-0.6	0.4	0.7	1.6	2.2	2.0	3.0
South Africa	1.3	1.6	1.5	2.0	2.8	3.5	1.3	1.9
Other South and East Asia	0.2	0.3	0.2	0.5	1.9	2.7	2.0	3.8
OPEC	-1.6	-2.0	-1.6	-2.7	-8.4	-9.9	-7.8	-10.0
Rest of w orld	0.1	0.2	0.4	0.6	-0.5	-0.8	0.4	0.0

Note: (a) Commonwealth of Independent States.
Source: Treasury estimates from GTEM.

Permit sales

The emission price and coverage of the emission trading scheme primarily determine regional emission reductions. In an international trading environment, with no restrictions on permit trade, actual emissions within country borders are relatively insensitive to emission permit allocations. The allocations, however, are important in determining economic impacts, as the sale (or purchase) of permits will alter the region's wealth. Significant global trade in permits occurs in all the policy scenarios (Table 5.16).

Gross permit transfer differs across the allocation approaches. The CPRS -5 scenario has less than half the gross permit sales in 2050 than the Garnaut -10 scenario owing to differences in the economy-by-economy allocation.

Table 5.16: GTEM international trade in permits

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Mt CO_2-e				Mt CO_2-e			
United States	795	930	1698	1568	324	-187	1080	288
European Union	882	1011	406	539	1206	932	854	731
China	-691	-782	94	66	-598	689	3848	3930
Russia + CIS(a)	399	478	309	271	-27	-507	468	-127
Japan	330	386	297	365	413	347	299	272
India	-576	-701	-369	-205	-524	-275	-2373	-1297
Canada	121	140	263	245	176	93	309	170
Australia	64	60	103	77	85	-47	209	49
Indonesia	-84	-148	-183	-234	-157	-218	-345	-333
South Africa	-36	-38	34	26	-53	-78	130	28
Other South and East Asia	-304	-468	-566	-768	-1266	-1735	-1536	-2021
OPEC	252	281	204	309	1445	1164	1645	687
Rest of w orld	0	0	-2290	-2258	-1023	-178	-4589	-2378

Note: Note: (a) Commonwealth of Independent States. Positive values represent purchases of permits; negative values represent sales of permits.
Source: Treasury estimates from GTEM.

Table 5.17: GTEM regional emissions

Change from 2001

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent				Per cent			
United States	-19	-26	-20	-33	-62	-74	-62	-83
European Union	-16	-22	-16	-26	-48	-57	-47	-63
China	120	99	128	89	89	75	91	47
Russia + CIS(a)	11	2	10	-7	-56	-77	-54	-85
Japan	-15	-19	-14	-20	-50	-57	-49	-63
India	38	25	54	30	139	89	145	56
Canada	-5	-12	-4	-16	-36	-53	-35	-63
Australia	3	-8	3	-15	-42	-71	-39	-77
Indonesia	-23	-33	-21	-40	-25	-53	-12	-61
South Africa	26	14	26	5	-4	-32	-7	-56
Other South and East Asia	-43	-54	-39	-63	-95	-136	-76	-142
OPEC	45	36	48	32	106	66	94	0
Rest of w orld	47	47	2	-17	43	16	52	-2
World	21	12	15	-4	-2	-22	2	-39

Note: (a) Commonwealth of Independent States.
Source: Treasury estimates from GTEM.

In GTEM, developed regions generally purchase permits from developing economies across all scenarios, because developed regions have higher marginal costs (Table 5.16). In addition, economies with large forestry resources can create substantial revenue from the sale of sequestration credits.

Regions with high emissions per capita will buy more emission permits in the Garnaut scenarios than in the CPRS scenarios, as their proportional mitigation obligations are greater under a per capita allocation approach. As a result, the contribution of income transfer from permit sales to GNP losses in Australia, the United States, China and South Africa tends to be lower in the CPRS -5 than in Garnaut -10 scenario.

The G-Cubed model indicates international permit trading has very different results for the United States, China and the rest of world group (Table 5.18). High coal-intensity economies, such as China and the United States, find it relatively cheap to mitigate, while the rest of world finds it harder. China and the United States become significant sellers of permits, and the rest of the world is a net purchaser of permits. Trade patterns across economies in G-Cubed do not change between the scenarios.

Table 5.18: G-Cubed international trade in permits

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Mt CO_2-e				Mt CO_2-e			
United States	165	-20	615	123	-2105	-2317	-2775	-2448
Japan	236	292	393	475	32	25	-293	-263
Australia	59	95	179	193	-1	-125	268	-5
Europe	964	1151	898	1254	1033	582	359	-198
Other OECD	63	93	245	256	-254	-400	61	-141
China	-449	-635	-3900	-4389	-11310	-9459	-5294	-3633
Rest of w orld	-1576	-1576	-672	-341	9318	9364	4879	5917
Former Soviet Union	988	1234	2020	2304	1194	707	1823	1257
OPEC	-449	-635	222	126	2094	1623	973	-487

Note: Positive values represent purchases of permits; negative values represent sales of permits.
Source: Treasury estimates from G-Cubed.

Constraints on international permit trade in the CPRS scenarios are binding in G-Cubed. Economies that cannot meet their targets through domestic mitigation and trade up to the allowed level have higher domestic emission prices than the global price (Table 5.19). For example, in 2016, the European Union price is over 40 per cent higher than the global price. Australian emission prices are slightly higher in 2018 and 2019, by US$0.4 in 2018 and US$3 in 2019.

Table 5.19: G-Cubed CO_2-e permit prices

CPRS scenarios

US$ 2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CPRS -5										
World price	8	9	9	9	10	10	10	11	11	12
Japan					11			15	19	24
European Union					13			17	24	31
Former Soviet Union				10	15			18	26	36
CPRS -15										
World price	10	10	11	11	12	12	13	13	14	14
Japan				14	18	13	19	25	30	35
Australia									14	17
European Union				17	24		18	30	39	45
Former Soviet Union			11	18	24	17	21	32	40	49

Note: Blank cells indicate no divergence from the global price. Regions not listed are either not yet in the emission trading scheme or do not diverge from the global price.
Source: Treasury estimates from G-Cubed.

Foreign interest payments

Foreign interest payments are influenced by changes in exchange rates and changes in savings and investment rates. Depreciating exchange rates or decreasing savings to investment ratios (or both) increase foreign interest payments owed (or reduce foreign interest payments received), resulting in a negative impact on GNP.

Exchange rates in regions which export fossil fuels (Australia, Canada and OPEC) depreciate in most scenarios as global demand for fossil fuels falls (Table 5.20). In Australia and Canada, the depreciation in exchange rates increases foreign interest payments owed, causing a decline in GNP relative to the reference scenario. However, for OPEC, foreign interest payments to other economies fall as the depreciated exchange rate is more than offset by a large reduction in investment levels, triggered by a large reduction in OPEC's relative rate of return, which leads to a large increase in the savings to investment ratio.

Developing regions, such as India and the rest of world, experience a large increase in GNP from changes in foreign interest payments across the policy scenarios. This is because their exchange rates appreciate (primarily as a result of lower fossil fuel imports) and their savings to investment ratios increase through decreased relative rates of return.

Table 5.20: GTEM regional real exchange rate impacts
Change from reference scenario

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent				Per cent			
United States	0.4	0.5	0.2	0.3	0.4	1.0	0.2	1.0
European Union	0.7	0.9	0.9	1.4	0.7	1.1	1.2	1.9
China	1.0	1.3	0.5	0.9	2.1	1.8	0.6	0.2
Russia + CIS(a)	2.5	3.0	2.1	3.1	4.0	7.1	3.1	7.4
Japan	0.8	1.0	1.2	1.7	0.0	0.0	0.4	0.1
India	1.3	2.4	1.2	1.8	3.3	4.3	5.8	7.8
Canada	0.3	0.3	0.1	0.3	-1.3	-0.6	-1.4	-0.5
Australia	-0.7	-0.9	-1.4	-2.3	-3.1	-1.3	-3.8	-2.1
Indonesia	0.9	1.3	1.9	3.1	3.1	4.3	3.8	6.1
South Africa	0.5	0.7	0.1	0.2	2.4	4.1	1.0	3.7
Other South and East Asia	0.8	1.1	0.8	1.5	2.4	3.6	2.7	5.1
OPEC	-0.3	-0.4	-0.1	-0.5	-4.9	-5.8	-4.4	-4.9
Rest of w orld	0.8	1.1	1.5	2.5	1.1	1.4	2.5	3.5

Note: (a) Commonwealth of Independent States. Negative figures indicate depreciation in the real exchange rate.
Source: Treasury estimates from GTEM.

5.4 SECTORAL ANALYSIS

The broad sectoral trends in the reference scenario — services comprising a growing share of the global economy, and agriculture and energy-intensive industries comprising a declining share — continue in the policy scenarios. However, reducing emissions does require a shift away from the production of emission-intensive goods towards low emission-intensive goods, combined with a general decline in the emission intensity of production across all sectors.

5.4.1 Sectoral output

Global demand for most commodities and services remains strong under global mitigation scenarios. While sector outputs fall slightly relative to reference scenario levels, most emission reductions come from changes in production processes and adoption of new technology driven by the emission price. Value added across many sectors declines slightly more than sector output because capital and labour prices decline slightly. The relative impacts across sectors are fairly consistent across scenarios, with only the magnitudes of impacts changing.

Services are generally less affected than other sectors of the economy, with output across most regions declining in 2050 by less than 1.5 per cent below reference scenario levels in the

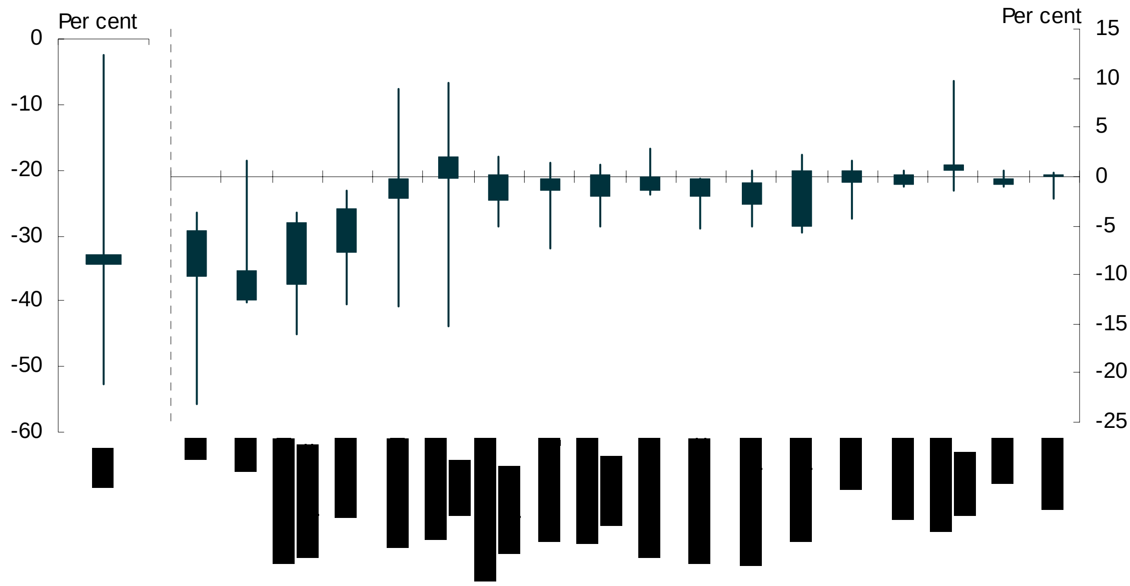
CPRS -5 scenario (Chart 5.18). Manufacturing output falls more, around 0-4 per cent below the reference scenario in 2050, reflecting its higher emission intensity. Transport sectors fall in the CPRS -5 scenario, around 0-8 per cent lower than the reference scenario in 2050. Emission-intensive industries' output, excluding the fossil fuel sectors, falls to around 12 per cent below the reference scenario in 2050. In some emission-intensive industries, output in the CPRS -5 scenario rises relative to the reference scenario in 2050, reflecting improvements in comparative advantage following emission pricing.

The fossil fuel mining sector declines considerably as a result of substitution towards cleaner fuel sources. In 2020, coal mining experiences the largest declines in the CPRS -5 scenario and is around 33-35 per cent lower than the reference scenario. Oil and gas mining output is 5-10 per cent and 9-13 per cent respectively, lower than the reference scenario in 2020 across major producing regions. Electricity generation is less affected, and is around 3-8 per cent lower than the reference scenario in 2050, as it switches from fossil fuels to nuclear and renewables.

Over time, development and deployment of technologies significantly affects sectoral growth. The commercial development and widespread deployment of carbon capture and storage technologies reduce the impact of emission pricing on coal mining. Output of coal mining in the key production regions in the CPRS -5 scenario is between 2 per cent higher and 36 per cent lower than the reference scenario in 2050 depending on the region (Chart 5.18). Oil and gas mining, however, continues to fall relative to the reference scenario levels throughout the projection period. Oil and gas mining in the key producing regions falls to 22-52 per cent and 21-43 per cent lower than the reference scenario in 2050. The output of electricity generation rises significantly to be higher than the reference scenario in 2050, as continued switching to cleaner technology options enables electricity to become cost competitive against direct use of fossil fuels, resulting in considerable substitution towards electricity consumption by energy consumers.

Chart 5.16: GTEM sectoral output relative to the reference scenario in 2020

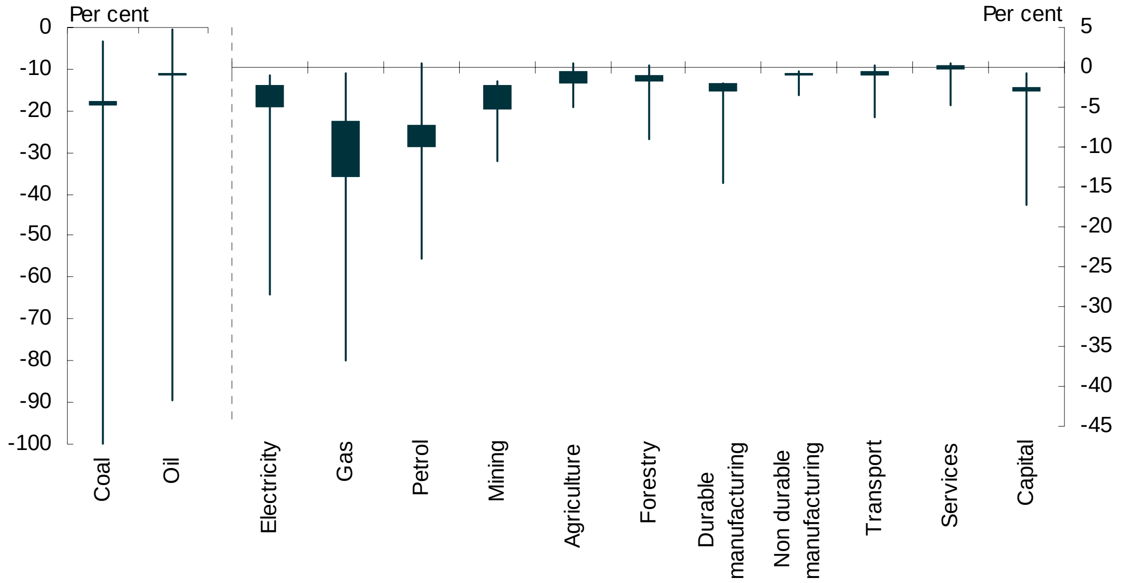
Change from reference scenario, CPRS -5 scenario



Note: The lines indicate the full range of regional output changes relative to the reference scenario. The bars show the output impact for the central 50 per cent of economies, weighted by their output in that sector.
Source: Treasury estimates from GTEM.

Chart 5.17: G-Cubed sectoral output relative to the reference scenario in 2020

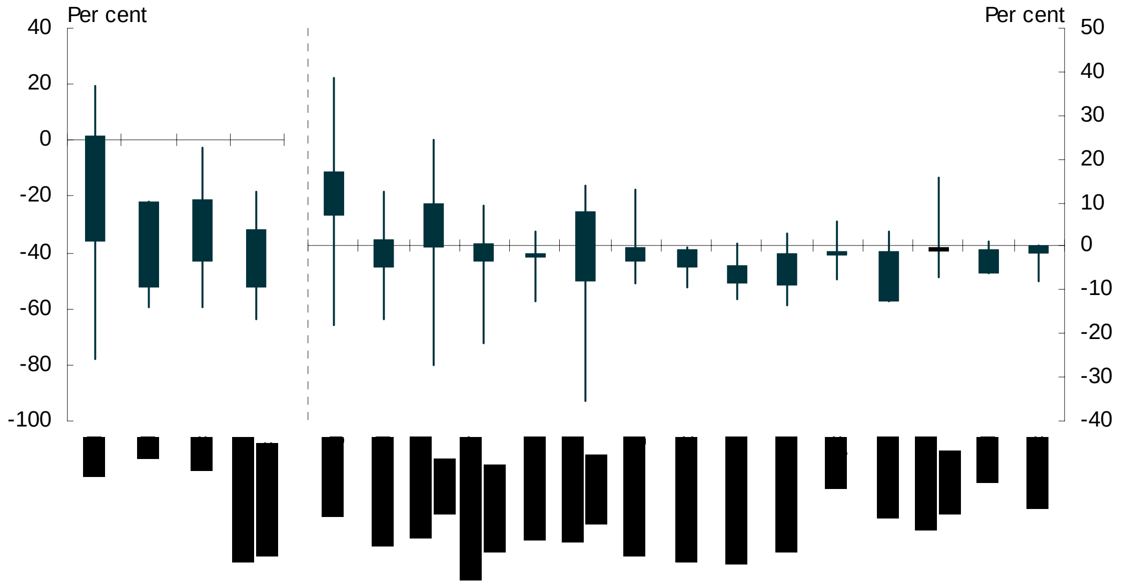
Change from reference scenario, CPRS -5 scenario



Note: The lines indicate the full range of regional output changes relative to the reference scenario. The bars show the output impact for the central 50 per cent of economies, weighted by their output in that sector.
Source: Treasury estimates from G-Cubed.

Chart 5.18: GTEM sectoral output relative to the reference scenario in 2050

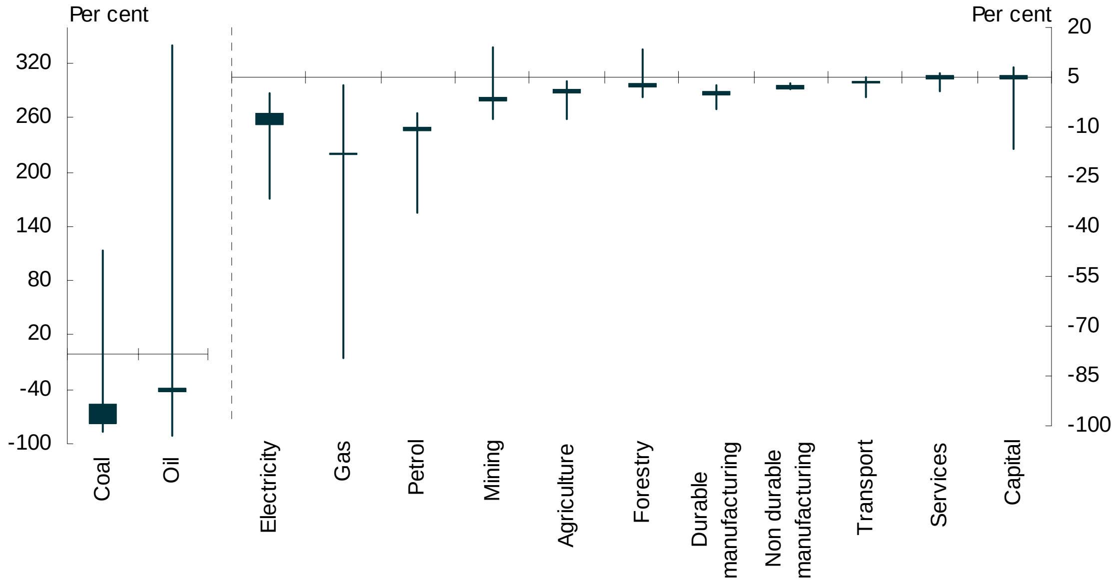
Change from reference scenario, CPRS -5 scenario



Note: The lines indicate the full range of regional output changes relative to the reference scenario. The bars show the output impact for the central 50 per cent of economies, weighted by their output in that sector.
Source: Treasury estimates from GTEM.

Chart 5.19: G-Cubed sectoral output relative to the reference scenario in 2050

Change from reference scenario, CPRS -5 scenario



Note: The lines indicate the full range of regional output changes relative to the reference scenario. The bars show the output impact for the central 50 per cent of economies, weighted by their output in that sector.
Source: Treasury estimates from G-Cubed.

5.4.2 Sectoral emissions

Mitigation occurs across the economy. The ranking of adjustment across sectors does not change significantly across the range of scenarios (Table 5.21).

The largest source of mitigation to 2050 is in electricity generation. Electricity emissions decline relative to the reference scenario in 2020, owing to a decline in electricity output and substitution towards cleaner technologies. The electricity sector decarbonises considerably between 2020 and 2050, as renewable technologies become competitive and carbon capture and storage technologies become commercialised and widely deployed. This enables global electricity generation emissions to decline by around 75-85 per cent across the range of scenarios, relative to the reference scenario in 2050, despite increases in global electricity demand.

Mitigation in the transport sector is considerably less than in the electricity generation sector, as petroleum remains the primary source of fuel to 2050 across most scenarios. Widespread deployment of fuel efficient vehicles including hybrid vehicles and advanced internal combustion engines contributes noticeably in 2050 in all scenarios. In the Garnaut -25 scenario, hydrogen vehicles become competitive, enabling larger declines in emissions. By 2050, transport emissions decline by around 39-59 per cent across all scenarios, relative to the reference scenario.

In agriculture, mitigation primarily occurs through the uptake of low-emission technologies and substitution to less emission-intensive practices. Agriculture emissions in 2050 decline by around 46-55 per cent, across the range of scenarios, relative to the reference scenario. In energy-intensive sectors (iron and steel, petroleum, chemicals rubber and plastics, non-metallic minerals, and non-ferrous metals) mitigation occurs through both the uptake of low-emission technologies and fuel substitution away from fossil fuels to electricity generation. In aggregate, energy-intensive sectors' emissions in 2050 decline by around 53-66 per cent across the range of scenarios, relative to the reference scenario.

Mining mitigation occurs through the uptake of low-emission technologies and a decline in global fossil fuel demand. Mining emissions in 2050 decline by around 73-79 per cent across the range of scenarios, relative to the reference scenario.

A small net sink is created through global land-use change by 2020, with this sink increasing to around 5-7 Gt of CO_2 by 2050 across all scenarios. Other sectors experience similar proportional levels of mitigation in 2020 and 2050.

Table 5.21: Emissions by sector

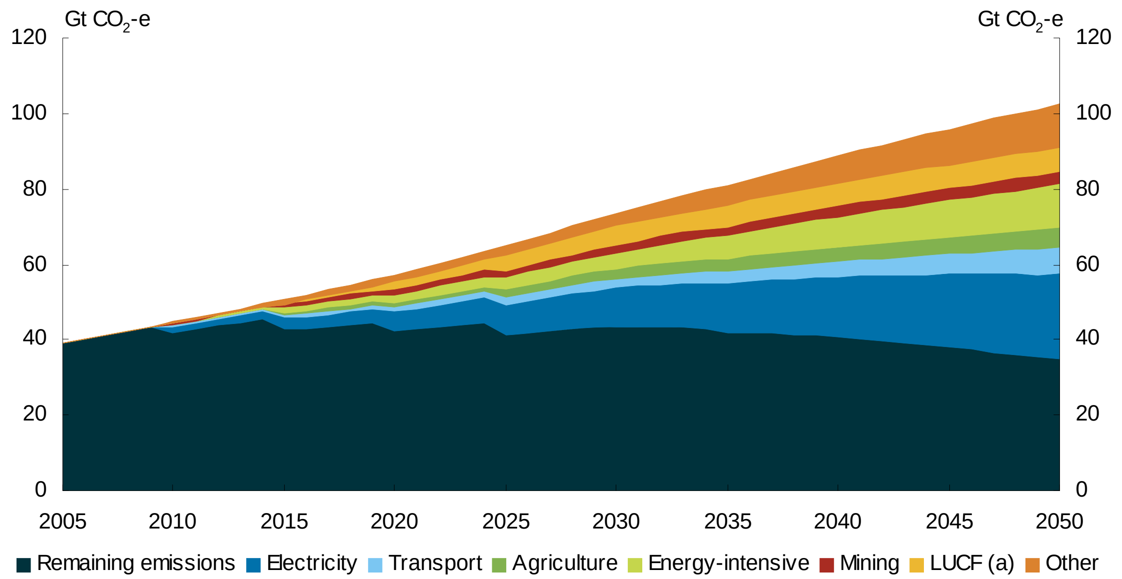
Change from reference scenario

	Reference Gt CO_2-e	CPRS -5 Per cent	CPRS -15 Per cent	Garnaut -10 Per cent	Garnaut -25 Per cent
2020					
Electricity	16.1	-30	-37	-29	-43
Transport	10.0	-13	-16	-13	-20
Agriculture	6.8	-18	-22	-25	-36
Energy-intensive	7.1	-22	-26	-23	-33
Mining	3.0	-49	-56	-49	-61
Land-use change and forestry	1.4	-126	-144	-242	-291
Other	9.7	-5	-8	11	6
Total	54.2	-23	-28	-24	-35
2050					
Electricity	30.1	-76	-81	-75	-84
Transport	17.5	-41	-50	-39	-57
Agriculture	11.2	-47	-52	-46	-55
Energy-intensive	14.1	-55	-58	-55	-63
Mining	4.4	-77	-79	-73	-78
Land-use change and forestry	0.5	-1157	-1315	-1101	-1391
Other	22.2	-38	-44	-38	-48
Total	100.0	-61	-67	-60	-72

Source: Treasury estimates from GTEM.

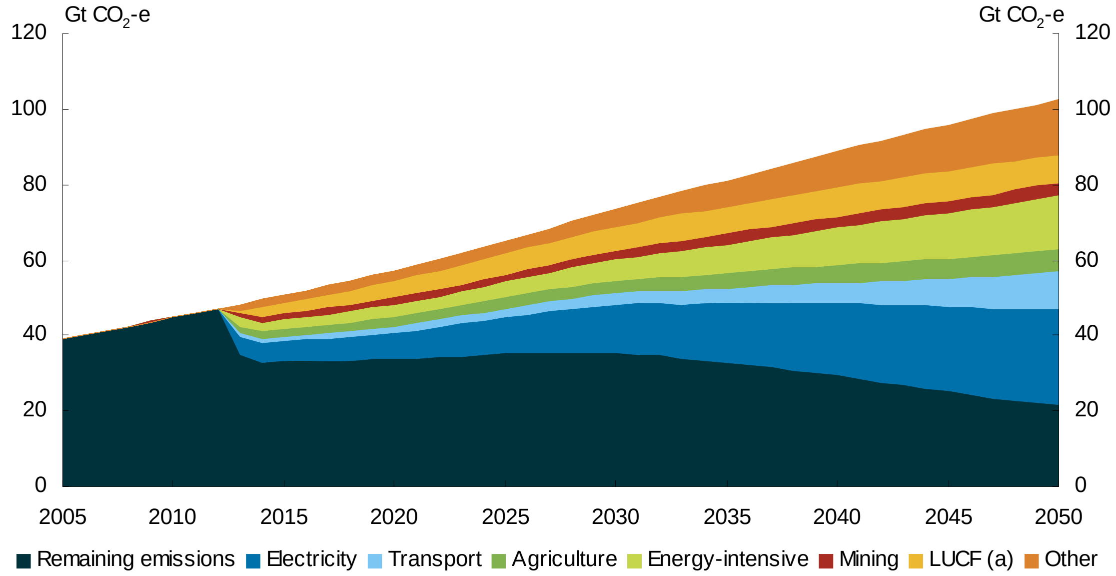
Chart 5.20: Global emissions mitigation, by sector

CPRS -5 scenario



Note: (a) Land-use change and forestry.
Source: Treasury estimates from GTEM.

Chart 5.21: Global emissions mitigation, by sector
Garnaut -25 scenario



(a) Land-use change and forestry.
Source: Treasury estimates from GTEM.

In all economies, most emissions in the reference scenario come from energy consumption and production. Consequently, mitigation opportunities from energy are important.

Energy emissions can be mitigated through a range of adjustments. Consumers and producers can reduce their demand for energy by substituting other resources for energy, such as capital. Energy sources can shift to emission-free renewables. Technology options, such as drying of coal or carbon capture and storage, could reduce emissions from fossil fuels. As the electricity sector reduces its emissions, other sectors, such as transport and industrial processes, could 'plug in' to the electricity grid (Chart 5.21).

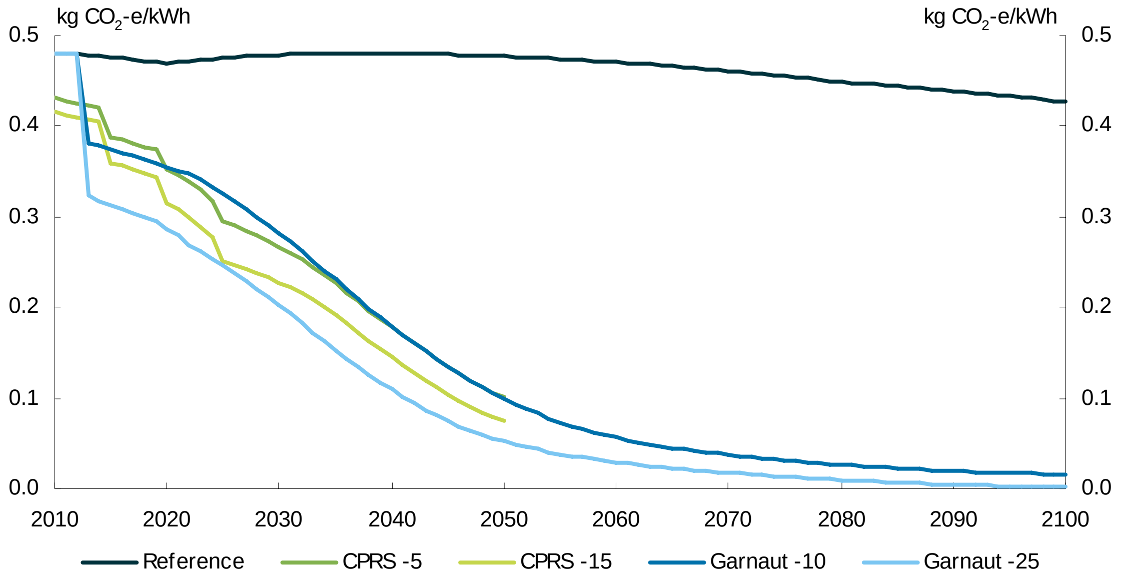
For developing economies, where non-energy emissions from agriculture and land-use change and forestry play a larger role, similar adjustment processes are expected. For agriculture, while proven low-emission options are fewer, areas of promise include changing fertiliser application methods, changes to animal management practices and changes to animal diets. For land-use change and forestry, stopping deforestation is important.

5.4.3 Electricity

Significant mitigation occurs from the electricity sector in all scenarios. By 2050, global electricity sector emissions are 75-85 per cent lower than the reference scenario.

Global electricity emission reductions are due to the decarbonisation of electricity supply through use of low and zero emission energy sources, and carbon capture and storage. The proportional decline in emission intensity of electricity generation is greater than the decline in emissions by 2050, as global electricity demand increases relative to the reference scenario, as relatively clean electricity replaces use of other more emission-intensive fossil fuels in industry and households. In all scenarios, the emission intensity of electricity generation is around 0.05 to 0.1 kg of CO_2-e per kWh by 2050, compared with just under 0.5 kg of CO_2-e per kWh in the reference scenario (Chart 5.22).

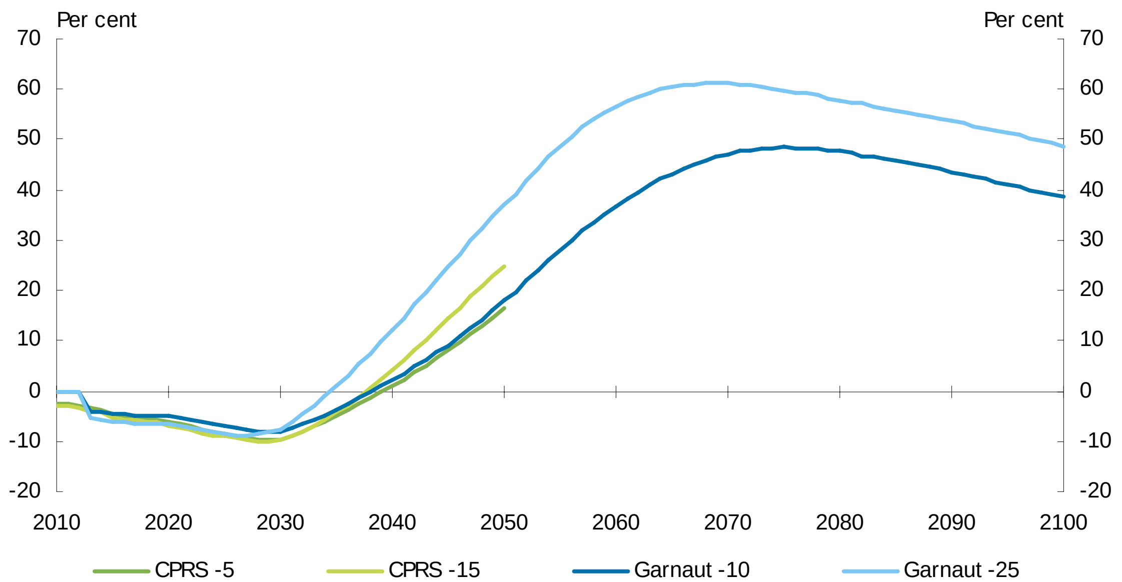
Chart 5.22: Emission intensity of world electricity generation



Source: Treasury estimates from GTEM.

Global demand for electricity, however, initially contracts in response to an emission price, reflecting higher electricity prices and reduced overall economic activity. However, over time, as the electricity sector decarbonises, demand begins to increase, relative to the reference scenario, as energy consumers switch from direct fossil fuel use towards electricity. Global electricity demand increases above reference scenario levels between 2030 and 2040 in all scenarios. The transport sector accelerates growth in global electricity demand between 2040 and 2070 through the widespread uptake of vehicles that 'plug in' to the electricity grid.

Chart 5.23: Global electricity generation, Change from reference scenario



Source: Treasury estimates from GTEM.

Electricity technologies

Fossil fuels, particularly coal, dominate global electricity generation in the reference scenario. In the policy scenarios, the emission price adds to the costs of fossil fuel-fired electricity. This makes zero emission technologies, such as renewables and nuclear, more cost competitive. Once a threshold price is reached, the emission price provides an incentive to deploy carbon capture and storage to reduce emissions from fossil fuel electricity.

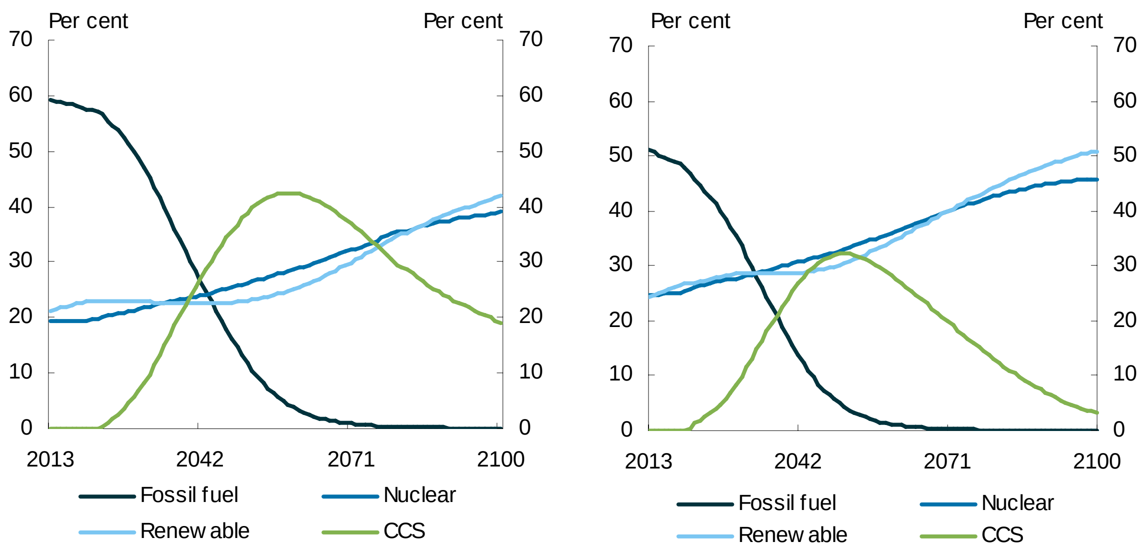
In all scenarios, fossil fuels' share falls consistently, with the fall more pronounced under the Garnaut -25 scenario due to higher emission prices (Chart 5.24). The reduction in fossil fuel initially is taken up by renewables, in particular wind and nuclear power, which are established zero emission technologies.

The share of nuclear power continues to grow. Increases in nuclear power across the range of policy scenarios are all well within the current view of available fuels and technologies (IEA, 2008; and Commonwealth of Australia, 2006). The modelling assumes nuclear power generation is available only where the nuclear power industry already exists. As a result, Australia is not assumed to have this technology available.

From the early to mid-2020s, decarbonisation accelerates as carbon capture and storage technologies are widely deployed.

Chart 5.24: Global electricity sector technology share

Garnaut -10 | Garnaut -25



Source: Treasury estimates from GTEM.

Carbon capture and storage plays a significant role in global electricity generation in the policy scenarios. This reflects abundant fossil fuel resources across the world. Carbon capture and storage begins to be commercially adopted between 2020 and 2025 in all policy scenarios. Coal carbon capture and storage is adopted first, with gas carbon capture and storage requiring a higher emission price to be competitive with conventional gas-fired generation, reflecting its lower emission intensity than coal.

While carbon capture and storage plays an important role from the 2030s, its share of global electricity generation declines from around 2050. Carbon capture and storage is assumed to capture only 90 per cent of emissions. As a result, carbon capture and storage finds it harder to compete against zero emission technologies at high emission prices. This loss of competitiveness is more pronounced in the Garnaut -25 scenario, with renewables increasing their generation share more rapidly. Sensitivities around the availability of carbon capture and storage were explored (Box 5.7).

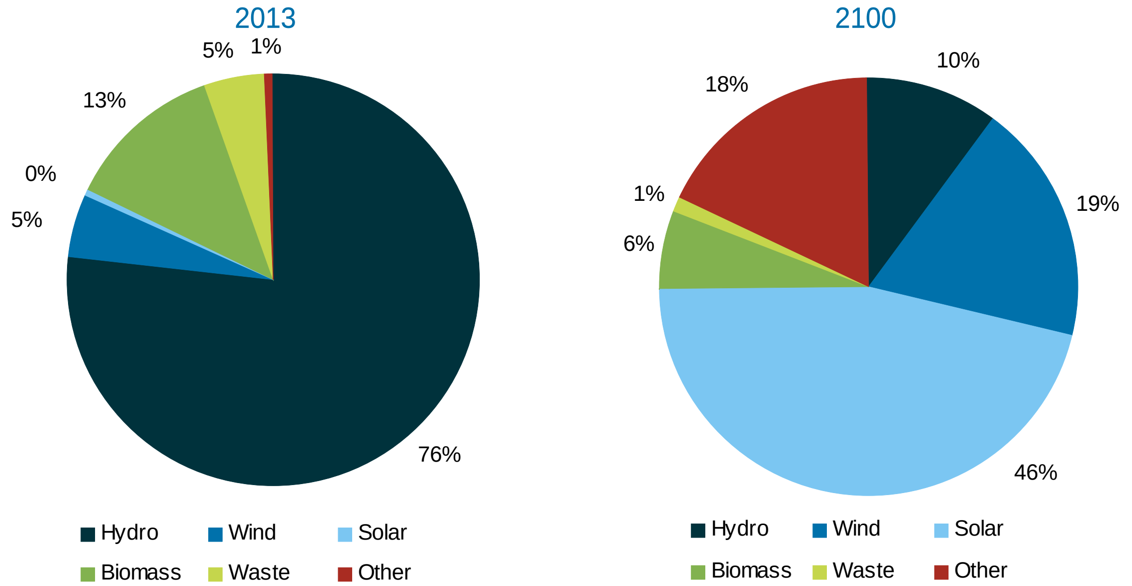
The uptake of carbon capture and storage across the range of scenarios result in the capture and storage of 900-1,600 Gt of CO_2-e globally over this century. This is well within existing estimates of global storage capacity (IPCC, 2005; and CCSP, 2007).

Under all policy scenarios, the share of electricity generation from renewables increases due to their improved competitiveness relative to emission-intensive fossil-fuel generation technologies. Initially hydro electricity accounts for most new renewable electricity generation; however, its share declines over time as constraints on available hydro resources bite.

Wind's share of electricity rises strongly in the first 20 years, as initially it is less expensive than other non-hydro renewables. However, constraints on the uptake of wind prevent a sustained long-term relative average cost decline. Solar's share increases most sharply, especially after 2050, to reach almost 20 per cent of total generation in 2100 in the Garnaut -10 scenario. This reflects significant scope for cost reductions and an abundance of widely distributed solar resources.

Chart 5.25: Composition of renewable electricity generation

Garnaut -10 scenario



Source: Treasury estimates from GTEM.

Box 5.7: The role of carbon capture and storage

How global electricity generation responds to emission pricing depends on how technology options develop, such as carbon capture and storage (IEA, 2007; Stern, 2007). While carbon capture and storage eventually may be deployable, its future role is uncertain, especially as it is currently at the demonstration stage.

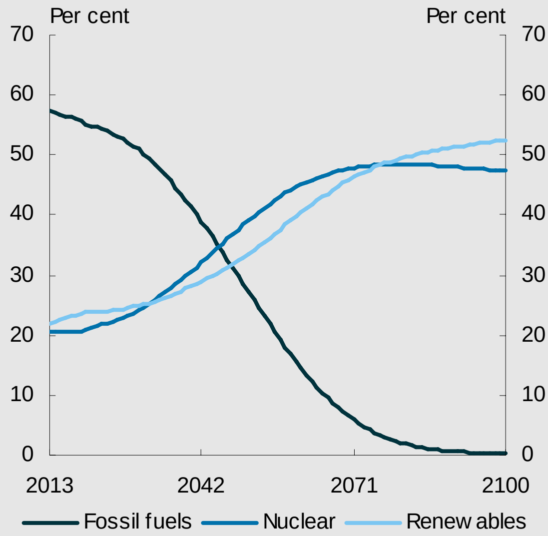
Two sensitivity scenarios, compared with the Garnaut -10 scenario, were explored: one where carbon capture and storage is not available and one where carbon capture and storage is more efficient, capturing 100 per cent of emissions compared to 90 per cent in the central scenarios.

Where carbon capture and storage is not available, the share of nuclear and renewables increases (Chart 5.26). The global renewable share increases to around 53 per cent of electricity generation by 2100, compared with around 42 per cent in the Garnaut -10 scenario. The nuclear share increases to just below 50 per cent, compared with 40 per cent in the Garnaut -10 scenario in 2100.

In the zero emission carbon capture and storage scenario, carbon capture and storage technology share of global electricity generation remains above 50 per cent after 2050, significantly higher than in the Garnaut -10 scenario, where its share declines to under 20 per cent in 2100.

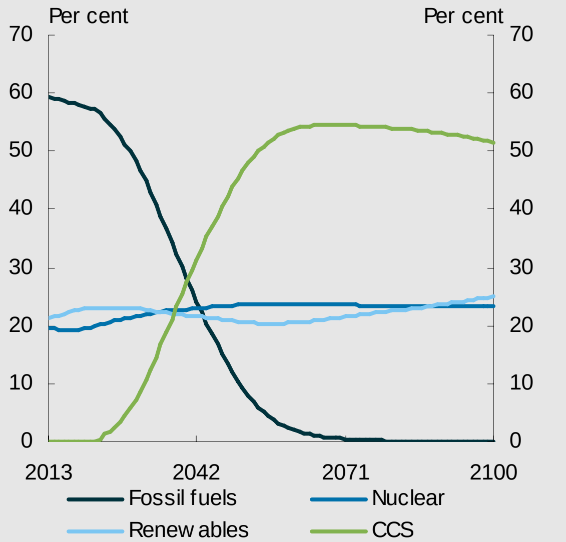
Chart 5.26: Global technology shares in electricity generation

No carbon capture and storage



Source: Treasury estimates from GTEM.

Zero emissions carbon capture and storage



Source: Treasury estimates from GTEM.

Where the emission capture efficiency of carbon capture and storage rises to 100 per cent, global mitigation costs are 9 per cent lower in 2050 and 16 per cent lower in 2100 compared to the Garnaut -10 scenario. More mitigation is done by coal, at lower cost, reducing the emission price needed to achieve stabilisation.

Where carbon capture and storage technology is not available, global mitigation costs are around 10 per cent higher in 2050. The costs of competing technologies are only marginally higher than carbon capture and storage, capping the mitigation cost increase.

Australian mitigation costs are more than the global average. Without carbon capture and storage, Australian mitigation costs rise by 23 per cent in 2050.

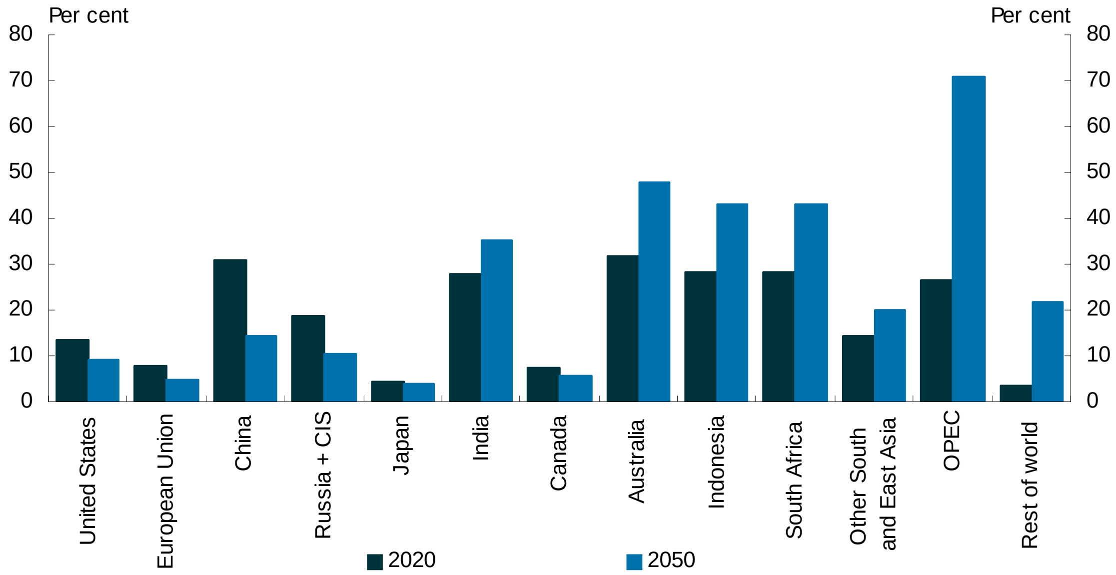
Electricity prices

The impact of emission pricing on electricity prices varies considerably across economies, reflecting large differences in technologies used to generate electricity and the sector's emission intensity.

Australia's price impacts are greatest in the CPRS -5 scenario in 2020, when supply prices rise by over 30 per cent. In 2050, Australia's electricity price impacts remain high, 50 per cent higher than the reference scenario.[5] Where nuclear, gas and hydro contribute to a large share of electricity, price changes in electricity generation are considerably smaller. Electricity prices in Japan, European Union, United States and Canada increase by less than 10 per cent compared with the reference scenario in 2050. This large price variation plays an important role in influencing the comparative advantage in producing electricity-intensive commodities.

Some regions' electricity prices initially rise before easing over time, despite the rising emission prices, as new electricity-generating technologies are introduced. Learning by doing[6] can lower the costs of low emission but immature technologies in the longer term. Long-term electricity price changes in the CPRS -15 and Garnaut -25 scenario are fairly similar to the CPRS -5 scenario, despite the higher emission prices. Initially, however, the electricity price impacts are higher in the CPRS -15 and Garnaut -25 scenarios as a result of the higher emission price.

Chart 5.27: Regional electricity supply prices
Change from reference, CPRS -5 scenario



Source: Treasury estimates from GTEM.

5 These estimates are from GTEM. Bottom-up electricity modelling estimates of price increases for Australia are discussed in Chapter 6.

6 Learning-by-doing is when technology costs fall due to greater use of a technology, such as incremental innovations. Changes to learning rates change the rate at which these improvements occur.

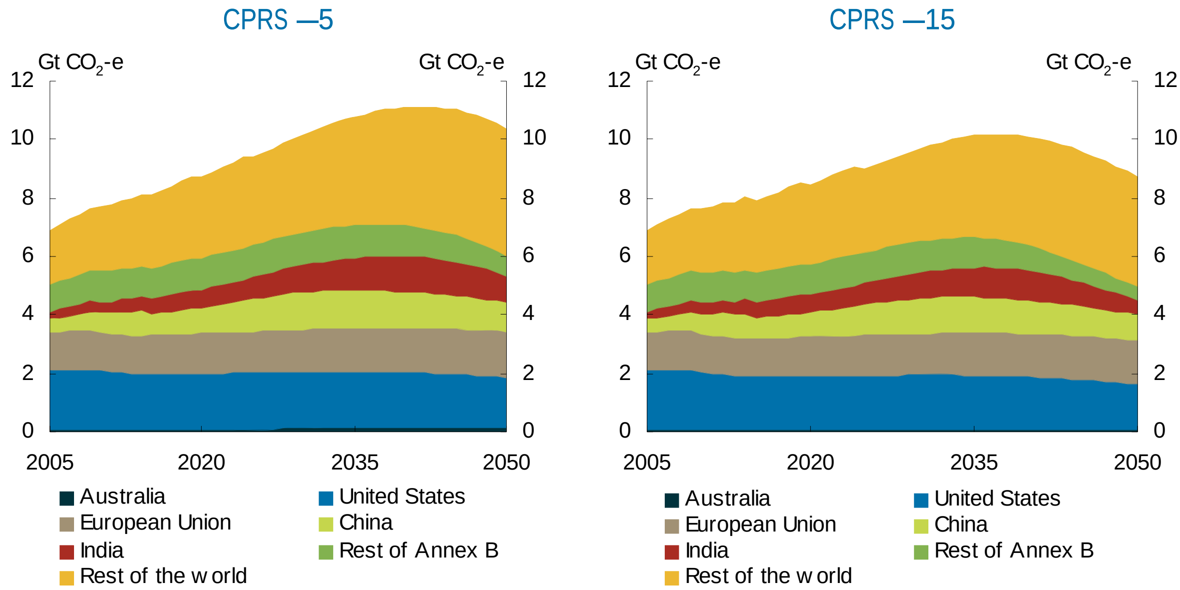
5.4.4 Transport

Global transport emissions grow to 2050, as demand strengthens and emission intensity improves only moderately with the uptake of energy-efficient vehicles and hybrids. Global transport emissions grow 0.1-1.0 per cent per year on average to 2050. This compares with growth in the reference scenario of more than 2 per cent per year to 2050. Emissions decline by around 41-59 per cent relative to the reference scenario across all scenarios by 2050. Similar mitigation occurs across water, air and land transport.

Strongest growth in transport emissions occurs where income growth is most rapid, including China, India and the rest of world, which includes other fast growing developing economies.

Mitigation in transport is considerably less than for electricity generation as petroleum remains the primary source of fuel to 2050.

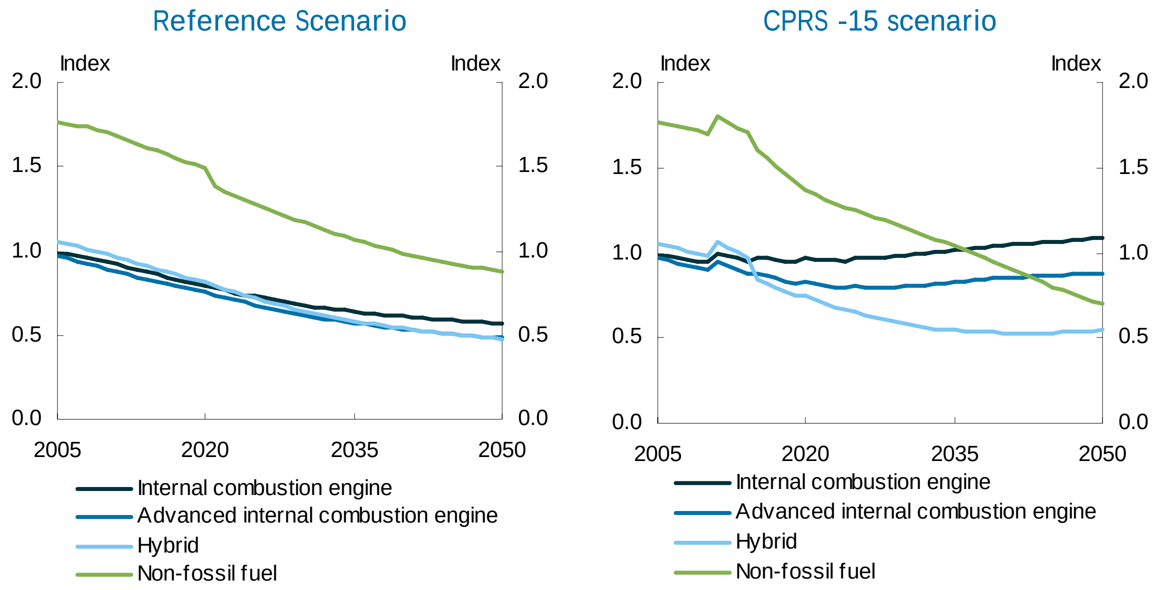
Chart 5.28: Global transport emissions



Source: Treasury estimates from GTEM.

Fuel-efficient vehicles, including hybrid vehicles and advanced internal combustion engines, are deployed widely, contributing noticeably to mitigation in 2050 (Chart 5.29). Around 2050, the emission price makes advanced vehicle technologies competitive with alternatives. Consequently, significant mitigation in transport occurs after 2050.

Chart 5.29: Cost of transport technology

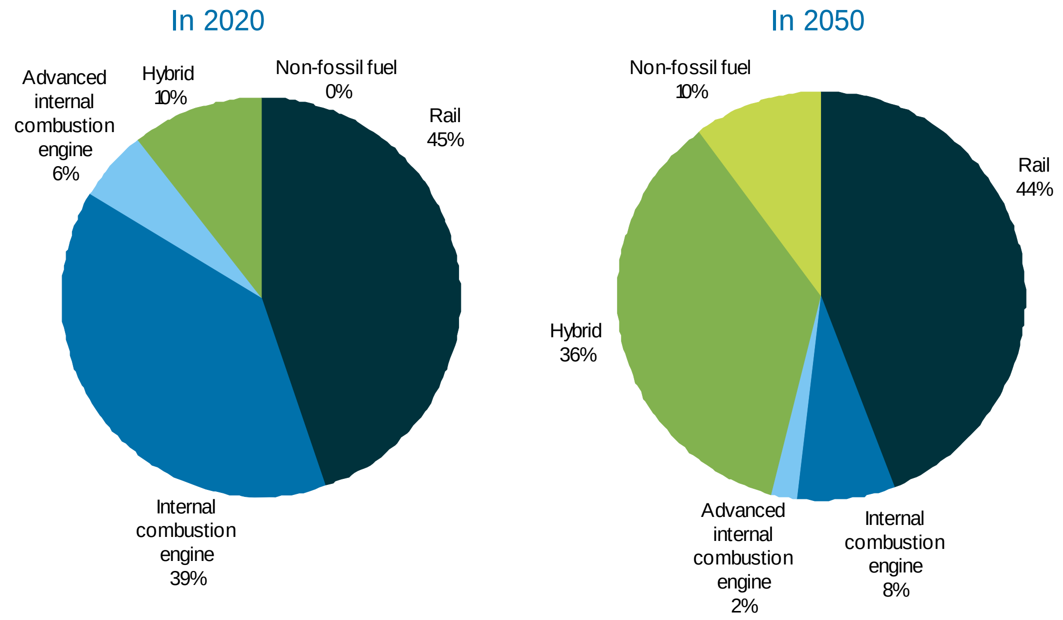


Note: Indexed relative to costs of internal combustion engine technology in 2001.
Source: Treasury estimates from GTEM.

The uptake of more advanced vehicle technologies is more pronounced in the CPRS -15 scenario, with hydrogen and electric vehicles comprising 10 per cent of road transport, compared with the CPRS -5 scenario of around 5 per cent (Chart 5.30). In the Garnaut -25 scenario, hydrogen and electric vehicles comprise almost 45 per cent of total road transport by 2050.

Chart 5.30: Transport technology shares

CPRS -5 scenario



Source: Treasury estimates from GTEM.

Box 5.8: Electric vehicles and fuel cell technology

An electric motor with a large rechargeable battery powers electric vehicles. The batteries are powered by plugging in to the electricity grid. These vehicles do not produce any emissions. The energy source of the electricity determines the emissions.

Batteries are expensive. This is the biggest barrier to success for these vehicles. Electric vehicles could cost around US$10,000 more than a comparable hybrid (plug-in) vehicle (IEA, 2008). These costs would drop if passengers accepted more frequent recharging.

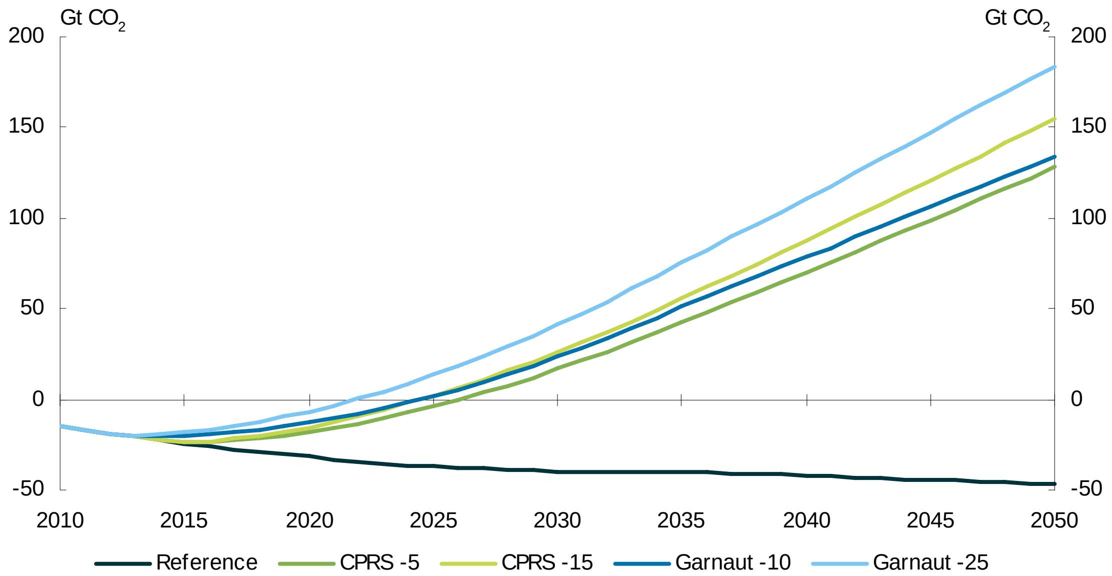
Fuel cells are electrochemical devices that convert hydrogen and oxygen into water to produce energy. An electric motor propels fuel-cell vehicles, and electricity is produced within the vehicle. These vehicles generally store hydrogen on board or in a blend with ethanol.

For fuel-cell vehicles to become viable, the cost must drop significantly. Fuel-cell vehicles cost at least US$100,000 and a bus costs up to US$1 million (IEA, 2008). Even with large-scale production, the costs of the fuel-cell 'stacks' in the vehicle are likely to remain high. Systems for storing hydrogen are currently costly.

5.4.5 Land-use change and forestry

The emission prices across policy scenarios dramatically reduce deforestation rates, and stimulate large scale reafforestation. Globally, land-use change and forestry provide a cumulative net global sink of 130-180 Gt CO_2 to 2050. Asia (excluding China and India) contribute the largest forest sinks across the range of scenarios to 2050.

Chart 5.31: Cumulative global sequestration from land-use change and forestry



Note: Sequestration rates vary from year to year, depending on the amount of land planted, growth rates, harvesting and other factors.
Source: Lawrence Berkeley National Laboratory estimates from GCOMAP.

Box 5.9: Future transport fuels

Biofuels

Different types of biofuels include liquid forms, such as ethanol and biodiesel, and gaseous forms, including methane and hydrogen. Liquid fuels are compatible with existing technology and infrastructure, and the feedstock conversion is either first or second generation. First generation biofuels are already under production based on food-crop feedstocks; second generation biofuels come from ligno-celluosic feedstock, such as straw and wood (IEA, 2006).

In some developing economies, production of first generation biofuels is associated with deforestation and rising food prices. Second generation biofuels have the promise of being high-yielding and sustainable without competing with the world's food supply. Costs are the biggest barrier to a wider uptake of biofuels.

Hydrogen

Hydrogen can be used directly in an internal combustion engine, but most likely will be used with fuel cell propulsion systems. Hydrogen is most likely to be used in cars, buses and small trucks. Long haul trucks, shipping and aircraft are less likely to use hydrogen due to their long range requirements. The shift to an entire new system of vehicle would require strong policy interventions and financial support from governments around the world (IEA, 2008).

Hydrogen could have high fuel efficiency and near zero greenhouse gas emissions. However high costs and shorter ranges require more refuelling, and longer refuelling times are issues. In addition, hydrogen has no major production or distribution system anywhere in the world. Hydrogen production is energy intensive, and to offer genuine emission reductions would need to be produced using low-emission energy sources.

In addition, hydrogen storage, distribution and delivery are undeveloped. Total overall infrastructure worldwide could be trillions of dollars (IEA, 2008).

Other fuels

Non-conventional oil sources include tar sands, shale oil and heavy oil; they are more costly to extract than conventional oil sources and more emission intensive (IEA, 2006). Coal and gas can be converted to liquid fuels through Fischer-Tropsch synthesis. These fuels are more costly to produce and are more emission intensive than conventional oil fuel sources.

In Africa, cumulative emissions from deforestation are over 90 per cent below reference scenario levels by 2050. To 2050, African forests provide a net sink of 1.3-7 Gt CO_2, in contrast to a net source of almost 60 Gt in the reference scenario. Similar trends occur in South American forests; cumulative emissions fall to 7-17 Gt CO_2 by 2050, rather than 60 Gt in the reference scenario. China and India establish only relatively small forest sinks, reflecting limits on the availability of land; the European Union and United States establish large net sinks by 2100.

Table 5.22: Global land-use and forestry sequestration
Cumulative 2005-2050

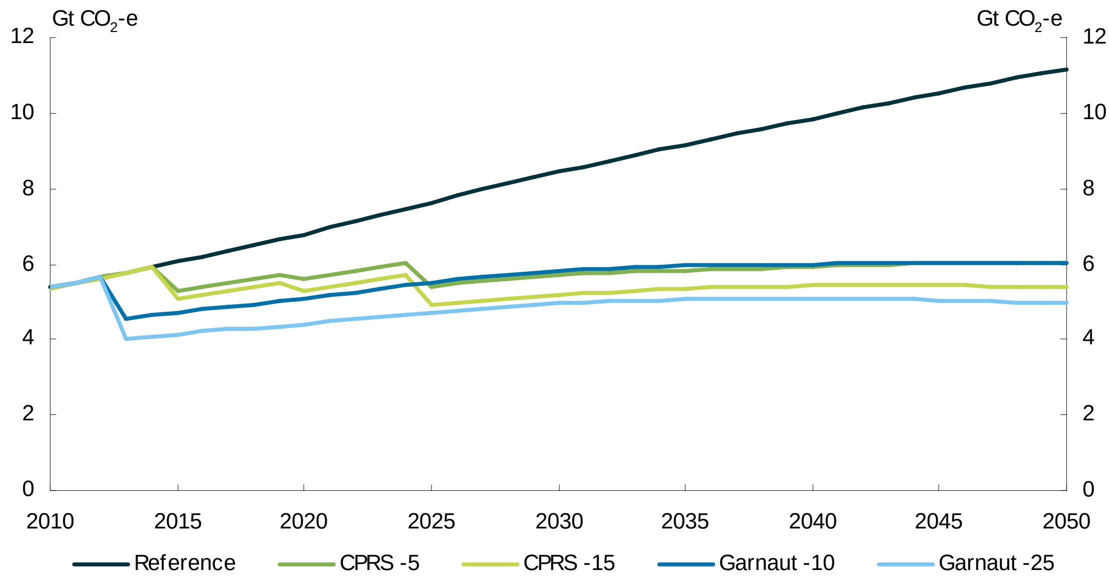
	Reference	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Gt CO_2	Gt CO_2	Gt CO_2	Gt CO_2	Gt CO_2
Africa	-57	-7.0	-5.5	-4.1	-1.3
Central America	-6.1	-1.5	-1.0	-1.4	-0.5
China	16	17	17	17	17
European Union	3.8	15	19	15	22
India	9.0	9.5	9.5	9.1	9.1
Oceania	3.3	7.2	9	7.4	10.6
Rest of Asia	26	58	71	58	82
Russia	3.7	8.8	8.8	9.4	9.4
South America	-61	-17	-11.5	-16	-7
United States	16	37	39	39	42
Total	-47	128	155	134	184

Note: These estimates do not include emissions from land-use change in Australia.
Source: Lawrence Berkeley National Laboratory estimates from GCOMAP.

5.4.6 Agriculture

Agriculture generates relatively modest mitigation, with emission levels increasing to 2050. The emission intensity of production improves over time, but output grows strongly as living standards in developing economies rise, shifting consumers towards emission-intensive livestock products. Agriculture accounts for around 17 per cent of global emissions in 2050 in the Garnaut-10 scenario, compared with only 11 per cent in the reference scenario, rising to over 41 per cent of global emissions by 2100, compared with 12 per cent in the reference scenario. The industry structure is highly aggregated in GTEM, so it could underestimate substitution opportunities from high-emission to low-emission agricultural products.

Chart 5.32: Global agriculture emissions



Source: Treasury estimates from GTEM.

5.4.7 Other

In energy-intensive sectors, mitigation occurs through uptake of low-emission technologies and fuel substitution away from fossil fuels. Global demand for these sectors deviates little from the reference scenario in all policy scenarios.

In both the resource processing and other emission-intensive manufacturing sectors, emissions decline 22-38 per cent relative to the reference scenario in 2020, with the greatest declines occurring in the Garnaut -25 scenario. In 2050, emissions decline by around 57-71 per cent across all scenarios.

Table 5.23: Direct and indirect emissions for other emission-intensive sectors
Change from reference scenario

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent				Per cent			
Resource processing	-23	-29	-24	-38	-57	-64	-57	-70
Other emission-intensive manufacturing	-22	-27	-23	-32	-60	-65	-59	-71

Source: Treasury estimates from GTEM.

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Chapter 6: Mitigation scenarios — Australian results

Key points

Large reductions in emissions do not require reductions in economic activity because the economy restructures in response to emission pricing.

Australia's aggregate economic costs of mitigation are small. Costs to sectors and regions vary widely: growth in emission-intensive sectors slows, and growth in low and negative emission sectors accelerates.

Real household incomes continue to grow, although households face higher prices for emission-intensive products, such as electricity and gas.

Some costs are unavoidable and would arise regardless of whether Australia chooses to participate in the global mitigation effort. These costs arise from other economies' actions, particularly through trade in energy- and emission-intensive commodities.

Australia's mitigation costs are higher than most developed economies due to its large share of emission intensive industries.

International trade in permits reduces the cost of Australia's contribution to the global mitigation effort. Australia's emissions fall significantly once new low-emission electricity generation technologies become cost-effective.

Allocation of some free permits to emission-intensive trade-exposed sectors, as the Government proposes, eases their transition to a low-emission economy in the initial years. Shielding redistributes costs from shielded to unshielded sectors, and could redistribute costs amongst shielded sectors.

Australia's comparative advantage will change in a low-emission world. Impacts on Australian producers will depend largely on their emission-intensity relative to other producers.

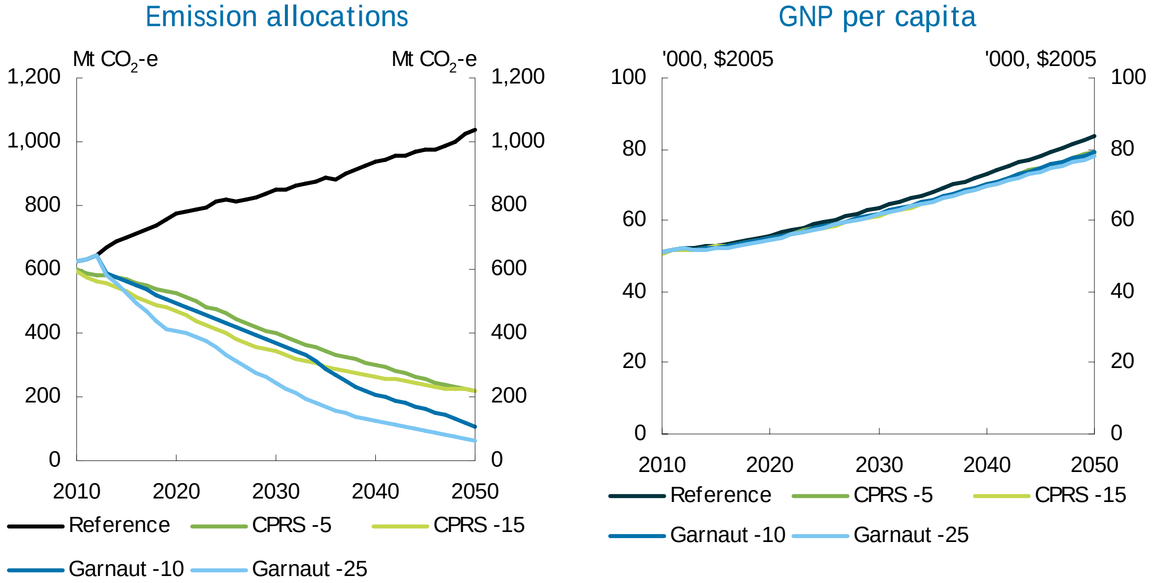
Lower demand for Australia's emission-intensive commodity exports could generate benefits for other export-oriented and import-competing industries through its impact on Australia's exchange rate.

All scenarios show Australia, at the-whole-of-economy level, can achieve substantial emission reductions with relatively small reductions in economic growth (Chart 6.1). From 2010 to 2050, Australia's real GNP per capita grows at an average annual rate of 1.1 per cent in the policy scenarios, compared to 1.2 per cent in the reference scenario.[1] By 2020, real GNP per capita is around 9 per cent above current levels, compared to around 11 per cent in the reference scenario. By 2050, real GNP per capita is 55-57 per cent above current levels, compared to 66 per cent in the reference scenario.

1 GNP (Gross national product) measures the total output of the Australian economy and international income transfers. It is a more complete measure of the current and future consumption possibilities available to Australians than GDP (Gross Domestic Product) (Box 2.3).

Emission pricing has a slightly smaller impact on Australia's GDP, as GDP does not include income transfers associated with international emissions trading. From 2010 to 2050, real GDP per capita grows at an average annual rate of 1.2-1.3 per cent in the policy scenarios, compared to 1.4 per cent in the reference scenario.

Chart 6.1: Australian emission allocations and GNP per capita



Note: Emission allocations will differ from actual emissions due to banking of permits and international trade in permits. Comparable Australian results were obtained in GTEM and G-Cubed.
Source: Treasury estimates from MMRF.

While mitigation policies impose relatively small aggregate costs on Australia, impacts will vary widely across sectors and regions. Putting a price on emissions drives a structural shift in the economy, from emission-intensive goods, technologies and processes, towards low-emission goods, technologies and processes. As a result, growth in emission-intensive sectors slows, and growth in low and negative-emission sectors accelerates. This transformation will shift investment and employment between sectors.

This chapter explores how Australia could manage the transformation to a low-emission economy. In particular, this chapter reports the extent of emission reductions and the economic impact at the national, regional, sectoral and household levels of the Australian economy for four alternative policy scenarios. In doing so it draws on the MMRF, GTEM, G-cubed and PRISMOD models.

6.1 Impact on emissions

6.1.1 Emission allocation

Australia can meet its allocated emission target either through domestic mitigation, such as adopting low-emission technologies, or the purchase of permits from overseas or a combination of both.

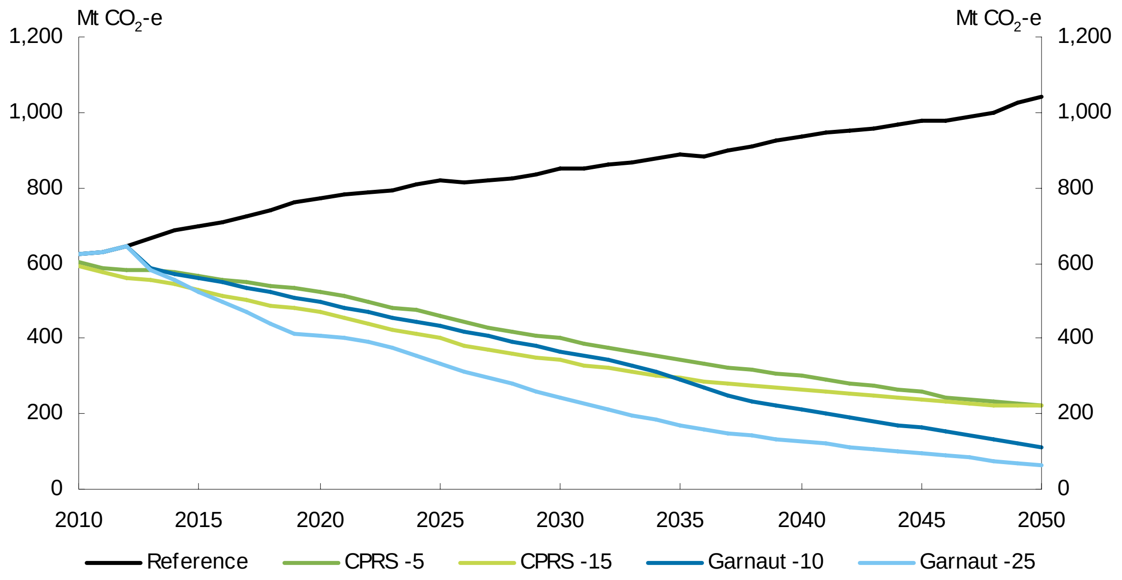
Each policy scenario has a different emission allocation for all countries, including Australia, (Table 6.1 and Chart 6.2).[2] Generally, the more stringent the environmental target the lower Australia's and other countries' allocations. As in Chapter 5, emission allocations in the Garnaut scenarios use the contraction and convergence approach. And, allocations in the CPRS scenarios use the multi-stage approach. Australia's emission allocation significantly affects mitigation costs as measured by the impact on GNP. Allocations influence the number of emission permits bought or sold in the international market.

Table 6.1: Mitigation scenarios

	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
Emission stabilisation goal (CO_2-e ppm)	550	510	550	450
Emission target (per cent change from 2000 levels)				
2020	-5	-15	-10	-25
2050	-60	-60	-80	-90
Australian permit price (CO_2-e)				
Start of scheme ($nominal)	23	32	30	52
2020 ($2005 prices)	35	50	35	60
2050 ($2005 prices)	115	158	114	197

Note: The CPRS scenarios start in 2010. The Garnaut scenarios start in 2013. The CPRS -5 price is A$30 in 2013, the same as the Garnaut -10 scenario.
Source: Treasury estimates from MMRF.

Chart 6.2: Australia's emission allocation



Source: Treasury estimates from MMRF.

6.1.2 Emission prices

International markets set the global emission price. Australia's emission price will equal this global price, adjusted for exchange rate changes, if there are no binding restrictions on international emissions trade. Changes to Australia's actual emission level will change the number of permits Australians buy or sell, rather than the price of permits in Australia.

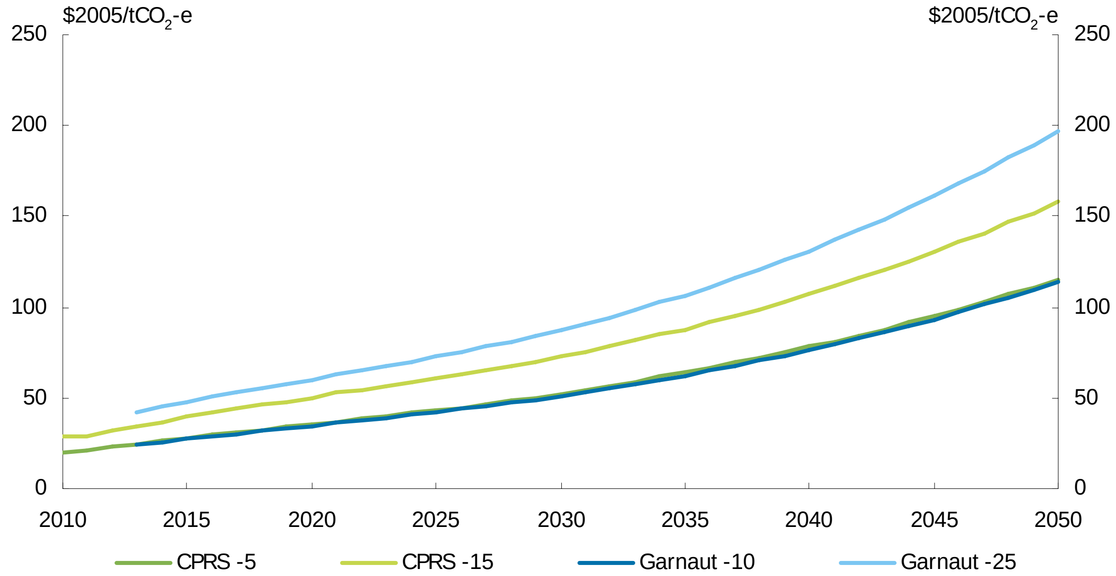
As discussed in Chapters 4, the global price is assumed to be set efficiently. With unlimited banking and an allocation approach that requires no borrowing, firms will allocate the finite

2 Chapters 4 and 5 describe the allocation of emission rights to Australia under alterative scenarios in detail.

global emissions budget efficiently through time. Emission prices (in global currency terms) rise exponentially at a real rate of 4 per cent per year.

More stringent stabilisation targets require higher emission prices (Table 6.1 and Chart 6.3). The CPRS -5 scenario has a very similar price path to the Garnaut -10 scenario, as they have the same greenhouse gas concentration stabilisation target. The CPRS -15 scenario, which has a stabilisation level at around 510 ppm, has emission prices between the Garnaut -25 and CPRS -5 scenarios.

Chart 6.3: Australian emission price



Note: Prices are in 2005 Australian dollars.
Source: Treasury estimates from MMRF.

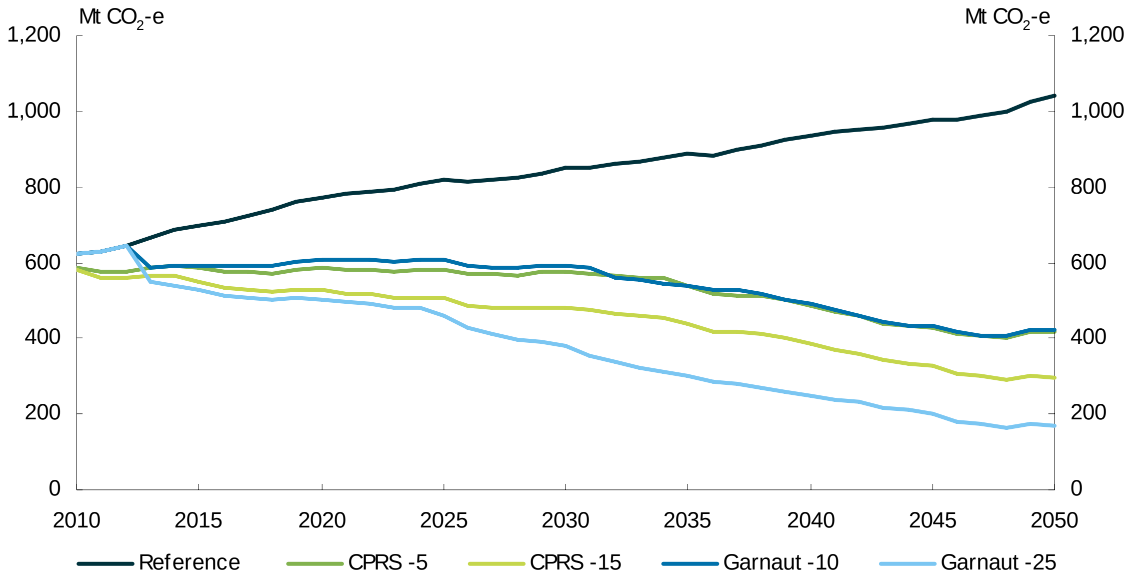
6.1.3 Domestic mitigation

Putting a price on emissions breaks the link between economic activity and emissions. It allows for significant cuts in emissions without large economic costs. In all policy scenarios, the emission intensity of GDP falls significantly. New technologies and production processes increase the emissions efficiency of production and demand for low-emission-intensive products, such as consumers choosing to use public transport. This moves the composition of the Australian economy towards low-emission industries.

Emission reductions occur at different rates across sectors and over time. The ability to reduce emissions when it is cheap to do so, through a market-based mechanism, keeps mitigation costs as low as possible.

Australia's actual greenhouse gas emissions are reduced significantly across all policy scenarios (Chart 6.4). In the CPRS -5 scenario, while emissions in 2020 are broadly the same as current levels, they are 25 per cent lower than the reference scenario, before falling to 60 per cent below the reference scenario in 2050.

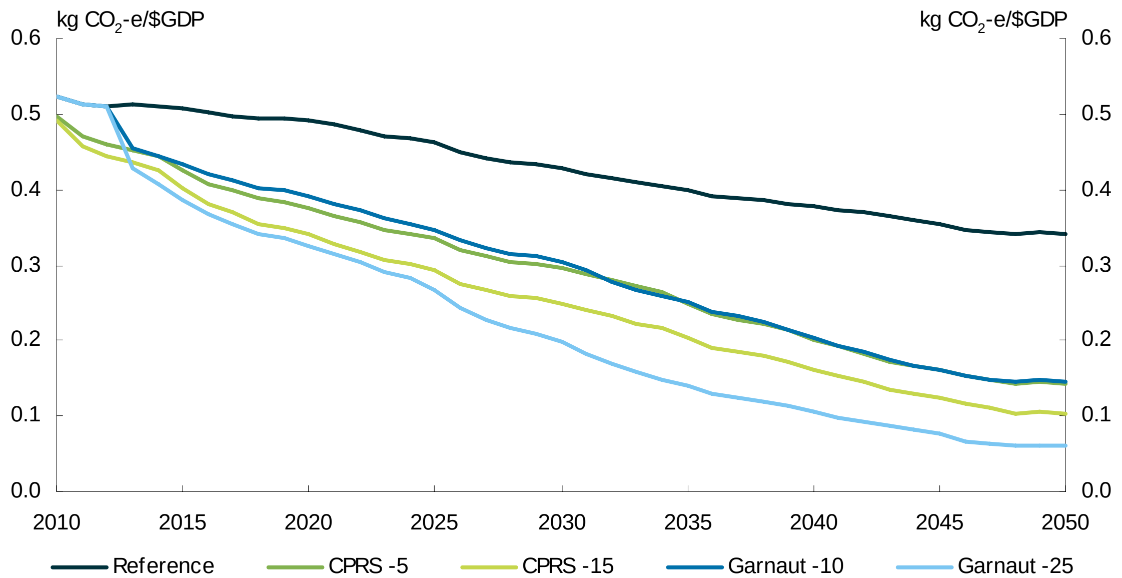
Chart 6.4: Australia's emission pathways



Source: Treasury estimates from MMRF.

Australia's emission reductions result primarily from a reduction in the emission intensity of GDP rather than reductions in actual GDP (Chart 6.5). The emission intensity of the Australian economy is reduced from around 0.6 kg CO_2-e/\$GDP in 2005 to less 0.15 kg CO_2-e/\$GDP in 2050.

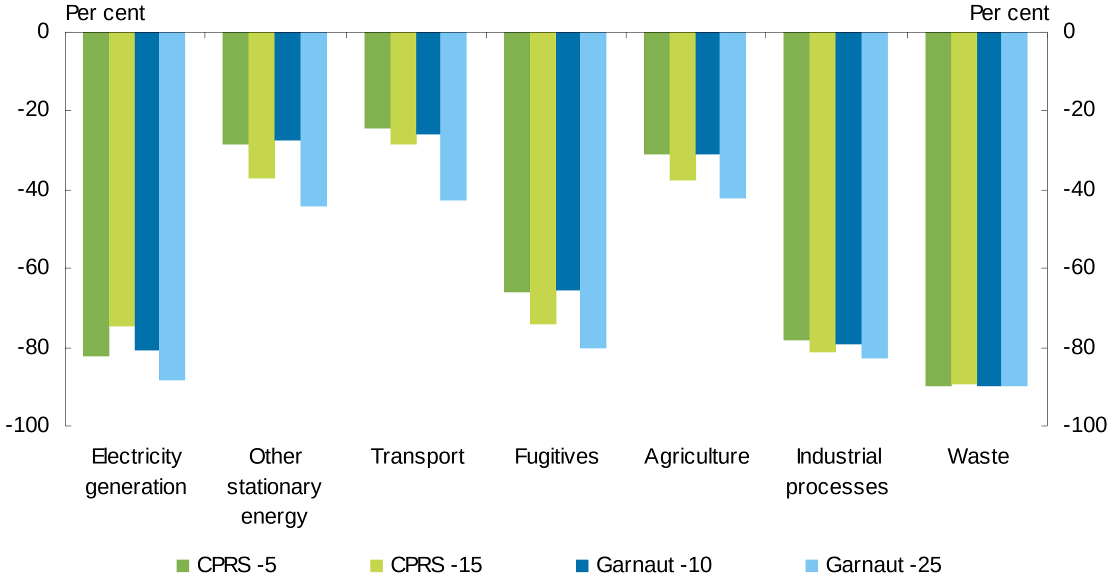
Chart 6.5: Emission intensity of GDP



Source: Treasury estimates from MMRF.

Mitigation opportunities vary greatly across sectors and over time. All sectors reduce emissions relative to the reference scenario in all the policy scenarios. By 2050, the greatest percentage reduction in emissions occurs in the waste, industrial process and electricity generation sectors relative to the reference case (Chart 6.6). Emissions from fugitives are reduced by over 60 per cent. Less mitigation is achieved in the other stationary energy, transport and agriculture sectors. Mitigation in these sectors is more costly and household demand is more inelastic.

Chart 6.6: Sector emissions
Change from reference scenario, 2050



Source: Treasury estimates from MMRF.

The shares of emission reductions across sectors reflect the quantity of emissions (with sectors having more emissions better able to reduce emissions) and the potential mitigation costs within each sector (Chart 6.7).

The electricity generation sector provides the largest share of emission reductions; 44 per cent by 2050. This sector moves towards low-emission technologies, such as carbon capture and storage and renewable sources including wind, solar and geothermal. Reduced emissions in the electricity sector drive reductions in energy-related emissions in other sectors, as fossil fuel users switch to electricity, particularly in transport where the share of hybrid and full electric plug-in motor vehicles increases over time.

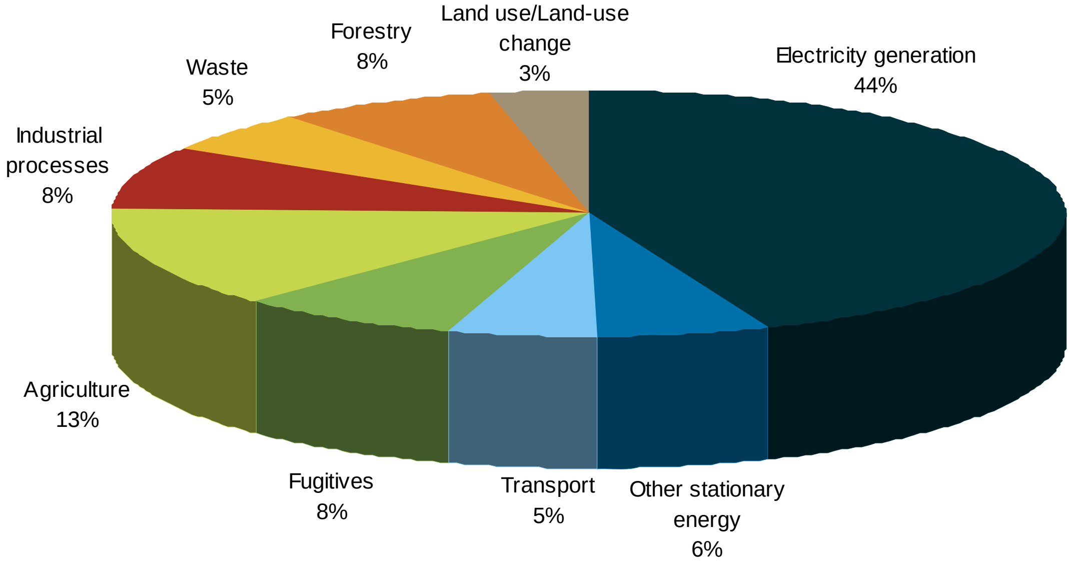
Agriculture has more costly mitigation than other sectors, as most emissions occur naturally and fewer technological options are available. Mitigation options currently available include changes in land and animal management, and substitution between activities within agriculture.

Emissions from the transport sector are reduced from weakening demand for transport, fuel switching and purchases of more fuel-efficient vehicles in the road transport sector. Opportunities for water and air transport mitigation are more costly, and demand in these sectors remains strong, in line with higher incomes.

The forestry sector also responds to emission pricing, particularly through the establishment of sequestration forests, which provide a source of relatively low-cost mitigation.

Chart 6.7: Share of cumulative emission reductions by sector

CPRS -5 scenario, 2010-2050

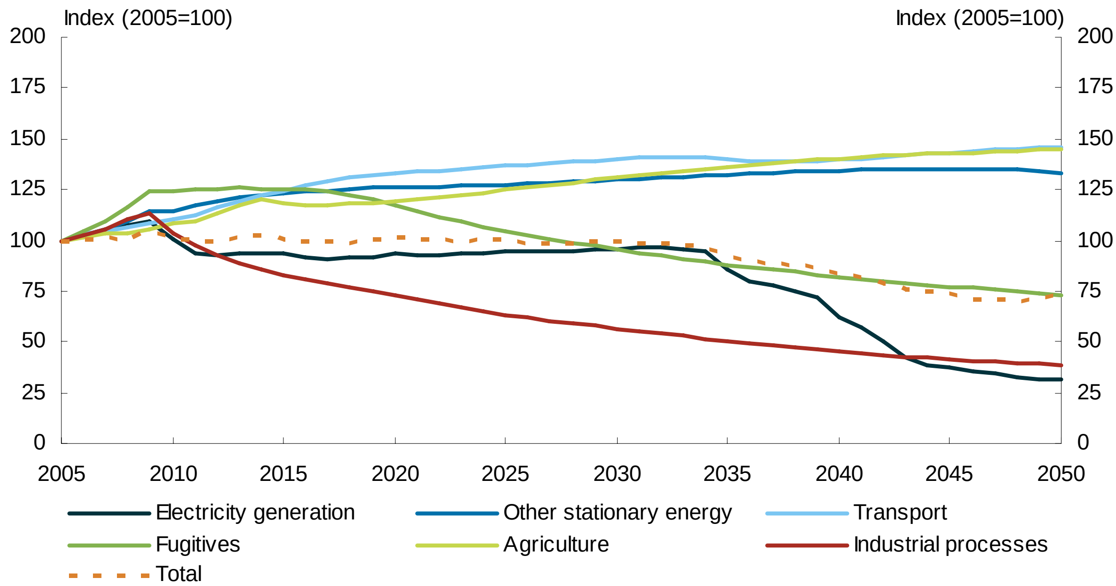


Source: Treasury estimates from MMRF.

Although all sectors show mitigation relative to the reference scenario, reductions in emission intensities are slower where mitigation costs are higher. Emissions in some sectors continue to grow reflecting output growth, and relatively high mitigation costs. In the electricity generation sector emissions do not fall significantly, relative to current levels, until the mid-2030s when additional technology options become available (Chart 6.8). This spread of mitigation across sectors highlights the value of market-based mechanisms, which allow abatement to occur where mitigation costs are lowest.

Chart 6.8: Sector emissions

CPRS -5 scenario



Note: Emissions from forestry are not reported.
Source: Treasury estimates from MMRF.

Australian emissions plateau until the emission price facilitates large-scale commercial deployment of carbon capture and storage in the electricity sector. In the CPRS -5 scenario, Australia's emissions remain at around 2005 levels until the mid 2030s, with Australia meeting its reduction targets by purchasing lower cost global permits. Australia's emissions fall significantly beyond this time as carbon capture and storage technology is adopted. In the Garnaut -25 scenario, higher emission prices associated with larger global emission reductions cause commercial deployment of carbon capture and storage earlier, from around 2026.

While the modelling suggests carbon capture and storage technologies become a commercial alternative for electricity generation, this is not crucial for the aggregate mitigation cost results. If alternative technologies are adopted at similar emission prices, overall mitigation costs would be broadly unchanged. However, global adoption of carbon capture and storage technology will affect significantly the long-term viability of Australian's coal industry.

6.2 Impact on the Australian macroeconomy

6.2.1 Gross national product

The introduction of emission pricing will reduce Australia's GNP per capita compared with the reference scenario, but GNP per capita continues to grow across all the mitigation scenarios (Table 6.2 and Chart 6.9).

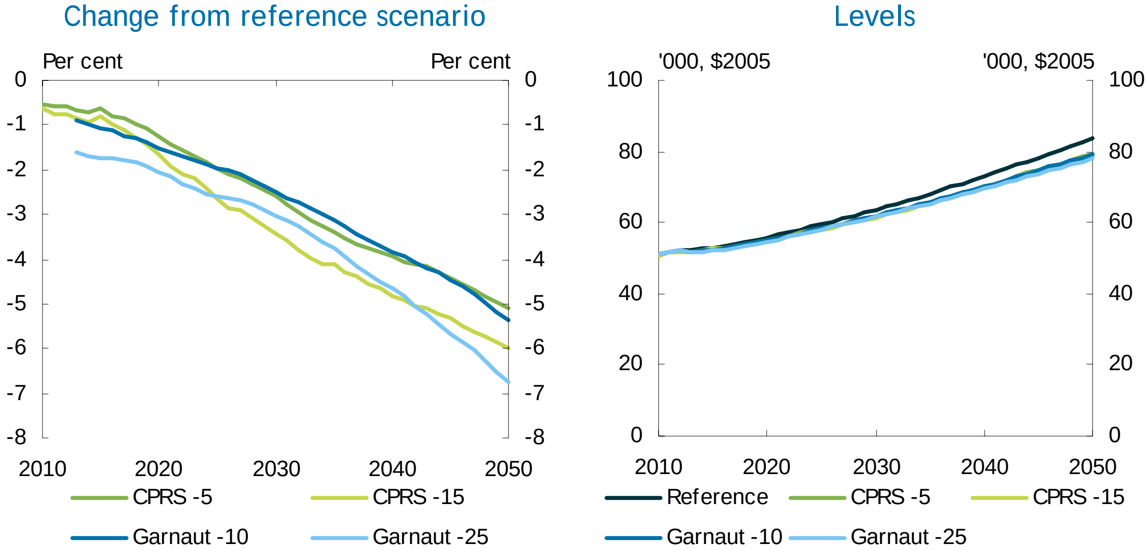
Table 6.2: GNP per capita annual growth rates

	Reference Per cent	CPRS -5 Per cent	CPRS -15 Per cent	Garnaut -10 Per cent	Garnaut -25 Per cent
2010s	0.9	0.8	0.8	0.7	0.7
2020s	1.3	1.2	1.1	1.2	1.2
2030s	1.4	1.3	1.2	1.3	1.2
2040s	1.4	1.3	1.3	1.2	1.2
Average	1.2	1.1	1.1	1.1	1.1

Source: Treasury estimates from MMRF.

The reduction in GNP in 2050 relative to the reference scenario level is around 5.1 per cent in the CPRS -5 scenario and 6.7 per cent in the Garnaut -25 scenario; however, GNP per capita is roughly 1.5 times larger in 2050 than in 2008 (Chart 6.9).

Chart 6.9: GNP per capita



Source: Treasury estimates from MMRF.

GNP is reduced partially through reductions in production (GDP) in Australia, increased income transfers to overseas associated with international permits and reductions in the terms of trade, but is also affected by changes in interest payments on foreign borrowing, and changes in equity payments made to foreign investors.

Australian GNP costs are higher than those in other developed economies, because Australia is a relatively emission-intensive economy. Australia has developed a comparative advantage in high energy and emission-intensive industries such as mining, resource processing industries fossil fuels and agriculture.

6.2.2 Gross domestic product

The impact on output, or GDP, is similar to GNP. From 2010 to 2050, growth in the mitigation scenarios is 2.2-2.3 per cent, slightly slower than the 2.4 per cent in the reference scenario (Table 6.3).

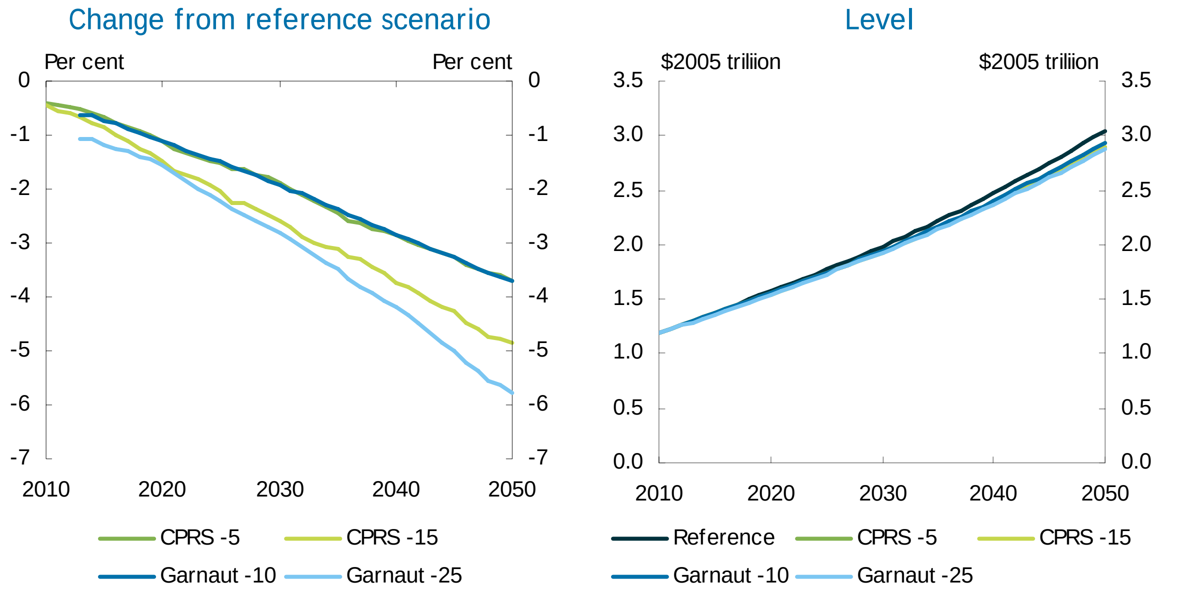
Table 6.3: GDP annual growth rates

	Reference Per cent	CPRS -5 Per cent	CPRS -15 Per cent	Garnaut -10 Per cent	Garnaut -25 Per cent
2010s	2.8	2.7	2.7	2.7	2.6
2020s	2.3	2.3	2.2	2.3	2.2
2030s	2.2	2.1	2.1	2.1	2.1
2040s	2.1	2.0	2.0	2.0	1.9
Average	2.4	2.3	2.3	2.3	2.2

Source: Treasury estimates from MMRF.

The reduction in the level of GDP in 2050 relative to the reference scenario ranges from 3.7-5.8 per cent across the scenarios; however, GDP is roughly three times larger in 2050 than in 2005 (Chart 6.10).

Chart 6.10: Gross domestic product



Source: Treasury estimates from MMRF.

Table 6.4: Headline national indicators

	2020					2050				
	Reference	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	Reference	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
Emissions response										
Emission allowance per cent change from 2000 level	n/a	-5.0	-15.0	-10.0	-25.0	n/a	-60.0	-60.0	-80.0	-90.0
Australian emissions price, real A$2005/tCO2e	n/a	35	50	35	60	n/a	115	158	114	197
Actual emissions (pre-trade), Mt $C0_2$-e										
MMRF	774	585	529	608	505	1039	420	297	425	171
GTEM	716	568	507	568	472	958	322	161	337	126
G-cubed	818	661	609	694	629	1007	247	16	393	76
Emissions intensity of GDP kg CO_2-e per $										
MMRF	0.5	0.4	0.3	0.4	0.3	0.3	0.1	0.1	0.1	0.1
GTEM	0.6	0.5	0.4	0.5	0.4	0.4	0.1	0.1	0.2	0.1
G-cubed	0.7	0.4	0.4	0.5	0.4	0.4	0.1	0.0	0.1	0.0
Global macroeconomic impacts										
GWP level, percentage deviation from reference										
GTEM	n/a	-0.7	-0.9	-0.7	-1.3	n/a	-2.8	-3.5	-2.7	-4.3
G-cubed	n/a	-2.3	-2.8	-2.2	-3.3	n/a	-3.3	-3.8	-3.2	-4.2
Macroeconomic impacts - Australia										
GNP per capita level, per cent change from reference										
MMRF	n/a	-1.3	-1.7	-1.5	-2.0	n/a	-5.1	-6.0	-5.4	-6.7
GTEM	n/a	-1.1	-1.6	-1.3	-2.1	n/a	-3.8	-3.2	-4.8	-5.2
G-cubed	n/a	-1.9	-2.5	-1.7	-2.6	n/a	-4.2	-4.7	-3.8	-4.8
GNP per capita, average growth per year from 2010										
MMRF	0.9	0.8	0.8	0.7	0.7	1.2	1.1	1.1	1.1	1.1
GTEM	1.6	1.5	1.5	1.5	1.4	1.5	1.4	1.4	1.3	1.3
G-cubed	1.5	1.4	1.4	1.4	1.3	1.4	1.3	1.3	1.3	1.2
GNP average growth per year from 2010										
MMRF	2.2	2.1	2.1	2.0	2.0	2.2	2.1	2.1	2.1	2.1
GTEM	2.9	2.8	2.8	2.8	2.7	2.5	2.4	2.4	2.4	2.3
G-cubed	2.8	2.7	2.7	2.6	2.6	2.4	2.3	2.3	2.3	2.3
GDP per capita level, per cent change from reference										
MMRF	n/a	-1.1	-1.5	-1.1	-1.6	n/a	-3.7	-4.9	-3.7	-5.8
GTEM	n/a	-0.9	-1.2	-0.8	-1.4	n/a	-2.9	-3.5	-3.2	-4.6
G-cubed	n/a	-2.2	-2.8	-1.8	-2.6	n/a	-5.3	-6.3	-3.9	-5.5
GDP per capita, average growth per year from 2010										
MMRF	1.5	1.5	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.2
GTEM	1.5	1.5	1.5	1.5	1.4	1.4	1.3	1.3	1.3	1.2
G-cubed	1.5	1.5	1.4	1.4	1.3	1.4	1.3	1.3	1.3	1.2
GDP average growth per year from 2010										
MMRF	2.8	2.7	2.7	2.7	2.6	2.4	2.3	2.3	2.3	2.2
GTEM	2.8	2.8	2.8	2.7	2.7	2.4	2.3	2.3	2.3	2.3
G-cubed	2.8	2.8	2.7	2.7	2.6	2.4	2.3	2.3	2.3	2.3

Note: Targets for Garnaut scenarios correspond to the smoothed global emissions pathway.

Source: Treasury estimates from MMRF, GTEM and G-Cubed.

Table 6.5:

Other national indicators

	2020				2050			
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
Consumption level, per cent change from reference								
MMRF	-1.2	-1.5	-1.3	-1.9	-4.8	-5.7	-5.2	-6.5
GTEM(a)	-1.1	-1.6	-1.3	-2.1	-3.8	-3.2	-4.8	-5.2
G-cubed	-0.4	-0.5	-0.2	-0.2	0.7	1.1	0.1	0.5
Real w ages level, per cent change from reference								
MMRF	-2.6	-3.1	-3.1	-4.2	-7.6	-9.1	-7.9	-10.3
GTEM	-2.4	-3.2	-2.9	-4.7	-5.4	-5.7	-6.0	-7.4
G-cubed	-4.2	-5.1	-3.1	-4.4	-10.7	-12.4	-8.0	-11.0
Investment level, per cent change from reference								
MMRF	-2.6	-3.3	-3.1	-4.0	-6.7	-8.1	-6.7	-9.2
GTEM	-0.5	-0.9	-0.7	-1.4	-2.7	-2.5	-3.5	-4.2
G-cubed	-3.8	-4.9	-3.1	-4.5	-9.2	-9.9	-5.8	-7.4
Terms of trade, per cent change from reference								
MMRF	-0.3	-0.4	-0.4	-0.2	-2.9	-3.1	-2.5	-2.1
GTEM	-0.5	-0.7	-0.5	-1.0	-2.2	-0.6	-2.7	-1.3
G-cubed	-1.6	-2.0	-1.4	-1.8	-3.3	-4.2	-2.0	-1.6

(a) GNP is presented. GNP is a proxy for consumption in GTEM as the savings rate is fixed.
Note: Targets for Garnaut scenarios correspond to the smoothed global emissions pathway.
Source: Treasury estimates from MMRF, GTEM and G-Cubed.

6.1.1

Box 6.1: Difference in GNP and GDP impacts across models

Despite using the same global and national allocations, Australian GNP and GDP impacts are different across the models because the structure and databases of the models vary (Table 6.3).

GTEM does not cost the mitigation effort to reduce fugitive emissions, whereas MMRF allows for additional inputs to implement new processes or technologies. GTEM does not do this; it is an international model and data on the likely costs of fugitive emission mitigation technologies in developing economies are very limited. G-Cubed has lower mitigation potential in non-combustion emissions; consequently the model requires greater proportional combustion emission reductions to achieve a given allocation and therefore greater adjustment in sectors that combust emissions.

Differences in databases and aggregation between models can influence mitigation costs. MMRF's database suggests that the resources required to produce a unit of conventional coal electricity is less than in the GTEM database. Switching from coal generation to alternative cleaner technologies requires a greater proportional increase in resources in MMRF than in GTEM. Switching from conventional coal fired generation therefore costs more in MMRF.

The GTEM data are based on a year (2001) when the Australian exchange rate appeared undervalued, while the MMRF data are based on 2005. This results in Australia's emission intensity (measured in 2001 US dollars) being higher in GTEM than in MMRF, potentially making the mitigation costs in GTEM higher than in MMRF.

Aggregate employment adjusts gradually to emission pricing in MMRF and G-Cubed. As emission prices changes over time and the models are either, not forward looking (MMRF), or only partly forward looking (G-Cubed), employment continues to adjust through time, adding to GDP costs. In contrast, GTEM adjusts labour fully each year, so aggregate employment remains unchanged between the reference scenario and policy scenarios, lowering GDP costs.

GTEM does not allow substitution from emission-intensive intermediate inputs in some sectors in response to the emission prices; whereas, MMRF and G-Cubed have some intermediate substitution across all sectors. MMRF disaggregates petroleum into cleaner fuels, such as biofuels or diesel, while GTEM does not.

The overall net effect of these differences is that Australian GDP impacts tend to be lowest in GTEM, higher in MMRF, and higher still in G-Cubed. GNP, however, not only differs across the models because of the GDP impacts, but also because of differences in impacts on international income transfers.

The main difference in income transfer impacts is due to the number of emission permits purchased in the international market. The number of permits purchased (and therefore the income outflows from these purchases) is considerably higher in MMRF than in GTEM and G-Cubed. This is because the economy can reduce emissions at lower cost in both GTEM and G-Cubed than in MMRF.

In G-Cubed, in the CPRS scenarios, Australia's GNP falls by less than GDP, despite a loss of income from permit purchases. In G-Cubed, lower foreign interest payments offset the outflow of income from buying permits. Australia's trade balance improves as imports fall by more than exports. Imports fall as consumption and investment fall. Australian exports fall, but are partially held up by demand from China and other economies initially not in the trading scheme. The trade balance reduces the current account deficit, reducing Australia's foreign debt and foreign interest payments, leading to a higher GNP. In contrast, GNP in MMRF is lower, as these dynamic trade impacts are not captured.

6.2.3 Decomposing the impact on GNP

Climate change mitigation policy can affect economic welfare in three ways (Harberger, 1971) (Table 6.6.).[3]

- Changes in deadweight loss that arise from reallocating existing resources within the economy.
- Changes in the supply or productivity of factors, such as increases or decreases in the amount of land, labour, capital and natural resources or improved productivity of existing resources.
- Changes in foreign income transfers and the terms of trade.

The first two of these sources decompose the impact on GDP, and when the impact on international income transfers and the terms of trade is added, the result is the impact on GNP.

Table 6.6: Contributions to GNP
Change from reference scenario

	CPRS -5 Per cent	CPRS -15 Per cent	Garnaut -10 Per cent	Garnaut -25 Per cent
2020				
Allocative efficiency	-0.1	-0.2	-0.1	-0.4
Capital and labour supply and productivity	-1.1	-1.3	-1.0	-1.6
GDP	-1.2	-1.6	-1.1	-1.6
Terms of trade	-0.2	-0.2	-0.2	-0.2
Permit trading	-0.1	-0.2	-0.4	-0.6
Other foreign transfers	0.2	0.2	0.2	0.4
GNP	-1.3	-1.7	-1.5	-2.0
2050				
Allocative efficiency	-0.5	-1.2	-0.5	-2.1
Capital and labour supply and productivity	-3.2	-3.8	-3.1	-4.0
GDP	-3.7	-5.0	-3.6	-6.1
Terms of trade	-0.8	-0.9	-0.7	-0.7
Permit trading	-1.5	-2.8	-1.8	-2.3
Other foreign transfers	0.6	2.5	0.6	2.1
GNP	-5.1	-6.0	-5.4	-6.7

Note: Contributions may not add due to rounding. GDP contribution is not equivalent to the GDP change from reference scenario.
Source: Treasury estimates from MMRF.

Allocative efficiency

When emissions are priced, existing resources are reallocated in the economy. The more emission intensive the economy, the greater the proportion of deadweight losses to GDP and the greater the adjustment costs.

In response to emission pricing Australia's resources shift from sectors where they currently have a comparative advantage to sectors that will have a comparative advantage in a low-emission economy.

3 Huff and Hertel (1996) and Pant et al. (2000) use this framework to derive a decomposition of the equivalent variation measure of the change in welfare within the context of a CGE model.

Energy related emissions are reduced by switching from emission-intensive fuels to less energy-intensive technologies. These adjustments come at a cost, as they result in a reallocation of existing resources.

In addition, substitution occurs to cleaner, but initially more expensive technologies. Changing production technologies (such as using solar hot water heaters rather than electric water heaters, using gas-fired and renewable electricity generation rather than coal-fired, and using steel recycling rather than blast furnace smelting) significantly reduces emissions.

Other industries can reduce the emission intensity of production for non-combustion/non-energy emissions. Non-combustion emissions include fugitive emissions from coal mining or gas extraction, and process emissions from cement production or agriculture. Mitigation opportunities for non-combustion emissions were modelled, drawing on relevant information from the bottom-up modelling, international research and sectoral experts.

In general, reducing non-combustion emissions increases the cost of production, as firms pay more for capital, labour or business inputs (or a combination of all three) to lower their emission intensity. This increases costs as resources are reallocated in the economy and is equivalent to a permanent loss in factors from the economy.

Capital and labour supply and productivity

Changes in the quantity of factors (labour and capital) used in production is the other primary source of GDP costs in response to emission pricing. In particular, reduced capital use significantly contributes to reductions in real GDP in MMRF relative to the reference scenario.

An emission price reduces the incentive for producers to employ variable factors of production — particularly capital in the latter years.

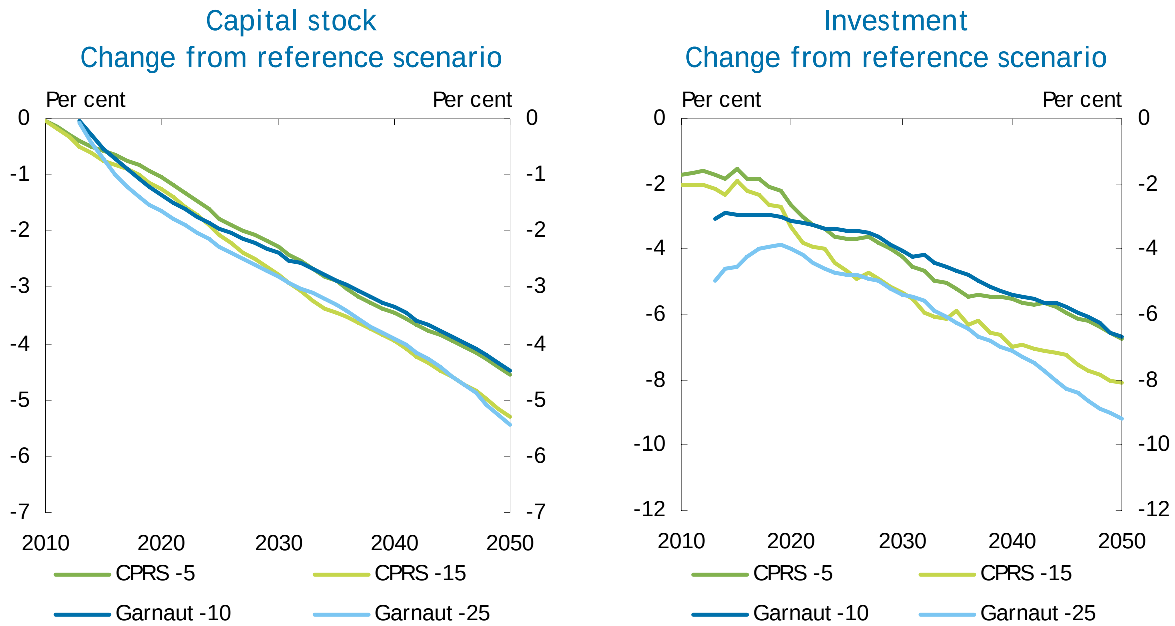
In all scenarios, and across all models, an important driver of the long-run reduction in GDP is the reduction in capital inputs. In MMRF, the capital stock reduction is caused by:

- a decrease in the economy-wide capital to labour ratio in response to an increase in the cost of capital relative to the price of labour; and
- a shift towards low-emission labour intensive sectors (such as services).

An emission price raises the cost of constructing a unit of capital relative to the price of aggregate production as capital goods are relatively emissions and energy intensive. In MMRF, the rate of return on capital is assumed to be fixed by the operation of global capital markets. Therefore, the rental price of capital is effectively indexed to the investment price. Both the investment price and rental price of capital rise relative to the price of production, reducing the incentive for firms to employ capital (relative to other factors, labour and land). As a result, the amount of capital per unit of GDP in the Australian economy falls (capital shallowing), and the aggregate level of investment also falls, relative to the reference scenario (Chart 6.11).

As a consequence, the economy is more labour intensive than in the reference scenario: the greater the mitigation effort, the more pronounced these effects.

Chart 6.11: Capital Stock and Investment



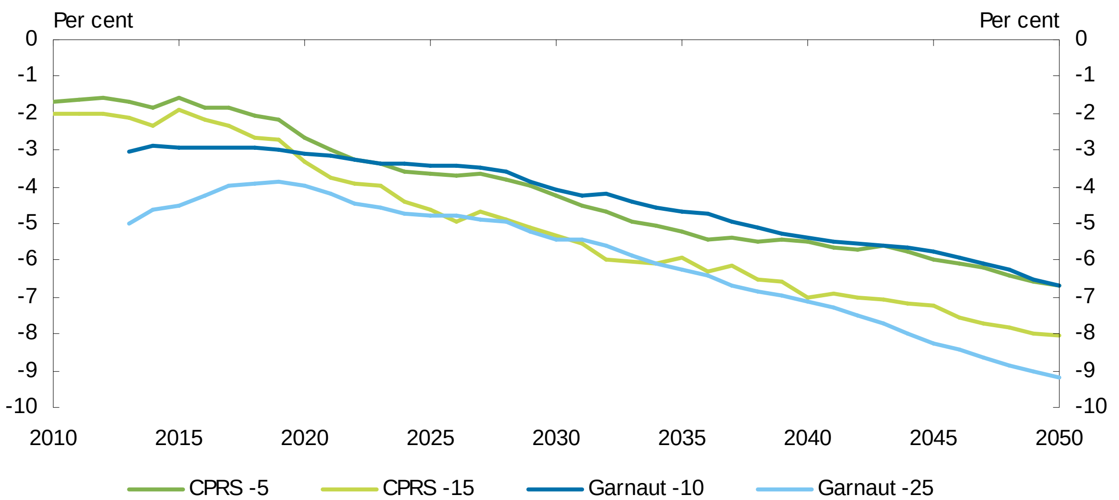
Note: These charts show changes from the reference scenario. The aggregate capital stock and investment continue to grow under all scenarios.
Source: Treasury estimates from MMRF.

In MMRF, real wages are assumed to adjust in the long run to ensure the labour market remains in equilibrium. As output slows slightly in response to emission pricing, firms' demand for labour also slows slightly. In the short run, real wages are assumed to be sticky, taking up to 10 years to adjust, resulting in some temporary unemployment. However over time, real wage growth slows, demand for labour increases, returning employment to reference case levels (Chart 6.12). The progressive increase in the permit price requires steadily increasing real wage adjustments.

Aggregate output is also lower due to compositional changes in the economy. Emission pricing shifts demand to low-emission, labour-intensive sectors. These sectors typically have lower levels and growth of labour productivity, gradually reducing growth in aggregate productivity.

Chart 6.12: Real wages

Change from reference scenario



Note: These charts show changes from the reference scenario. Real wages continue to grow under all scenarios.
Source: Treasury estimates from MMRF.

The effect on investment and capital stocks varies across sectors. Australia's emission and energy-intensive sectors, particularly the mining, metal production and transport sectors, experience a significant decline in rates of return, reflecting lower demand and profitability in an emission-constrained world. As a result, investment in these sectors falls significantly (Table 6.7).

Table 6.7: Industry investment

Change from reference scenario

	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	Reference growth
	Per cent	Per cent	Per cent	Per cent	2010 - 2020
2020					
Agriculture	0.3	0.6	-1.0	-1.2	5.3
Coal Mining	-12.8	-18.1	-8.0	-19.1	-3.6
Other Mining	-2.0	-2.6	-1.1	-2.7	-3.4
Manufacturing	-3.1	-3.6	-3.1	-1.6	0.1
Utilities	-0.8	-1.3	-1.6	-1.9	0.3
Trade	-2.3	-2.7	-2.6	-2.5	1.0
Construction	-4.3	-5.5	-4.9	-6.2	0.3
Transport	-1.6	-2.1	-1.8	-2.9	2.1
Services	-2.3	-2.8	-3.0	-3.8	2.4
2050					
Agriculture	-1.8	-3.0	-1.7	0.9	2.8
Coal Mining	-30.0	-37.1	-25.7	-42.3	1.6
Other Mining	-9.5	-11.2	-7.1	-13.2	0.8
Manufacturing	-1.6	-3.4	-1.3	-2.7	0.6
Utilities	-3.5	-5.1	-3.6	-6.0	1.3
Trade	-4.8	-5.0	-4.8	-4.3	1.5
Construction	-9.1	-10.3	-9.6	-12.6	1.8
Transport	-2.7	-4.0	-2.2	-4.9	1.9
Services	-5.7	-6.7	-6.3	-8.1	2.3

Source: Treasury estimates from MMRF.

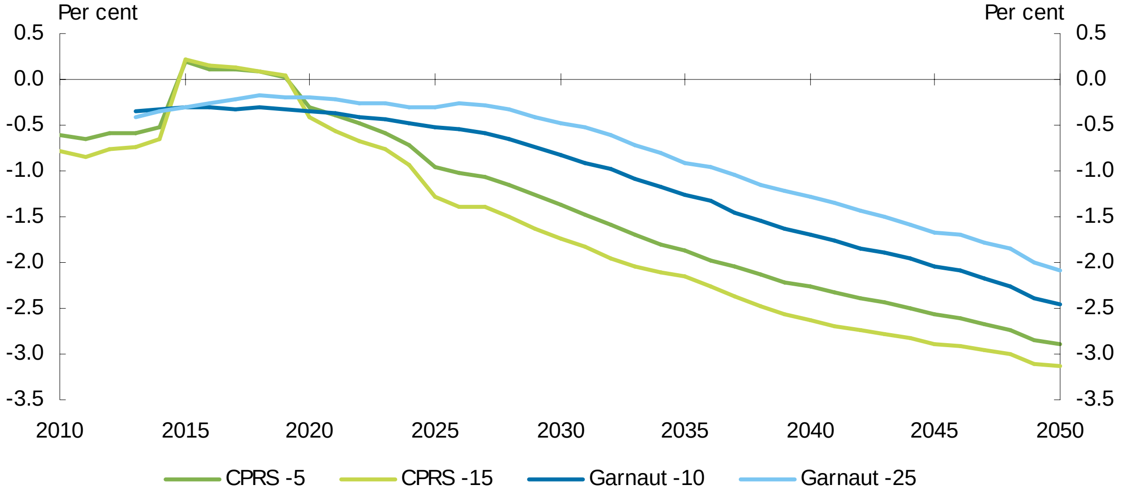
Terms of trade and foreign income transfers

Terms of trade

A decline in Australia's terms of trade relative to the reference scenario — which measure the price of Australia's exports relative to the price of Australia's imports — reduces Australia's income. Global mitigation is likely to lower Australia's terms of trade, through lower world demand for Australia's abundant fossil-fuel resources, particularly coal.

In the Garnaut scenarios, Australia's competitors and trading partners all price emissions. This reduces world demand for energy-intensive exports, most notably coal and natural gas. Australian export prices fall. This, coupled with higher import prices, leads to a fall in Australia's terms of trade. Lower world demand for Australia's energy exports reduces Australia's terms of trade till 2050. The terms of trade stay higher in the Garnaut -25 scenario than the Garnaut -10 scenario because the higher emission price causes earlier and more widespread uptake of carbon capture and storage, boosting world demand for Australian coal exports (Chart 6.13).

Chart 6.13: Terms of trade
Change from reference scenario



Source: Treasury estimates from MMRF.

In the CPRS scenarios, the terms of trade initially decline. However, when China and India join the international coalition this materially affects Australia's terms of trade — the Garnaut scenarios do not show this because all countries are assumed to start together in 2013. In the CPRS scenarios, China's assumed entry into the scheme in 2015 causes global coal prices to jump (as China, a major coal producer, consumer and exporter, prices emissions). Australia's terms of trade then drop when India and the rest of the world join the scheme in 2020, and world demand falls. Australia's terms of trade decline gradually to 2050, reflecting lower world demand for Australia's energy exports. In the CPRS -15 scenario, emissions and electricity are priced higher, so the decline in the terms of trade is larger than in the CPRS -5 scenario.

Some of Australia's declining terms of trade, relative to the reference scenario, would occur if a global scheme was introduced, regardless of whether Australia participated (Box 6.2).

The real exchange rate across all models reflects the terms of trade.

Box 6.2: Unavoidable mitigation cost impacts

Trade effects from other economies' climate change policies mean Australia would face costs even if it did not adopt national emission reduction targets. These costs arise from external factors as a result of other economies' actions, particularly their trade in energy and emission-intensive commodities.

Sensitivity analysis explored this with all economies, except Australia, adopting emission targets (so Australia free rides).

When Australia free rides, the modelled economic costs to Australia are lower. Initially, when fossil fuels dominate energy sources, Australia benefits from a higher terms of trade effect, relative to the reference scenario, resulting from the cost competitive advantage of its commodities. However, by around 2020, Australia's terms of trade fall relative to the reference scenario largely because of reduced global demand for Australia's emission-intensive exports, such as coal and gas.

By 2050, Australian GNP is 0.6 per cent lower than the reference scenario, This estimated cost is much less than the 3.2-5.2 per cent mitigation costs for the policy scenarios.

Source: Treasury estimates from GTEM.

Permit sales

Australia imports permits in all policy scenarios (Chart 6.14 and Table 6.8). Purchasing permits from the international market does not compromise the environmental objective because there is an aggregate global emissions cap. However, Australia's allocation in a global agreement, and any resulting trade in permits significantly affects Australia's mitigation costs.[4]

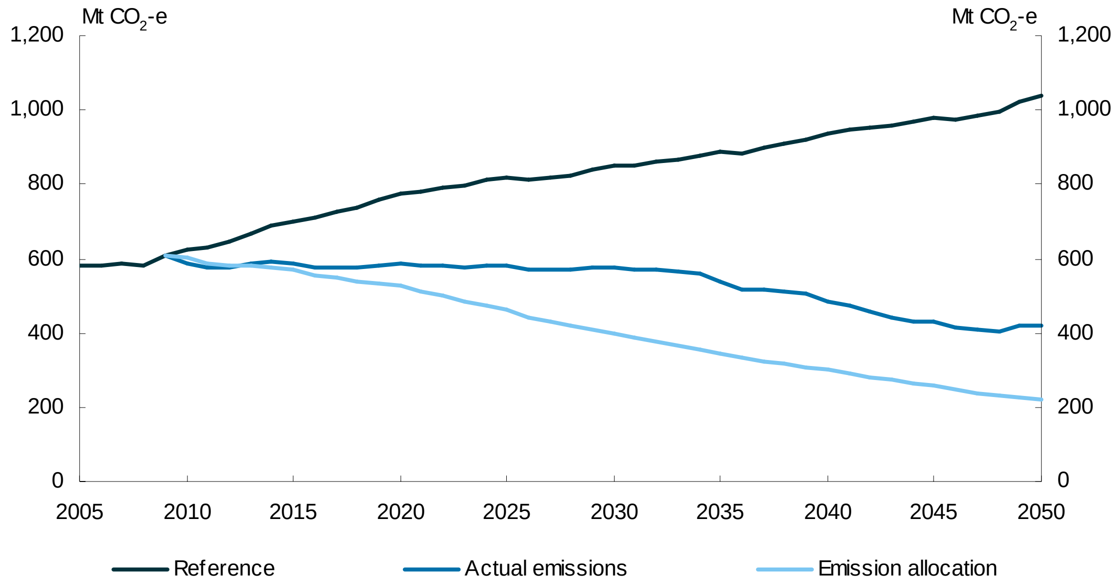
The cost of purchasing emission permits from overseas results in an income transfer from Australia to other economies. This transfer is determined by Australia's allocation of permits. For a given global emissions trajectory, the greater Australia's initial allocation, the lower the cost faced by Australians and the greater the cost faced by other economies.

Permit allocation and the associated international trade in permits helps explain the difference in costs between the CPRS -5 scenario and Garnaut -10 scenario. The emission price is roughly the same in both scenarios; as a small economy, Australia cannot influence the global emission price. The Garnaut -10 scenario implies a long-term reduction target for Australia of over 80 per cent below 2000 levels (compared to 60 per cent in CPRS -5). Consequently, Australia needs to purchase more permits from overseas in the Garnaut -10 scenario.

4 For a given mitigation task, different emission allocations across economies will result in different income transfers and hence economic cost, while achieving the same environmental goals.

Chart 6.14: Australia's actual emissions, allocations and permit trading

CPRS -5 scenario



Source: Treasury estimates from MMRF.

Table 6.8: Australian allocation, emissions, trade and banking

	Allocation	Emissions	Trade	Banked permits
	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e
2020				
CPRS -5	525	585	46	63
CPRS -15	470	529	46	48
Garnaut -10	496	608	112	0
Garnaut -25	405	505	100	0
2050				
CPRS -5	221	420	199	0
CPRS -15	221	297	76	0
Garnaut -10	109	425	316	0
Garnaut -25	63	171	108	0

Source: Treasury estimates from MMRF.

Australia purchases fewer overseas permits in the Garnaut -25 scenario than in the Garnaut -10 scenario. In the Garnaut -25 scenario, higher emission prices result in a disproportionate increase in land converted to forestry, resulting in more low-cost mitigation.

The CPRS scenarios constrain international trade in permits, capped at 50 per cent of the national mitigation effort up to 2020. This constraint is not binding in either scenario in either MMRF or GTEM.

Foreign interest payments

Foreign interest payments are affected by changes in exchange rates and the savings to investment ratio. A depreciating exchange rate and/or decreasing savings to investment ratio increase foreign interest payments, reducing GNP. In MMRF the savings to investment ratio increases in the policy scenarios, decreasing foreign debt payments compared with the reference scenario, offsetting GNP losses. In contrast, foreign debt payments in GTEM increase in the policy scenarios as the depreciating exchange rate leads to an increase in foreign interest payments.

Box 6.3: Impact on domestic consumption

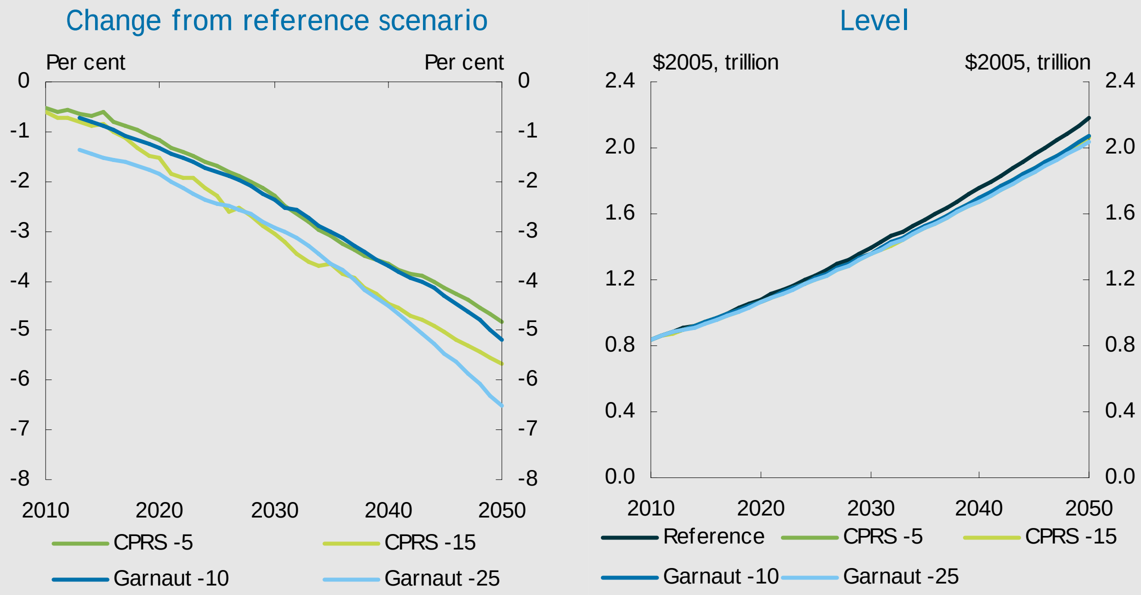
The introduction of an emission price will affect consumption. Consumption is another measure of economic welfare. Domestic consumption is the sum of private consumption and government expenditure on goods and services on behalf of households.

From 2010 to 2050, average annual growth in domestic consumption slows from 2.4 per cent in the reference scenario to between 2.2-2.3 per cent in the policy scenarios.

Domestic consumption falls relative to the reference scenario, but rises strongly through time in all policy scenarios (Chart 6.15).

Private consumption moves in line with GNP. The reduction in private consumption relative to the reference scenario, which results from lower labour and capital income, would be larger if remaining permit revenue were not returned to households.

Chart 6.15: Domestic consumption



Source: Treasury estimates from MMRF.

Box 6.4: Revenue recycling

The Government has committed to return to the community all the revenue raised from the sale of emission permits. The manner of its return is still being considered. Some will be returned to business through shielding emission-intensive trade-exposed industries and assisting other strongly affected industries to partially offset the initial effects of the Carbon Pollution Reduction Scheme (DCC, 2008).

In the modelling it is assumed that the remainder is returned to households through lump-sum transfers.

This is a conservative assumption that assumes no productivity or labour supply benefit from the revenue recycling. Final decisions on how revenue is returned could change the GDP and GNP impacts reported.

6.3 TECHNOLOGY SENSITIVITY ANALYSIS

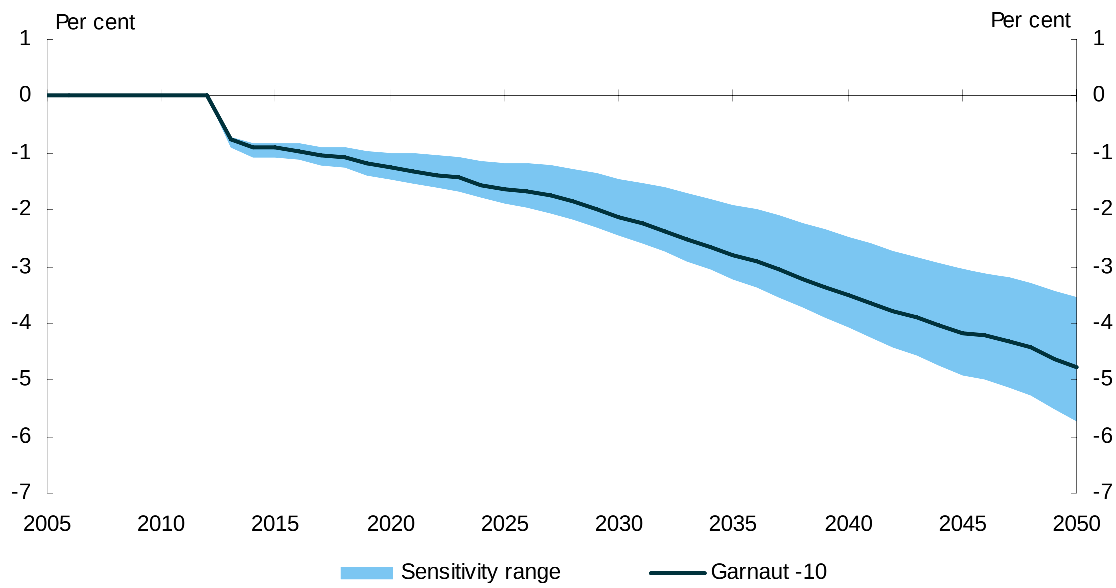
Modelling emission reductions over long timeframes is uncertain. How fast efficiency improvements occur; what low-emissions technologies will be available; when, at what cost, and how effective they will be are sources of uncertainty. Predictions of what mix of technologies will be most cost effective cannot be accurate. This underscores the importance of policies that create incentives for mitigation across all sectors and all technologies, without specifying precise technological pathways.

Progress in developing low-emission technologies is important for global and Australian mitigation costs. Greater technological progress will reduce costs; slower progress will increase costs. Greater technological progress is possible if real emission prices are sustained over time. However, currently uncommercial technological options, such as carbon capture and storage, may prove technically impossible. Sensitivity analysis explores some of these aspects.

The cost of mitigation is highly speculative over time and many of the modelling results in the literature report only to 2030-2050. Many of the more speculative technological sensitivities do not have a major influence on mitigation costs until the emission prices reach high levels, usually after 2050.[5]

The range established by these sensitivity scenarios does not establish firm bounds on the likely eventual cost of global mitigation. Technological progress could be faster than in the optimistic technology cases or slower than in the pessimistic ones. The sensitivities show a wide range of outcomes are possible. In 2050, Australia's GNP loss ranges from 3.6 per cent to 5.7 per cent (Chart 6.16 and Table 6.9). By 2100, the range has widened, from 2.7 per cent to 12.2 per cent.

Chart 6.16: Australian gross national product
Change from reference scenario



Source: Treasury estimates from GTEM.

5 This is the case for the 'backstop' technology options explored by Garnaut (2008).

Table 6.9: Technology sensitivities

Change from reference scenario	2020 Per cent	2050 Per cent	2100 Per cent
Gross World Product			
Garnaut -10 scenario	-0.8	-2.7	-4.1
1) Improved carbon capture and storage technology	-0.8	-2.7	-3.6
2) Extra energy-efficiency improvements	-0.6	-2.3	-3.8
3) Higher learning rates	-0.7	-2.6	-3.1
4) Agricultural backstop	-0.8	-2.7	-3.7
5) Enhanced technology scenario, fully costed	-0.6	-2.2	-4.3
6) Enhanced technology scenario, partly costed	-0.6	-2.1	-2.5
7) Costed MAC curves	-1.1	-4.4	-10.8
8) No carbon capture and storage technology	-0.9	-3.0	-4.7
9) Zero emission carbon capture and storage technology	-0.8	-2.5	-3.5
Australian GNP			
Garnaut -10 scenario	-1.3	-4.8	-7.1
1) Improved carbon capture and storage technology	-1.2	-4.4	-4.4
2) Extra energy-efficiency improvements	-1.0	-3.9	-6.5
3) Higher learning rates	-1.2	-4.1	-5.7
4) Agricultural backstop	-1.2	-4.5	-5.5
5) Enhanced technology scenario, fully costed	-1.0	-3.6	-4.3
6) Enhanced technology scenario, partly costed	-1.0	-3.6	-2.7
7) Costed MAC curves	-1.5	-5.7	-12.2
8) No carbon capture and storage technology	-1.5	-5.7	-8.8
9) Zero emission carbon capture and storage technology	-1.3	-4.4	-4.3

Note: The box on the next page outlines the assumptions used for this table. Weighted in 2005 US dollar purchasing power parity units.
Source: Treasury estimates from GTEM.

Box 6.5: Technology sensitivity details

Nine technology assumptions were tested (Table 6.9).

1. Carbon capture and storage technologies could improve in response to higher emission prices. The CO_2 captured from the combustion of gas or coal increases from 90 per cent to 99 per cent when emission prices rise above US$140/t CO_2-e. This increased capture does not incur any extra cost.

2. Energy-efficiency improvements could expand by an additional 1 per cent per year from 2013 to 2030, with an extra 0.5 per cent from 2031 to 2040 and then no extra improvements. (In the central case, the energy-efficiency improvement rate is 0.5 per cent per year.) Energy-efficiency for households could improve at the rate of 1 per cent from 2013 to 2030, at 0.5 per cent from 2031 to 2040, and then cease to improve. In the central case, the energy efficiency improvement rate for households is set at zero. However, households respond to relative prices by substituting to lower emission-intensive goods. These extra efficiency improvements are costed.

3. A boost to learning rates for electricity and transport technologies occurs by increasing learning parameters by 50 per cent relative to the central assumptions over the whole period. Higher learning rates are costed.

4. Non-combustion agricultural emissions are eliminated when the emission price exceeds US$250/t CO_2-e. This elimination does not incur any costs.

5. Improved carbon capture and storage technology, extra energy-efficiency improvements, higher learning rates and elimination of non-combustion agricultural emissions combine, forming an 'enhanced technology' sensitivity, where all technological changes are costed.

6. The same technology components as in the fully costed enhanced technology are used, but only the higher learning rates and extra efficiency improvements are costed. The improved carbon capture and storage and non-combustion agricultural emissions technologies are not costed.

7. In the central case, the marginal abatement curves (MAC) are not costed. All MACs are costed in an input-neutral way; the benefits from paying for lower emissions due to the MACs being offset by increased primary factor costs.

8. Carbon capture and storage technology does not prove to be viable.

9. Carbon capture and storage technology has zero emissions from the start.

6.4 Impact across states

Real gross state product (GSP) falls in most states/territories (Chart 6.17 and 6.18). Generally, the faster growing states, Queensland and Western Australia, face the greatest impacts from emission pricing. The impacts on real GSP across all mitigation scenarios are broadly comparable, although larger for lower stabilisation levels.

The impact of emission pricing on GSP is heavily influenced by differences in industry composition and the degree of export orientation across states. Without differences in industry structure, real GSP in each region would be expected to move with GDP.

Forestry sequestration provides a significant benefit to the South Australian and Tasmanian economies. In the Garnaut -25 scenario, South Australian GSP is higher than in the reference scenario. In Tasmania, the expansion of forestry results in a decrease in production by other agricultural industries as a result of increased competition for scarce productive land. These states also benefit from growth in low-emission technologies, such as renewable electricity.

The industrial composition of New South Wales is similar to Australia as a whole, so its proportionate loss in GSP is similar to the aggregate GDP impacts.

Victoria is relatively reliant on emission-intensive industries — coal-fired generation, aluminium and gas. Adverse impacts on these industries are, at least partially, offset by improvements in export-oriented or import-competing manufacturing.

In the CPRS scenarios, as the most export orientated state, Western Australia initially is relatively unaffected by emission pricing, as it continues to experience strong demand from developing economies outside the international permit trading scheme, most notably China. The decline in Western Australian GSP reflects the heavy influence of gas production, which eventually declines relative to the reference scenario, due to reduced domestic and foreign demand.

Queensland is projected to experience the largest percentage decline in GSP by 2050 of around 6-8 per cent relative to the reference scenario. Queensland has a heavy reliance on coal-fired electricity and has the highest national share of coal mining production, which is primarily for export. Queensland also accounts for a significant amount of Australia's aluminium production.

Chart 6.17: Gross State Product

CPRS -5 scenario

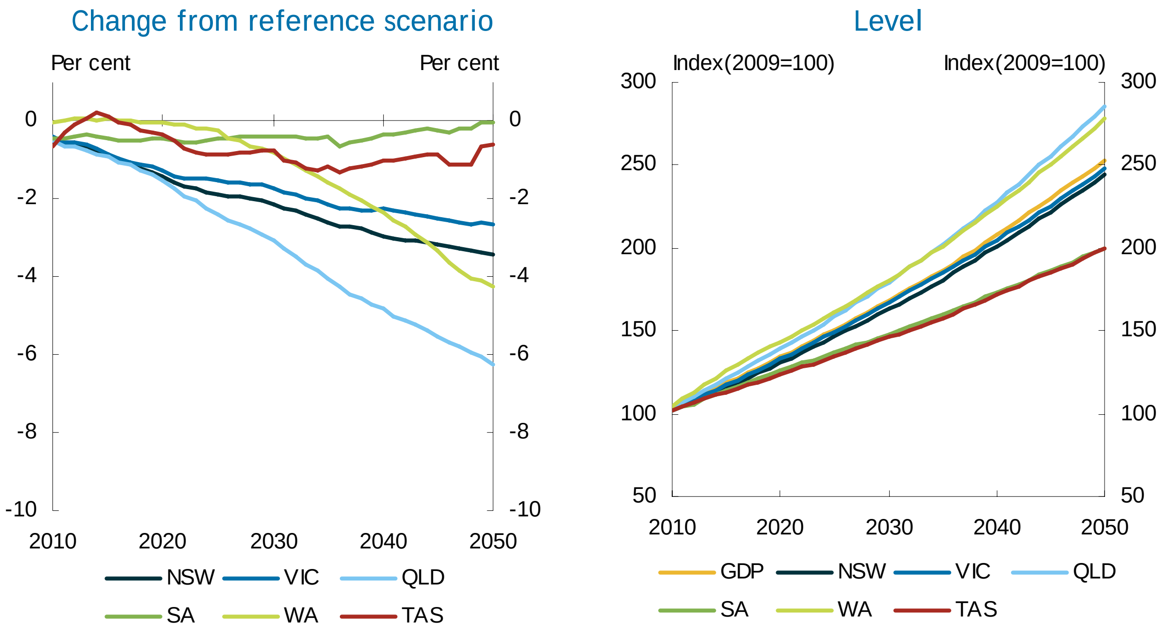
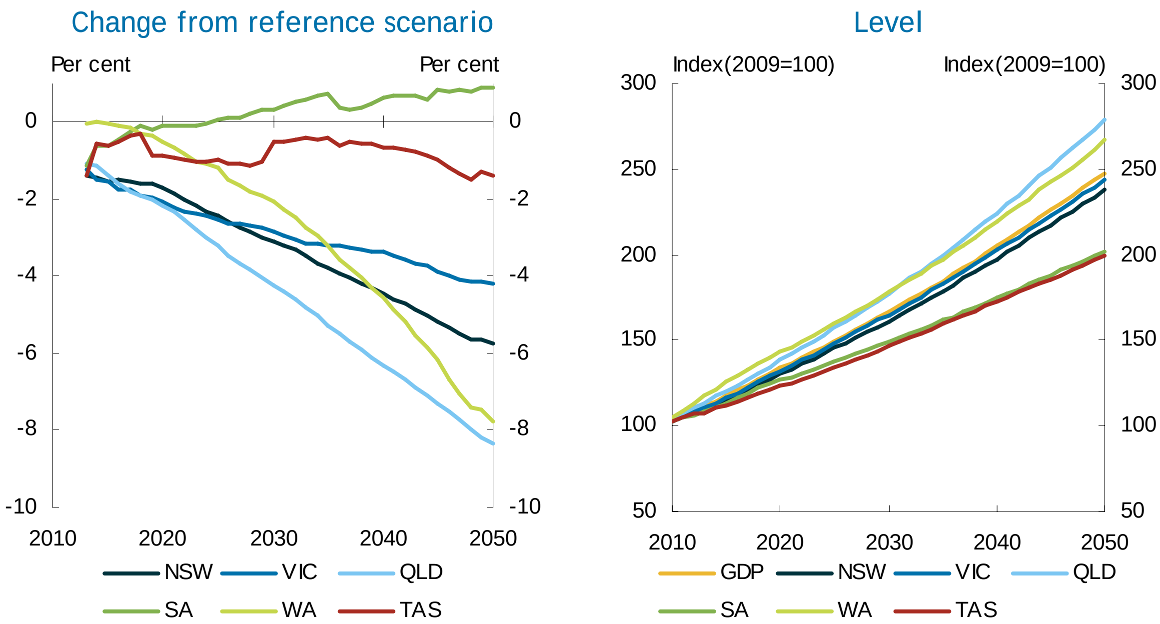


Chart 6.18: Gross State Product

Garnaut -25 scenario

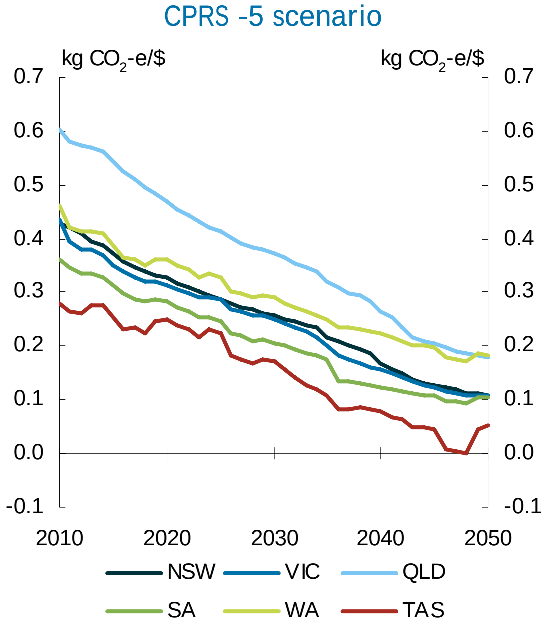


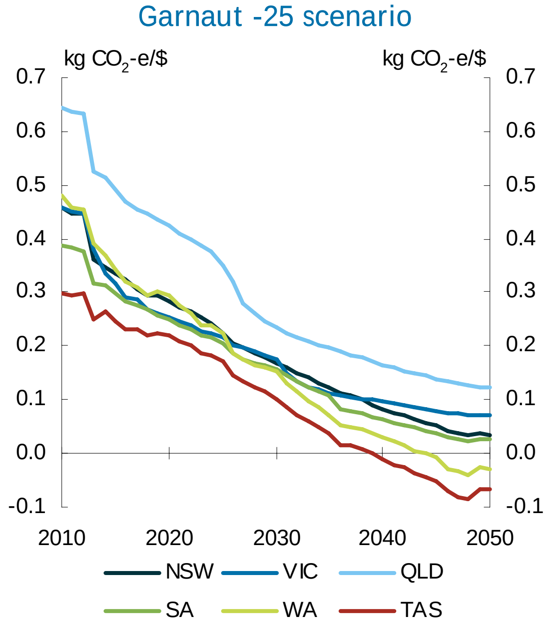
Source: Treasury estimates from MMRF.

6.4.2 Emission intensity

The reduction in emission intensity across sectors is broadly comparable across states. Although the emission intensity of GSP declines across all scenarios and for all states and territories, the rate of decline is different (Chart 6.19). This is due to changes in the composition of industries within the states and changing relative competitiveness of industries. In high mitigation scenarios, such as the Garnaut -25, Tasmania has negative emission intensity due to sequestration from the forestry sector.

Chart 6.19: Emission intensity





6.5 IMPACTS AT THE SECTORAL LEVEL

While mitigation policies impose relatively small aggregate costs on Australia, impacts vary widely across sectors.

Sectoral impacts are largely determined by the relative emission intensity of goods and services; degree of trade exposure; the relative emission intensity of production across economies (how Australia compares with other producers); potential mitigation options; and the relative price elasticity of demand (whether consumers substitute away as prices rise) (Table 6.10).

Table 6.10: Impacts at the sectoral level
Change from reference scenario

	Trade-exposed	Non-traded
Emission-intensive	Face reduced world demand, and without unified global action, unable to pass through the increase in costs. Sectors include: metal manufacturing, petroleum refining and agriculture.	Able to pass through some of increased costs but faces reduced domestic demand from higher prices. Sectors include: fossil fuel electricity generation, gas supply and transport.
Low-emission	May benefit from changes in Australia's exchange rate and rising world demand. Sectors include: other manufacturing.	May experience relative price fall or benefit from an emission price due to the creation of new markets. Sectors include: forestry, services and renewable electricity generation.

Pricing emissions drives a structural shift in the economy, from emission-intensive goods, technologies and processes, towards low-emission goods, technologies and processes. As a result, growth slows for emission-intensive sectors, such as coal, gas, iron and steel, and livestock. Growth accelerates for low and negative-emission sectors, such as forestry, renewable energy, and rail transport (Table 6.11).

This structural shift requires a reallocation of resources across the economy. Employment shifts broadly reflect movements in industrial output (Table 6.12).

Pricing emissions also changes Australia's comparative advantage. Australia maintains or improves competitiveness where local production is less energy- or emission-intensive than production of the same good in other countries, such as for coal, and loses competitiveness where local production is more emission-intensive, such as for aluminium.

Lower demand for Australia's emission-intensive commodity exports is projected to generate benefits for other export-oriented and import-competing industries through its impact on Australia's exchange rate.

Non trade-exposed emission-intensive sectors will have a greater ability to pass through at least some of the increase in costs as higher prices. The key sectors are those related to energy production and transport. Over time, these sectors will transform towards lower emission and energy-efficient technologies.

Impacts on non-traded low-emission sectors, such as services, broadly reflect the aggregate impact on the whole economy.

With the exception of electricity generation, the modelling of sectors is aggregated to an industry level so that the impacts on individual firms are not explored. The following section discusses the main results across sectors, followed by more detailed analysis of the electricity, transport and forestry sectors where bottom-up modelling was used.

Effects are broadly consistent across all the scenarios, although sectoral gains and losses are generally larger for lower stabilisation levels.

Table 6.11: Gross output, by sector, 2050

Industry	Change from reference scenario				Change from 2008
	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25	CPRS -5
	Per cent	Per cent	Per cent	Per cent	Per cent
Sheep and cattle	-6.7	-10.2	-6.2	-12.7	88
Dairy cattle	3.9	2.9	4.3	7.9	116
Other animals	2.2	1.7	1.8	4.6	144
Grains	1.5	0.9	1.8	1.7	120
Other agriculture	-0.2	-1.0	0.3	-2.4	211
Agricultural services and fisheries	2.1	2.7	2.4	17.1	189
Forestry	150.1	584.5	166.2	874.9	484
Coal mining	-30.1	-38.0	-25.8	-42.4	66
Oil	-0.4	-0.6	-0.4	-0.6	-75
Gas mining	-17.0	-19.6	-16.5	-21.7	59
Iron ore mining	5.1	6.2	7.5	4.5	234
Non-ferrous ore mining	-5.6	-7.5	-3.8	-9.4	93
Other mining	0.0	-0.7	3.2	-1.8	120
Meat products	-4.8	-7.7	-4.5	-6.9	134
Other food	5.7	5.1	6.2	11.5	140
Textiles, clothing and footw ear	5.3	2.8	4.2	-2.4	33
Wood products	8.8	11.9	8.3	10.5	124
Paper products	3.1	2.6	2.9	2.3	87
Printing	1.2	0.8	1.0	0.2	139
Refinery	-37.7	-45.3	-35.0	-52.2	88
Chemicals	1.6	3.8	2.2	6.4	-7
Rubber and plastic products	2.2	2.2	2.5	3.2	39
Non-metal construction products	4.2	6.1	4.6	7.8	92
Cement	-6.0	-6.4	-5.9	-6.9	106
Iron and steel	0.7	-0.2	1.1	-0.6	12
Alumina	-16.8	-24.2	-15.2	-21.3	73
Aluminium	-45.2	-56.3	-48.9	-61.9	-7
Other metals manufacturing	21.1	20.9	22.8	33.5	-71
Metal products	-2.5	-2.8	-2.7	-3.0	54
Motor vehicles and parts	7.8	7.9	7.3	7.3	45
Other manufacturing	5.7	5.1	5.6	4.2	55
Electricity: coal-fired	-71.5	-68.3	-56.3	-65.9	-38
Electricity: gas-fired	12.0	6.8	-1.2	-33.8	132
Electricity: hydro	24.6	-0.6	9.2	31.1	71
Electricity: other	1735.4	1534.8	1302.6	1692.5	2960
Electricity supply	-12.8	-17.4	-13.6	-18.1	71
Gas supply	-2.8	-5.0	-3.2	-8.2	107
Water supply	-2.8	-3.6	-3.1	-4.2	100
Construction	-6.4	-7.6	-6.5	-8.9	145
Trade	-1.8	-1.8	-1.8	-1.1	158
Accommodation and hotels	-3.8	-5.3	-4.4	-7.7	187
Road transport: passenger	-3.4	-5.6	-4.1	-8.5	245
Road transport: freight	-0.5	0.8	-0.3	1.8	189
Rail transport: passenger	10.4	9.5	9.9	6.7	359
Rail transport: freight	-0.1	-1.5	1.2	-4.0	222
Water transport	-1.8	-2.5	-1.6	-2.5	174
Air transport	-1.1	-3.4	-1.7	-7.0	592
Communication services	-3.1	-3.6	-3.4	-4.0	321
Financial services	-1.1	-1.4	-1.3	-1.8	242
Business services	-0.8	-1.2	-0.8	-1.6	327
Ow nership of dw ellings	-4.2	-5.0	-4.4	-5.2	161
Public services	-0.8	-1.2	-0.9	-1.7	229
Other services	-4.2	-4.8	-4.5	-5.5	170

Note: Output of the forestry sector is based on land area.
Source: Treasury estimates from MMRF.

Table 6.12: Employment, by sector, 2050

Industry	Employment shares				
	Reference	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent	Per cent	Per cent	Per cent	Per cent
Sheep and cattle	1.0	1.0	0.9	0.9	0.9
Dairy cattle	0.2	0.3	0.3	0.3	0.3
Other animals	0.1	0.1	0.1	0.1	0.1
Grains	0.9	1.0	1.0	1.0	1.0
Other agriculture	1.0	1.0	1.0	1.0	1.0
Agricultural services and fisheries	0.5	0.5	0.5	0.5	0.6
Forestry	0.1	0.2	0.6	0.2	1.0
Coal mining	0.2	0.1	0.1	0.1	0.1
Oil	0.0	0.0	0.0	0.0	0.0
Gas mining	0.1	0.0	0.0	0.0	0.0
Iron ore mining	0.1	0.1	0.1	0.1	0.1
Non-ferrous ore mining	0.2	0.2	0.2	0.2	0.2
Other mining	0.1	0.1	0.1	0.1	0.1
Meat products	0.3	0.3	0.3	0.3	0.3
Other food	0.7	0.8	0.8	0.8	0.9
Textiles, clothing and footw ear	0.2	0.2	0.2	0.2	0.2
Wood products	0.3	0.3	0.3	0.3	0.3
Paper products	0.1	0.1	0.1	0.1	0.1
Printing	0.6	0.6	0.6	0.6	0.6
Refinery	0.1	0.0	0.0	0.0	0.0
Chemicals	0.1	0.1	0.1	0.1	0.1
Rubber and plastic products	0.1	0.1	0.1	0.1	0.1
Non-metal construction products	0.1	0.1	0.1	0.1	0.1
Cement	0.1	0.1	0.1	0.1	0.1
Iron and steel	0.1	0.1	0.1	0.1	0.1
Alumina	0.0	0.0	0.0	0.0	0.0
Aluminium	0.1	0.0	0.0	0.0	0.0
Other metals manufacturing	0.0	0.0	0.0	0.0	0.0
Metal products	0.3	0.3	0.3	0.3	0.3
Motor vehicles and parts	0.2	0.2	0.2	0.2	0.2
Other manufacturing	0.7	0.8	0.8	0.8	0.8
Electricity: coal-fired	0.1	0.0	0.0	0.0	0.0
Electricity: gas-fired	0.0	0.0	0.0	0.0	0.0
Electricity: hydro	0.0	0.0	0.0	0.0	0.0
Electricity: other	0.0	0.1	0.1	0.1	0.1
Electricity supply	0.1	0.1	0.1	0.1	0.1
Gas supply	0.0	0.0	0.0	0.0	0.0
Water supply	0.1	0.1	0.1	0.1	0.1
Construction	6.8	6.6	6.5	6.6	6.4
Trade	13.7	13.7	13.8	13.8	13.9
Accommodation and hotels	6.5	6.4	6.3	6.4	6.1
Road transport: passenger	0.4	0.4	0.4	0.4	0.4
Road transport: freight	0.7	0.7	0.7	0.7	0.7
Rail transport: passenger	0.0	0.0	0.0	0.0	0.0
Rail transport: freight	0.2	0.2	0.2	0.2	0.2
Water transport	0.7	0.7	0.7	0.7	0.7
Air transport	0.7	0.7	0.7	0.7	0.7
Communication services	0.6	0.6	0.6	0.6	0.6
Financial services	3.2	3.2	3.2	3.2	3.2
Business services	23.3	23.5	23.4	23.5	23.3
Ow nership of dw ellings	0.0	0.0	0.0	0.0	0.0
Public services	21.1	21.2	21.1	21.2	21.0
Other services	12.9	12.6	12.5	12.6	12.4

Source: Treasury estimates from MMRF.

6.5.1 Impacts on trade-exposed emission-intensive sectors

Australian output of some exports, such as mining (particularly coal and gas), resource processing (including metal manufacturing and refining), manufacturing (including chemicals, rubber and plastic products) and agriculture (particularly sheep and cattle), generally grows more slowly in the policy scenarios, as world demand slows and consumers across the world substitute towards lower-emission commodities.

Where Australia has relatively low-emission intensity of production, emission pricing improves Australia's competitiveness and is likely to increase its share of global trade in that commodity. This could partially or wholly offset the effect of slowing global demand growth. Where Australia has relatively high-emission intensity, competitiveness declines and Australia's share of global trade is likely to fall (Box 6.6).

Australia's share of global trade increases for coal, and is broadly maintained for iron and steel. Australia's share of global trade falls for aluminium, given its relatively higher emission intensity of production in Australia.

Box 6.6: Sectoral impacts and structural adjustment

The difference between changes relative to the reference scenario, and changes relative to the level of current activity, is important in assessing structural adjustment needs.

The economy will adjust from its current structure. Mitigation policies will change the pattern of future economic activity, so the reference scenario economy of 2050 will not eventuate. Today's economy, therefore, provides a useful reference point.

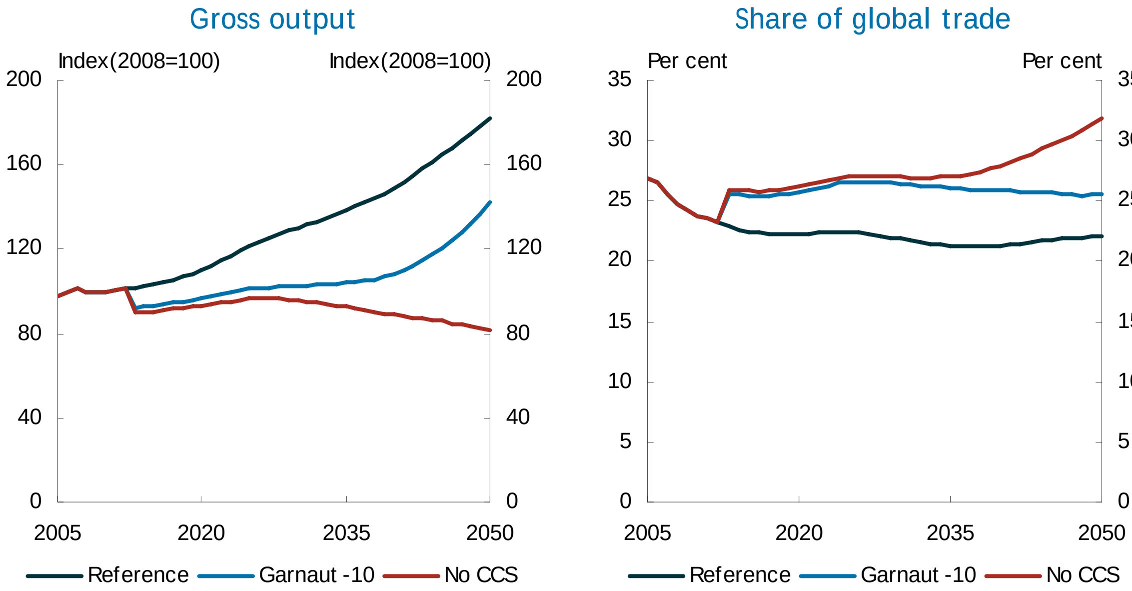
The policy scenarios project large reductions in the output of some sectors relative to the reference scenario. However, output from most of these sectors is projected to grow from current levels; the reductions relative to the reference scenario mean they grow more slowly than they would in a world without climate change (Table 6.11).

Within sectors, some firms and regions could face a serious adjustment task, including early plant closures. The transition will need careful management. The Government is committed to supporting affected workers and regions where required, and has proposed special measures to manage impacts on emission-intensive trade-exposed sectors and coal-fired generators (DCC, 2008a).

In the medium to long term, employment and investment will move to other lower-emission sectors (Table 6.12).

The future of coal depends heavily on the development of carbon capture and storage technologies. Without such technologies, Australia's coal production could fall to 4 per cent below current (2008) levels by 2030, and 18 per cent below by 2050. Overall, across the four scenarios (which assume this technology is viable) Australia's coal output falls relative to the reference scenario, but grows relative to current levels. If carbon capture and storage is not viable, coal output falls below current levels (Chart 6.20).

Chart 6.20: Australia's coal sector



Source: Treasury estimates from GTEM.

Without unified global action, such as in the CPRS scenarios, an emission price may distort the international competitiveness of Australia's emission-intensive trade-exposed sectors. Free allocation of some permits to these sectors, in accordance with the shielding arrangements proposed in the *Carbon Pollution Reduction Scheme Green Paper*, partially offsets any loss of competitiveness while maintaining incentives for these sectors to reduce emissions. Shielding imposes modest costs on other (unshielded) sectors, particularly through its impact on permit trading, electricity prices and capital and labour (Box 6.8).

All trade-exposed emission-intensive sectors reduce emissions relative to the reference scenario. Emission reductions in the Garnaut -25 scenario are greatest, reflecting the higher emission price (Chart 6.21). The Garnaut -25 scenario also employed very flexible marginal abatement curves (MACs); whereas, the CPRS -5 scenario adopts a smoother transition consistent with the multi-staged entry of economies into the scheme.

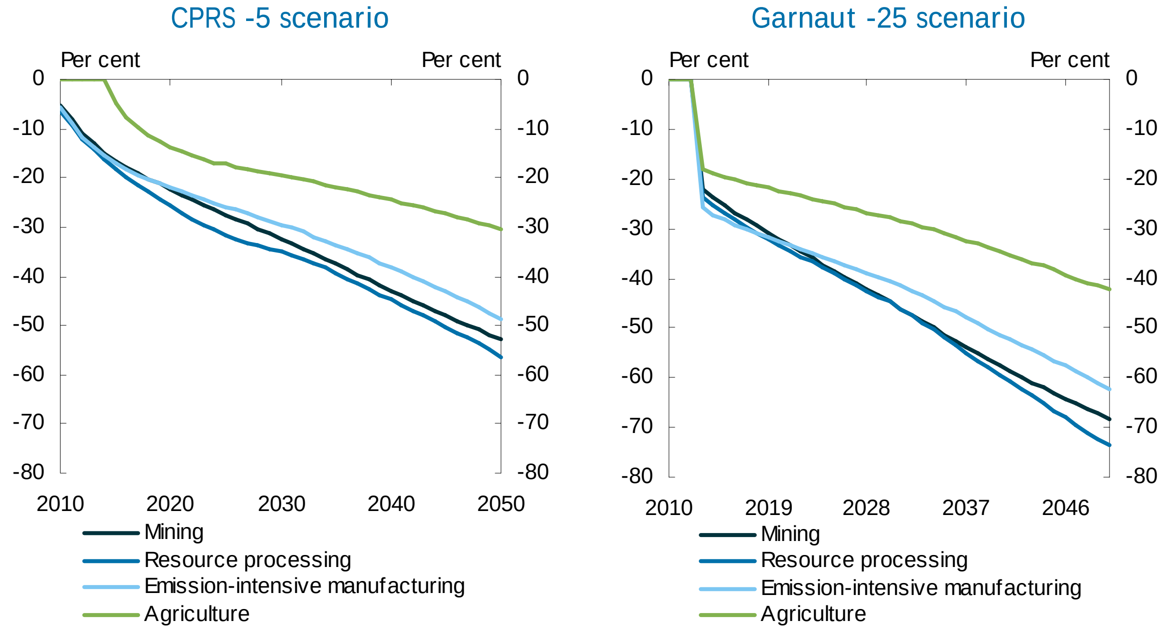
Differences in mitigation across sectors largely reflect differences in marginal costs of mitigation. Mitigation in mining and resource processing is the largest, while in agriculture it is the smallest, but still significant, with around a 30 per cent reduction relative to the reference scenario in 2050.

In the CPRS scenarios, deferring coverage of agriculture until 2015 delays emission reductions from this sector. Once agriculture joins the scheme, it is expected to have fewer mitigation options than other sectors. Australia retains a comparative advantage in agriculture in a low-emission world, so it tends to maintain agricultural output.

The fall in output in the mining and resource processing industries, as a result of lower world demand, also contributes to the fall in emissions in these sectors, especially after 2025.

Chart 6.21: Trade-exposed emission-intensive industries - emissions

Change from reference scenario



Source: Treasury estimates from MMRF.

Many large industrial processes rely heavily on energy as an input into production, and comprise a significant share of stationary energy emissions. The switch away from high-emission energy sources for industrial processes will occur over a long timeframe, and may not start until sectors can substitute towards low-emission electricity.

Box 6.7: Impact on competitiveness in a multi-stage world: the role of shielding

Coordinated global efforts help ensure any changes in Australia's comparative advantage arise from real differences in the emission intensity of production, rather than from uncoordinated policy action. Competitiveness distortions may arise where Australia prices emissions before other economies: emission-intensive trade-exposed sectors (EITES) could move to other locations that are more emission intensive than Australia, but not yet pricing emissions. As a result, global emissions could rise, a process called 'carbon leakage'.

The Government proposes transitional assistance for EITES when it introduces the Carbon Pollution Reduction Scheme, to reduce carbon leakage and support the transition to a low-emission economy (DCC, 2008a). This transitional assistance 'shields' EITES from the full effect of emission pricing. Crucial features of the proposed shielding are that shielded firms face a strong incentive to reduce emissions, even if they obtain free emission permits, and that the level of shielding gradually declines.

The risk of carbon leakage and cost of shielding is explored in the CPRS scenarios, which assume Australia prices emissions ahead of many other regions.[6]

The results show little evidence of carbon leakage. Where shielding is not applied, there is a small change in the emissions and output from EITES in non-participating regions. This suggests the emission prices in these scenarios are not high enough to induce significant industry relocation. Noticeable impacts only occur at higher emission prices (roughly double the price of the CPRS -5 scenario).

Nevertheless, shielding does reduce the impact of emission pricing on shielded sectors in the initial years of the scheme. When shielding is applied, output of EITES falls at a more gradual rate, relative to the reference scenario (reflecting the contraction in world demand). This suggests the shielding arrangements proposed in the *Carbon Pollution Reduction Scheme Green Paper* could ease the transition to a low-pollution future for the shielded sectors.

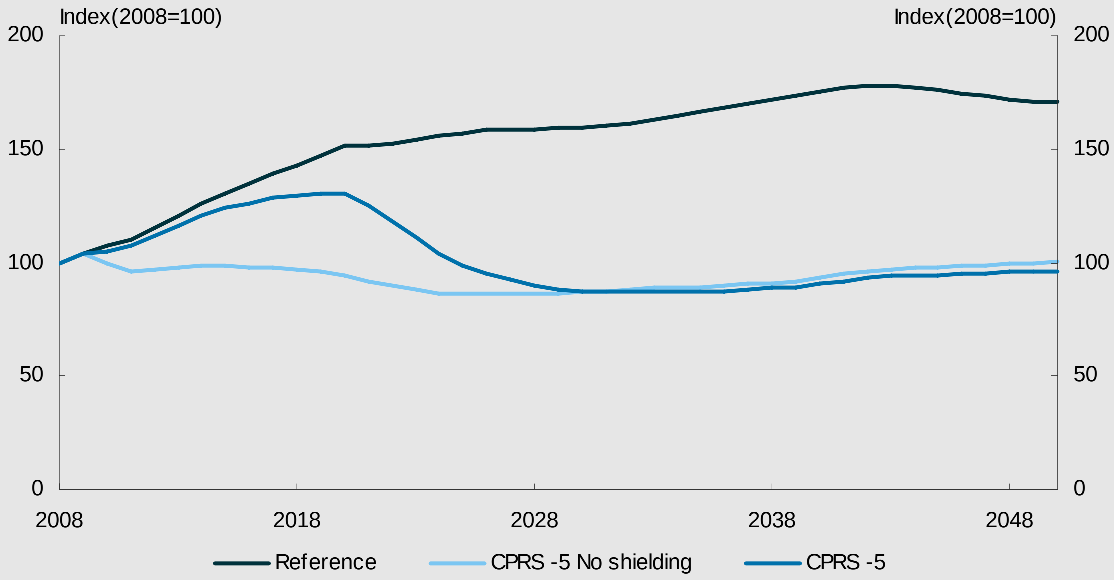
The very emission-intensive non-ferrous metals sector (aluminium) benefits most from shielding, and there is some evidence of benefits to other very emission-intensive sectors (such as sheep and beef cattle, once agriculture is included in the scheme). The aluminium sector's significant emission cost increases are offset when shielding is applied (Chart 6.22). However, once the sector is no longer shielded, as the rest of the world joins the scheme, aluminium sector output falls.

Shielding redistributes costs from shielded to unshielded sectors, through its impact on electricity prices (higher output in EITES brings greater demand for electricity and higher prices), and affects permit trading. Higher output in EITES means that Australia imports more permits to meet its emission target. Shielding also redistributes costs among shielded sectors, by diverting labour and capital from more to less competitive EITES.

6 The Garnaut scenarios assume emission pricing is introduced in all economies at the same time, so no carbon leakage occurs.

Box 6.7: Impact on competitiveness in a multi-stage world: the role of shielding (continued)

Chart 6.22: Australian aluminium output relative to current levels
Shielding and no shielding



Source: Treasury estimates from MMRF.

Redistribution effects would be greater if shielding mutes mitigation incentives, if a greater proportion of permit revenue is devoted to shielding, or if more permits could not be imported (because international permit trade was more limited).

Both GTEM and MMRF are likely to overestimate carbon leakage and the relocation of production activities: the models are not forward-looking (so firms are assumed to take no account of the possibility of future emission prices in the new location), and do not account for adjustment costs associated with relocation. In reality, industry location reflects multiple factors, including access to skilled labour, legal and political stability, access to resources and quality of infrastructure.

These results suggest that fears of carbon leakage, for the emission prices explored in the CPRS scenarios, may be overplayed.

6.5.2 Non-traded emission-intensive sectors

Firms producing non-traded emission-intensive commodities, such as electricity, gas, and transport services, are able to pass on much of the increase in costs to consumers as higher prices. This leads to a fall in demand, particularly where alternative low-emission commodities are available, or in the case of energy, opportunities to improve efficiency. Over time, firms will face competitive pressure to transform towards low-emission and energy-efficient technologies.

Output from the construction sector grows more slowly in the policy scenarios owing to slowing demand for dwellings, non-residential buildings and infrastructure.

6.5.3 Non-traded low-emission sectors

Demand for low-emission commodities increases, particularly where they provide an alternative to higher-emission commodities, or the emissions trading market creates a new source of revenue.

These effects are evident in the forestry sector. Consumers substitute towards wood products (a low-emission good) and forests sequester carbon and generate credits for sale in an emissions trading scheme.[7]

Forestry's expansion has flow-on effects for some agricultural sectors, particularly cattle and sheep grazing. These activities compete for land, so as forestry expands, livestock production contracts (relative to the reference scenario). This effect strengthens in the scenarios with lower stabilisation levels, as the higher emission prices make forestry even more profitable than competing land uses.

The modelling may overstate impacts on agriculture, as the MMRF model does not differentiate between different land types (high quality agricultural land versus marginal land). If forest expansion occurs predominantly on marginal land, agricultural output may be relatively less affected.

Output from the services sector grows, but more slowly than in the reference scenario, reflecting the effect of reduced consumption due to lower incomes (Table 6.11).

6.5.4 Traded low-emission sectors

Global demand for Australia's coal and aluminium falls in a low-emission world. As a result, Australia's terms of trade fall relative to the reference scenario. This in turn causes Australia's exchange rate to depreciate, which improves the competitiveness of many other export-oriented and import-competing industries, including manufacturing. Wood products; textiles, clothing and footwear; and non-meat food benefit from the lower exchange rate, and increase output relative to the reference scenario. Chemical manufacturing, iron ore mining, dairy and grains also benefit from the lower exchange rate (Table 6.11).

6.5.5 Electricity sector

Electricity generation accounts for the largest share of Australia's current emissions, so Australia's transition to a low-emission future will require a significant transformation in this sector. Australia has a range of options available to assist with this transition, including significant gas, wind, solar and geothermal resources. Furthermore, Australia's significant coal resources could play an important role in an emission-constrained world if carbon capture and storage technology proves commercial.

To explore how Australia's electricity sector could respond to emission reduction policies, bottom-up modelling was integrated into MMRF to capture the interactions between the electricity sector and the broader economy.[8]

7 The *Carbon Pollution Reduction Scheme Green Paper* proposes allowing reforestation activities to opt into the scheme from its start in 2010 (DCC, 2008a).

8 Annex A describes the process for linking MMA's bottom-up electricity model with MMRF.

Electricity generation was analysed in the context of a national and international mitigation framework by imposing the emission price path. This approach to modelling the electricity sector did not impose a specific emission reduction target on the electricity generation sector alone.[9]

The modelling also examined the interaction of the emission price with pre-existing and proposed national and state electricity sector policies, including the Government's proposed Mandatory Renewable Energy Target, the Victorian Renewable Energy Target (VRET) and the Queensland Gas Scheme. In the Garnaut scenarios, all such policies ceased once emission pricing began in 2013. In contrast, the CPRS scenarios included the Government's proposed expanded Renewable Energy Target and continued the Queensland Gas Scheme.[10]

Emissions

The emission price drives significant changes in the mix of technologies and fuels used in the electricity sector in all policy scenarios. The emission price makes gas and renewable energy sources more competitive against coal, leading to a progressive transition away from conventional coal-fired generation. However, coal continues to play a role in electricity generation with the adoption of carbon capture and storage.

The sector is almost decarbonised by 2050 (Table 6.13). By 2050, the remaining emissions come from carbon capture and storage, and remaining efficient coal and gas power plants, some of which provide back up to solar thermal plants.[11]

Table 6.13: Electricity sector emissions reductions

	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Per cent	Per cent	Per cent	Per cent
2020 emissions				
Relative to 2000	3.8	1.1	15.2	-11.1
Relative to reference	-31.7	-33.4	-23.8	-35.9
2050 emissions				
Relative to 2000	-64.6	-49.3	-61.6	-73.8
Relative to reference	-82.3	-74.6	-80.7	-87.8

Source: Treasury estimates from MMRF.

Output

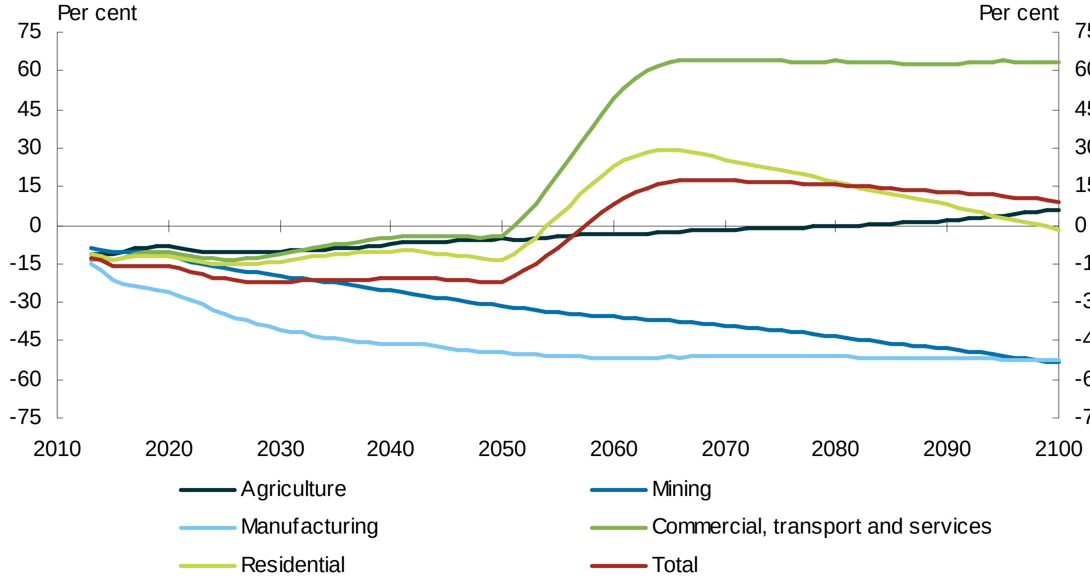
In all sectors, electricity demand falls relative to the reference scenario after an emission price is introduced. Contraction in economic activity (relative to the reference scenario) and increased electricity prices subdue demand. The reduction in electricity demand leads to immediate emissions mitigation.

In 2050, electricity demand is around 22 per cent below the reference scenario in the Garnaut -25 scenario (Chart 6.23). Manufacturing declines are mostly driven by aluminium.

The Garnaut -25 scenario, which was extended to 2100, shows an aggregate rise in electricity demand after 2050. This reflects the transport fleet and other energy users switching to low-emission electricity for energy.

9 For an example of where emission constraints were imposed, see Energy Supply Association of Australia (2008).
10 Annex A describes the treatment of the state and national policies in the scenarios.
11 Carbon capture and storage is not assumed to capture all emissions in the MMA modelling.

Chart 6.23: Electricity demand
Change from reference scenario, Garnaut -25 scenario



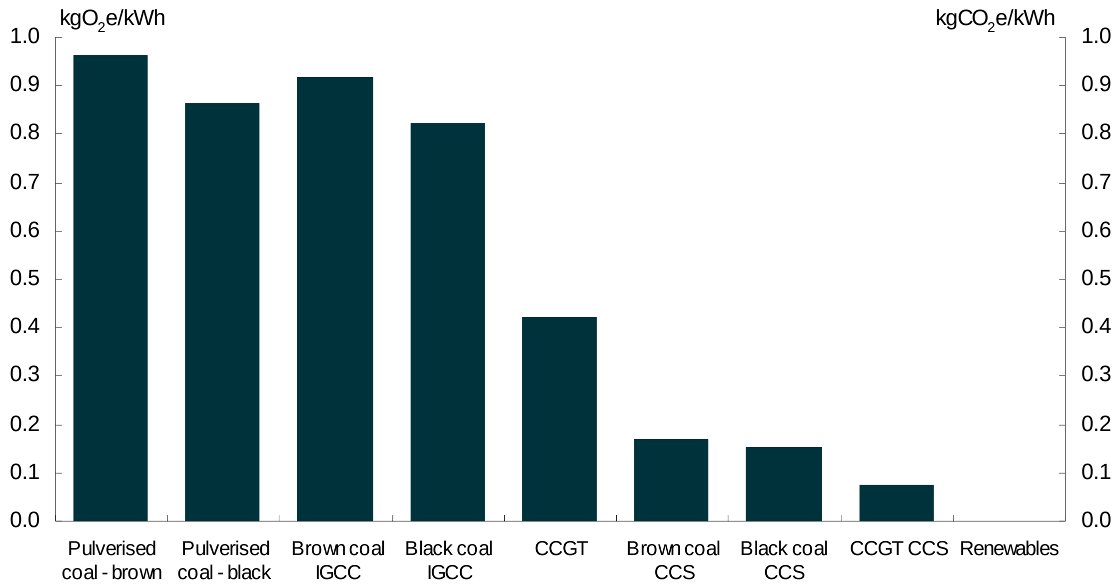
Source: Treasury estimates from MMRF.

Transformation of the electricity sector

In the reference scenario, coal continues to dominate Australia's electricity generation. In the policy scenarios, the emission price stimulates a transformation towards low and zero emission sources of electricity.

In the short term, the electricity sector switches from coal to gas, which has around half the emission intensity of coal, and renewables, which are emissions free (Chart 6.24). In the CPRS scenarios, the transition to renewables, primarily wind, is more rapid owing to the requirements of the expanded Renewable Energy Target.

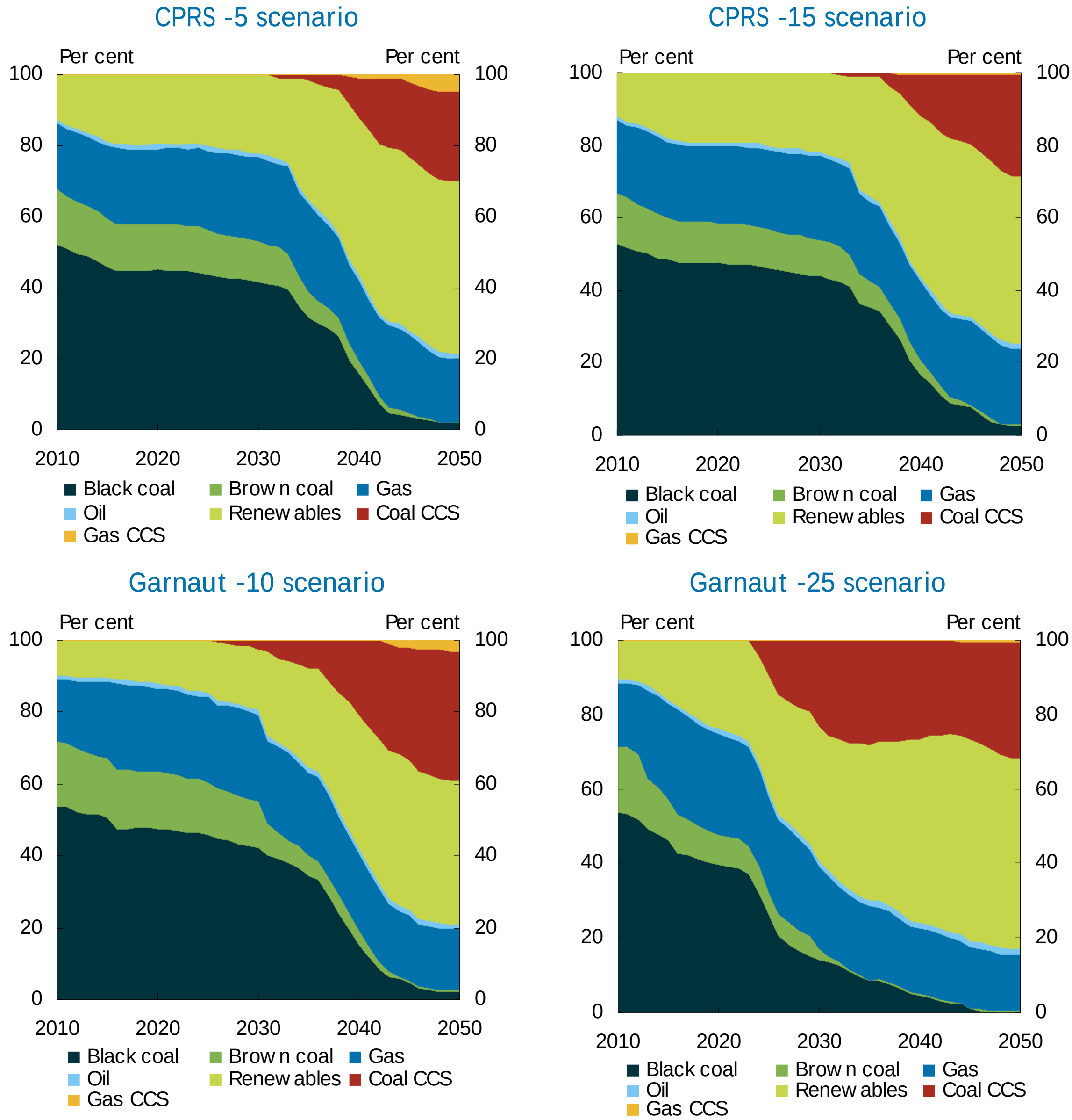
Chart 6.24: Emission intensity of electricity technologies



Note: Emission intensities are for new capacity in 2010. IGCC: Integrated gasification combined cycle; CCGT: combined cycle gas turbine; and CCS: carbon capture and storage.
Source: MMA.

During the 2020s and 2030s, carbon capture and storage technology starts to be deployed, and some existing power plants retrofit carbon capture technologies. By 2050, the share of electricity generated by carbon capture and storage ranges from 28 per cent in the CPRS -15 scenario to 39 per cent in the Garnaut -15 scenario. The share of renewables continues to rise strongly through the 2020s and 2030s. By 2050, the share of renewables is 40-51 per cent in the policy scenarios, compared with just over 5 per cent in the reference scenario (Chart 6.25).

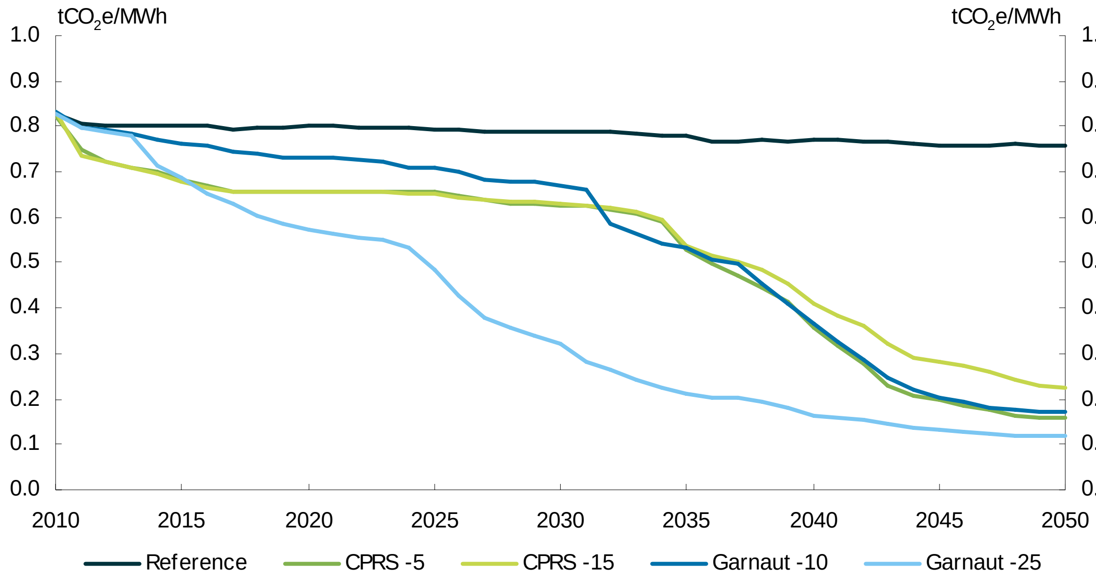
Chart 6.25: Technology shares of generation



Source: MMA.

Transforming the fuel and technology mix reduces the emission-intensity of electricity supply (Chart 6.26). While electricity demand drops in the policy scenarios compared with the reference scenario, most emission reductions are achieved through reduced emission intensity. Emission intensity falls most in the Garnaut -25 scenario, reflecting the faster uptake of renewables and carbon capture and storage owing to higher emission prices. By 2050, in the Garnaut -25 scenario, the emission intensity of electricity generation is around 0.1 tCO_2-e/MWh, around 85 per cent less than in the reference scenario.

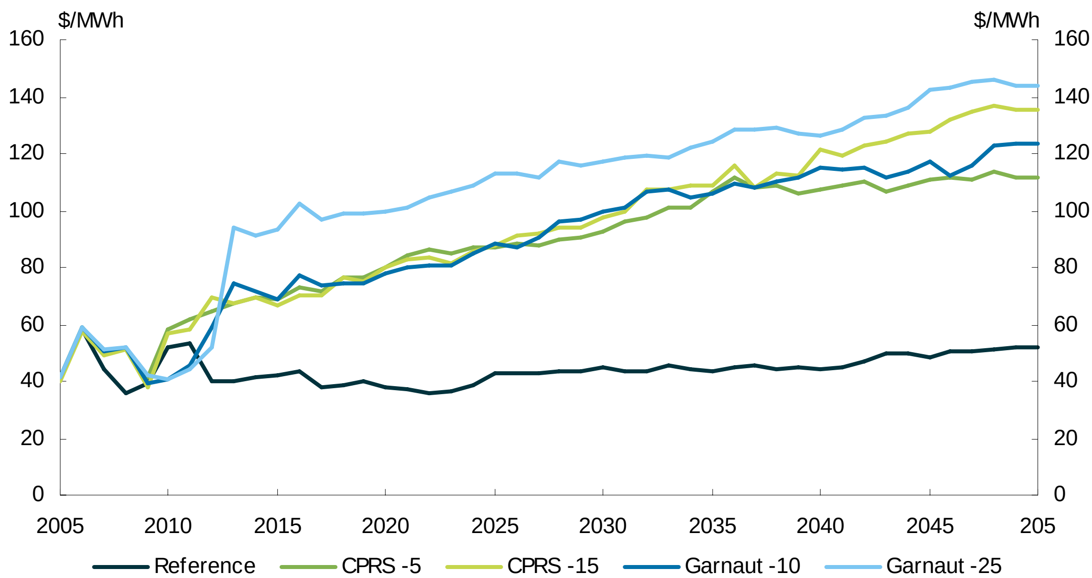
Chart 6.26: Emission intensity of electricity generation



Source: Treasury estimates from MMRF and MMA.

Pricing emissions and adopting low-emission technologies increase the cost of electricity for consumers. The short-term cost of the emission price on existing fossil fuel power plants feeds into electricity prices, making Australian wholesale electricity prices around 50-130 per cent higher (in real terms) than in the reference scenario (Chart 6.27). The medium and longer term deployment of more expensive low-emission technologies causes electricity prices to continue to increase, although by less than the increase in the cost of electricity from coal-fired sources, as low-emission technologies increase market share. By 2020 average wholesale prices could be 80-150 per cent higher, rising to 120-190 per cent higher by 2050 (Table 6.14)

Chart 6.27: Average Australian wholesale electricity prices



Note: Prices in mid-2007 dollars.
Source: MMA.

Table 6.14: Average wholesale electricity price increase

Change from reference scenario

	CPRS -5			CPRS -15			Garnaut -10			Garnaut -25		
	2010-15	2015-20	2045-50	2010-15	2015-20	2045-50	2013-15	2015-20	2045-50	2013-15	2015-20	2045-50
	Per cent			Per cent			Per cent			Per cent		
NSW	65	108	128	69	111	185	93	106	156	145	170	199
VIC	57	120	144	56	121	201	87	113	133	157	197	225
QLD	66	109	159	73	107	192	116	112	190	194	195	218
SA	50	72	62	49	69	116	83	85	83	125	126	104
TAS	40	96	74	44	102	112	76	91	70	144	166	127
SWIS	22	37	104	22	31	118	26	40	100	52	71	143
NT	10	10	27	14	15	39	6	10	36	17	24	84
Avg	48	86	122	48	84	164	75	86	134	126	146	186

Note: SWIS is the South-West Interconnected System in Western Australia. Projected increases in 2010-15 in the CPRS scenarios are muted by a projected spike in reference scenario prices early in that period. Values shown are averages across each period.
Source: MMA.

Higher wholesale electricity prices flow into retail prices which are faced by households (Table 6.15). In the initial years of emission pricing, average electricity prices faced by households increase by 20 per cent for the CPRS -5 scenario and 38 per cent for the Garnaut -25. The effect on households is muted by rising real incomes over time.

Table 6.15: Average household electricity price increases

Change from reference scenario

	CPRS -5			CPRS-15			Garnaut -10			Garnaut -25		
	2010-15	2015-20	2045-50	2010-15	2015-20	2045-50	2013-15	2015-20	2045-50	2013-15	2015-20	2045-50
	Per cent			Per cent			Per cent			Per cent		
NSW	23	27	33	25	29	48	25	24	41	38	39	52
VIC	23	30	37	23	31	52	25	26	35	44	46	59
QLD	21	25	37	24	26	45	26	24	44	44	41	51
SA	21	22	20	21	22	38	26	23	27	39	35	34
TAS	16	25	22	18	27	33	21	21	21	40	39	38
SWIS	11	14	34	12	13	39	10	13	33	20	23	47
NT	5	5	12	7	7	17	3	5	16	9	11	37
Avg	20	25	34	22	26	46	23	23	38	38	38	51

Note: SWIS is the South-West Interconnected System in Western Australia. The modelling assumes that wholesale price increases are passed through into retail prices. Values shown are averages across each period.
Source: MMA.

A key difference between the GDP impacts in GTEM and MMRF is the modelling of the electricity sector (Box 6.8).

Box 6.8: Modelling of electricity generation in GTEM and MMRF

Modelling of the Australian electricity sector is different in GTEM and MMRF; MMRF uses bottom-up modelling from MMA. The crucial difference is the level of detail. MMA modelling replicates actual short- and long-term market conditions; GTEM modelling is stylised to capture the long-term, high level trends.

MMA models the establishment, operation and retirement of individual electricity generating units in Australia, with specific assumptions about cost, performance and fuel use. It incorporates transmission between states and network infrastructure. In contrast, GTEM aggregates 12 technologies (three conventional fossil fuels, seven renewables and two carbon capture and storage). The share of electricity from each technology in GTEM is largely determined by technology price changes.

Demand for electricity from MMRF was divided by MMA into grid and off-grid, and modulated into base-load, intermediate and peak demand. GTEM can model fuel switching, but does not differentiate types of demand. The pre-existing and proposed national and state policies modelled by MMA were either not included in GTEM or modelled in a stylised fashion.

An important difference affecting the aggregate GDP impact in GTEM and MMRF is the wholesale electricity price. MMA sets wholesale electricity prices through the marginal generator, modelling strategic bidding behaviour by individual generators, consistent with the operation of the National Electricity Market. In contrast, GTEM determines wholesale electricity prices using the weighted average of the long-term marginal costs of all technologies. This approach produces significantly lower electricity prices and mitigation costs in GTEM.

In the longer term, as a result, energy consumers within GTEM substitute from fossil fuels towards electricity as it becomes more competitive. Electricity is competitive because its price is decoupled from the emission price through the uptake of clean generation technologies. As a result, electricity generation expands considerably in GTEM in the long term relative to the reference case. The substitution away from fossil fuels to electricity within industry and households enables the economy to significantly reduce emissions, resulting in lower economic costs per unit of mitigation in GTEM.

While the emission price adds to the cost of electricity from fossil fuels, both gas and coal continue to play important roles in the sector. Coal-fired electricity's share declines after emission pricing is introduced, with several existing fossil fuel power plants retiring earlier than in the reference scenario (Box 6.9). However, with electricity prices increasing due to the emission price, most existing power plants continue to operate. The assumed convergence of east coast gas prices to export parity also helps coal-fired electricity maintain its competitiveness for base-load generation.

Despite this, gas generation benefits from emission pricing, as it has a lower emission intensity (Chart 6.28). The share of gas in total generation at 2030 ranges from 22-24 per cent in the policy scenarios compared with 17 per cent in the reference scenario. In the Garnaut -25 scenario, gas generation declines in the longer term because of the high emission prices, lower electricity demand and the greater uptake of renewables.

Box 6.9: Early retirement of power plants

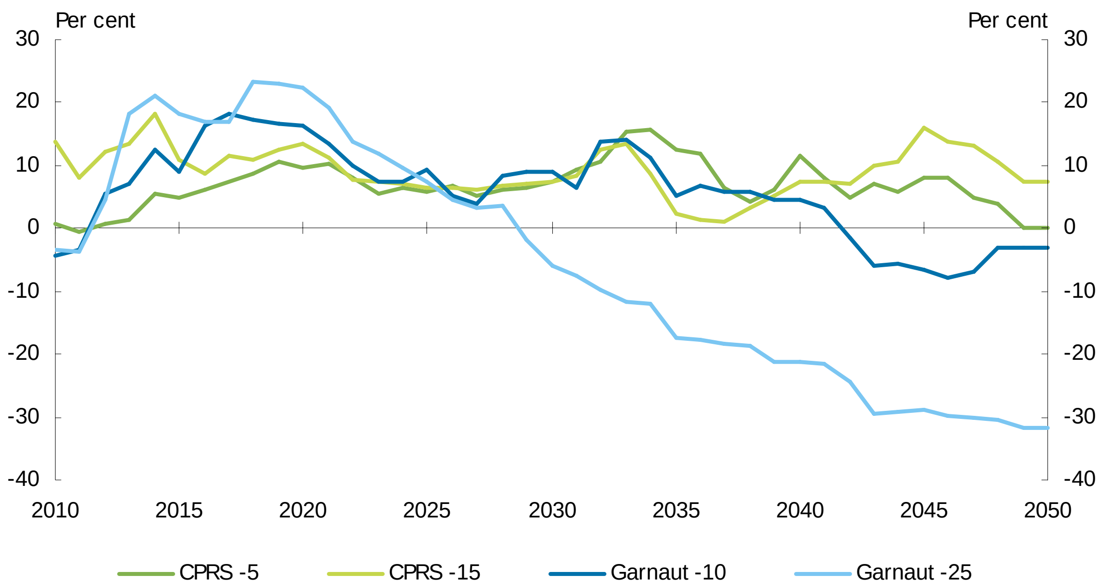
The retirement of several existing fossil fuel power plants, either fully or partially, owing to reduced profitability, does not lead to power shortages. The reduced demand for electricity and new investment in lower-emission sources ensures demand for electricity is met.

As with all industries adversely affected by emission pricing, the early retirement of power plants could lead to adjustment costs for firms and employees, such as through retraining and relocation.

Early retirement is most significant in the Garnaut -25 scenario, where the starting emission price is highest and reduction in demand for electricity is greatest. Electricity sector emissions in 2020 are 42 per cent below the reference scenario and 12 per cent below 2000 levels. Full or partial early retirement before 2020 could occur in Victoria, New South Wales, Queensland and South Australia.

This report projects retirement of electricity generation units by modelling them as physical economic assets. It does not take account of the impact of financial considerations, such as debt-equity ratios or ownership structures, on retirement decisions. In reality, these may be interrelated. The *Carbon Pollution Reduction Scheme Green Paper* identified the coal-fired generation sector as a strongly affected industry and proposed support comprising three elements: (1) direct assistance; (2) support for the development and deployment of carbon capture and storage technologies, including through existing programs; and (3) commitments to address particular impacts of the scheme on workers, communities and regions through various structural adjustment assistance packages as required (DCC,2008a). The modelling in this report does not account for this commitment.

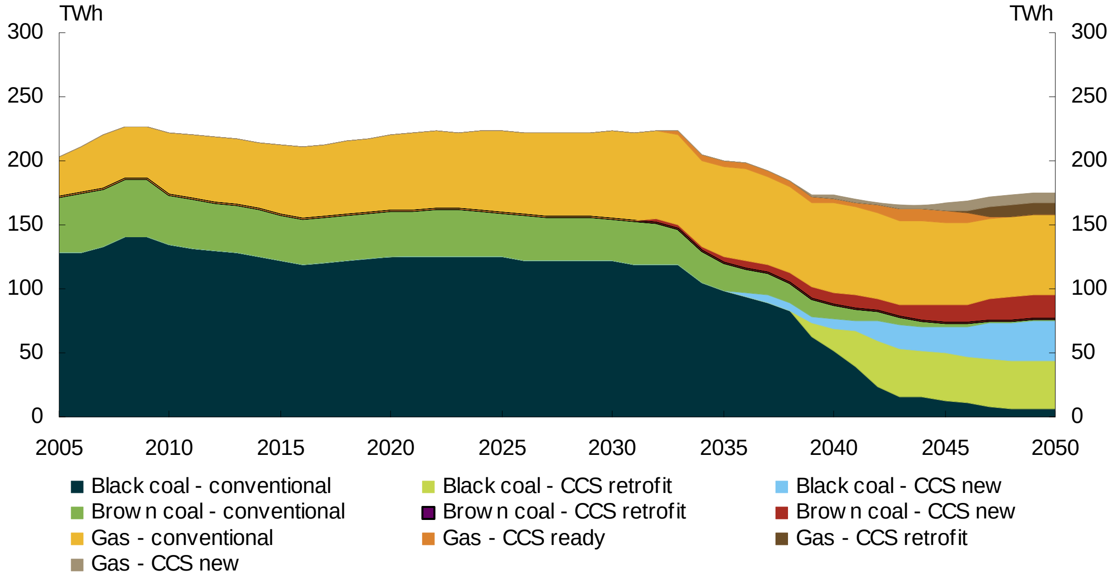
Chart 6.28: Gas-fired electricity generation
Change from reference scenario



Source: MMA.

The longer-term role of coal depends on the development and deployment of carbon capture and storage. Carbon capture and storage is taken up by the electricity sector through building new carbon capture and storage power plants, building power plants 'capture ready' then installing carbon capture and storage operations, and retrofitting existing power plants.

Chart 6.29: Coal and gas generation
CPRS -5 scenario



Source: MMA.

Carbon capture and storage reduces emissions but adds to the capital and operating costs of generating electricity. Installation will only occur when the additional costs are more than covered by savings on emission permits. The earliest year when carbon capture and storage is deployed in the scenarios will depend on when the investment is profitable (Table 6.16).

Table 6.16: Carbon capture and storage, estimated deployment year and emission price

	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
Year	2033	2033	2027	2026
Emission price (A$2005/t$CO_2$-e)	59	82	45	75

Source: MMA.

Carbon capture and storage requires the transport of significant quantities of carbon dioxide to sites for sequestration, and infrastructure and regulatory frameworks. It will create new industries and employment opportunities. In the CPRS -5 scenario, the annual rate of carbon capture and storage sequestration rises to around 128 Mt CO_2 by 2050. The total amount of CO_2 stored in 2050 is 945 Mt, distributed across Queensland (38 per cent), Victoria (35 per cent) and New South Wales (27 per cent).

The expanded Renewable Energy Target

The Carbon Pollution Reduction Scheme provides incentives to increase deployment of renewable electricity generation technologies. The emission price increases the cost of generating fossil fuel-fired electricity, which in turn raises the cost relative to renewables, which are emission free.

The Government is committed to providing additional support to deploy renewable energy beyond the Carbon Pollution Reduction Scheme with an expanded Renewable Energy Target. To assess the impact of an expanded Renewable Energy Target on the electricity sector and the economy more broadly, a sensitivity scenario around the CPRS -5 scenario was explored. This sensitivity excluded the expanded Renewable Energy Target.

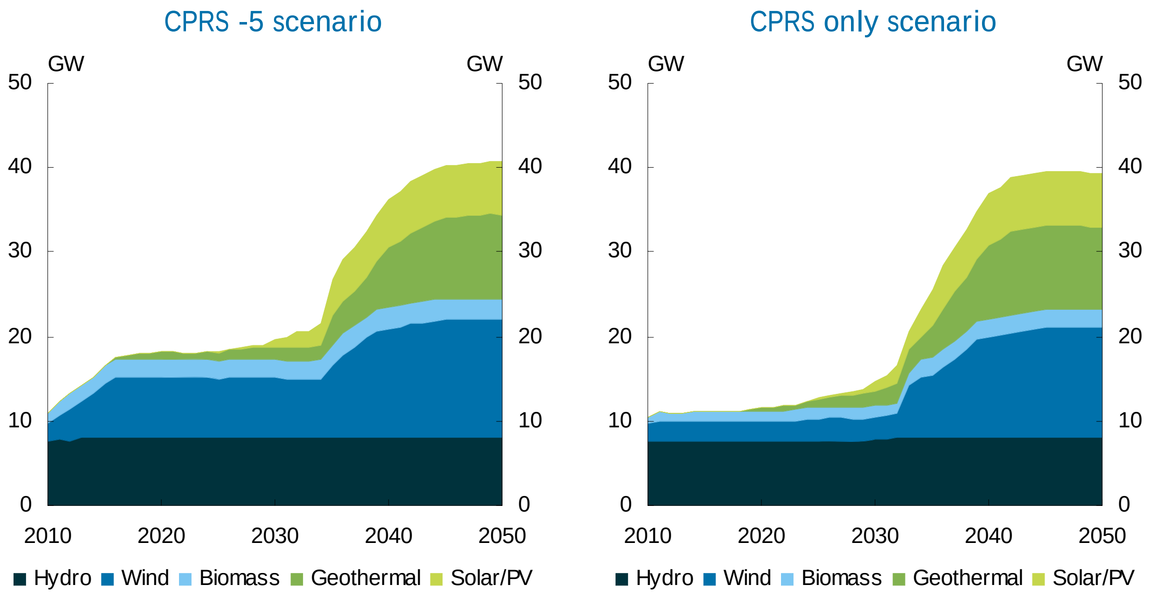
Box 6.10: The expanded Renewable Energy Target

The Mandatory Renewable Energy Target scheme started in 2001. It aims to increase the deployment of renewable energy in Australia's electricity supply by guaranteeing a market for additional renewables-based generation. Parties who buy wholesale electricity (retailers and large users) must source an increasing percentage of their electricity purchases from renewables-based generation. This is implemented through tradeable renewable energy certificates, where one certificate equals one megawatt-hour (MWh) of renewable energy.

In 2007, the Government committed to ensuring that 20 per cent of Australia's electricity supply — approximately 60,000 gigawatt-hours (GWh) — comes from renewable energy sources by 2020. To implement this, the Government will expand the Renewable Energy Target to 45,000 GWh by 2020 to help ensure that, together with the approximately 15,000 GWh of existing renewable capacity, Australia reaches the 20 per cent target by 2020. The Government also will bring the national Renewable Energy Target and existing state-based targets into a single national scheme (DCC, 2008b).

The expanded Renewable Energy Target provides additional support for the renewable electricity sector and lowers emissions from the electricity sector (Chart 6.30). With the expanded Renewable Energy Target in place, investment in renewables is higher between 2010 and 2030. Most of the additional renewables are wind and biomass; these account for 72 per cent and 14 per cent of the additional renewable capacity in 2020. The amount and timing of geothermal and solar thermal deployment are only marginally affected by this policy, since they are more expensive than other low-emission options.

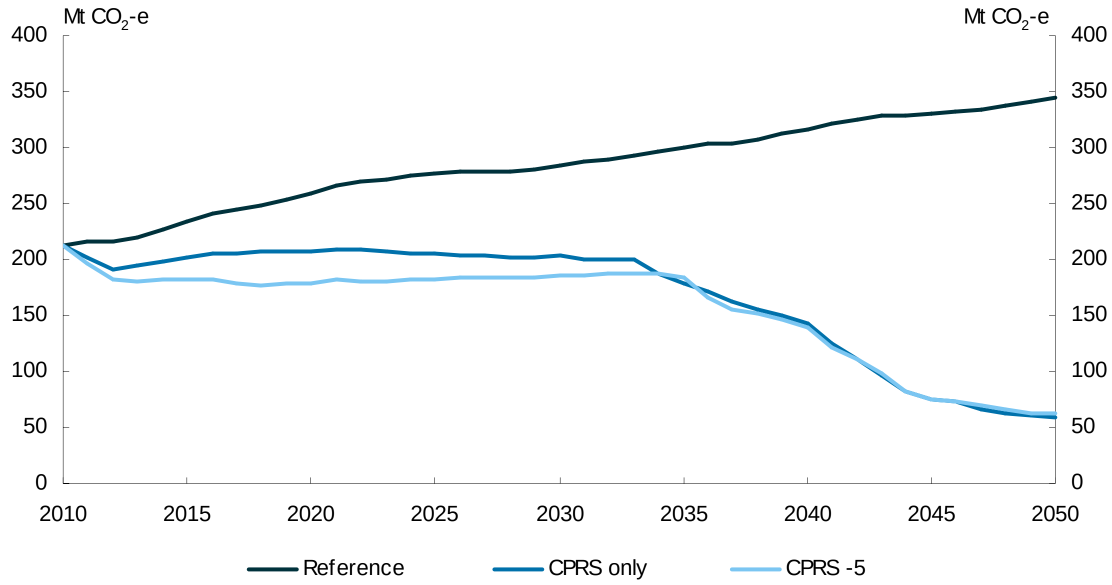
Chart 6.30: Renewables capacity



Source: MMA.

The cumulative mitigation attributed to the expanded Renewable Energy Target from 2010 to 2050 is 308 Mt CO_2-e, just over 5 per cent of the total mitigation undertaken in the CPRS -5 scenario (Chart 6.31).

Chart 6.31: Electricity sector emissions



Note: CPRS only scenario excludes the expanded Renewable Energy Target.
Source: Treasury estimates from MMRF.

Expanding the renewable energy target affects the rest of the electricity sector. Adoption of more renewables crowds out gas-fired generation and accelerates the transition away from coal, resulting in additional early retirement of existing fossil fuel power stations.

The expanded Renewable Energy Target also affects the broader economy as electricity retailers purchase renewable energy certificates from eligible renewable electricity generators. The certificate prices reflect the additional resource costs, in terms of capital, labour and other inputs, required to generate electricity from the new renewable sources. The cost of the renewable certificates is assumed to be passed on to customers as higher retail electricity prices: these rise by 2-4 per cent from 2010 to 2020. These higher resource costs would increase GDP costs. By 2020, GDP costs could be around 0.1 per cent higher than from an emission price alone.

Additional mitigation in the renewable energy target will not lower domestic emission prices if the Australian emission price is linked to the global price. Instead, fewer permits will be bought from the world market, reducing the income Australia transfers overseas.

The impact on GNP of the expanded Renewable Energy Target, taking into account both the increased GDP costs and the reductions in international income transfers, is $5.0-5.5 billion, when estimated as a net present value using real discount rates of 4-8 per cent. The average cost of the mitigation (per tonne of CO_2-e) from expanding the renewable energy target is around three times the average permit price from 2010 to 2020.

6.3.2 Transport sector

Emission pricing drives significant reductions in the emission intensity of transport, through changing fuel mix, vehicle types and transport modes. The transport sector has relatively high mitigation costs, and delivers less mitigation in the short term.

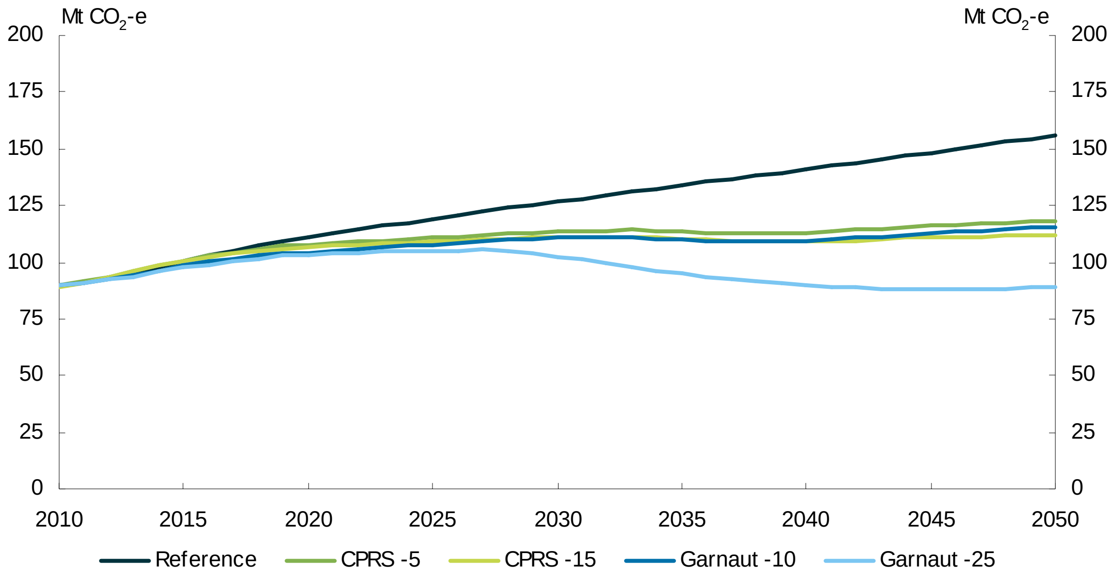
Three forces transform the transport sector: (1) lower demand; (2) less energy used per trip; and (3) fewer emissions per unit of energy used. Reduced demand comes from reduced economic activity and substitution from transport into other areas of economic activity. Less energy use per unit of transport comes from consumers choosing smaller and/or more fuel-efficient vehicles. Fewer emissions per unit of energy come from substitution to lower emission fuels.

The responsiveness of different transport activities to emission pricing varies. Road passenger transport responds most strongly; water transport is least affected.

6.3.2.1 Emissions

Emissions fall substantially across all transport modes relative to the reference scenario (Chart 6.32). In 2050, emissions are around 30 per cent lower than the reference scenario and around 5 per cent lower than 2006 levels in all scenarios except the Garnaut -25. In the Garnaut -25, emissions are around 40 per cent lower than the reference scenario.

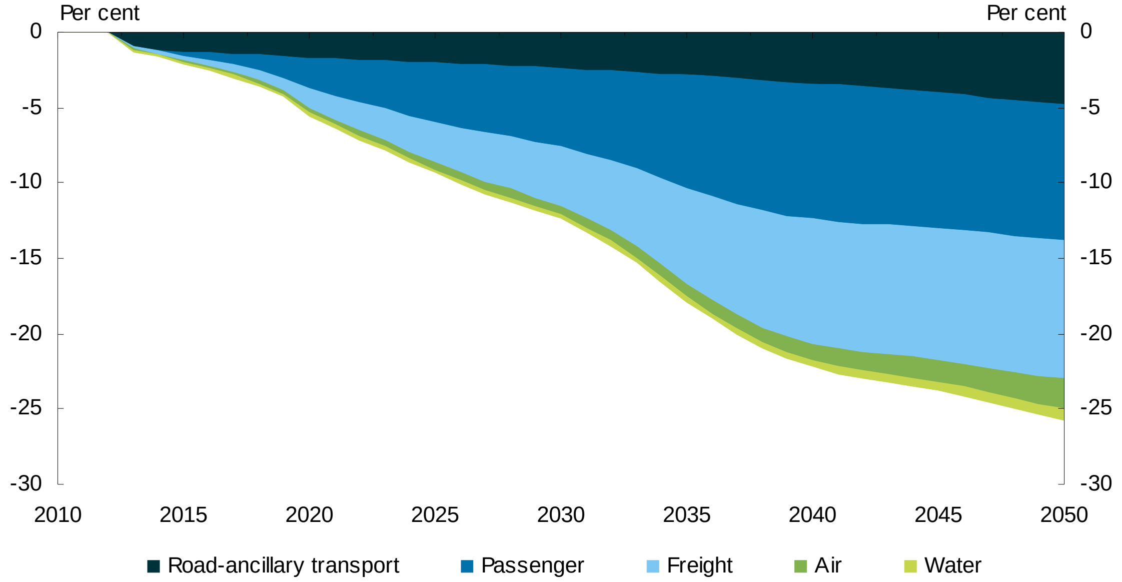
Chart 6.32: Transport sector emissions



Source: Treasury, BITRE and CSIRO.

Road passenger transport emissions fall throughout the projection period, while air and water transport emissions increase in absolute terms (but fall relative to the reference scenario) to 2050, then begin to fall after 2050. By 2050, passenger transport emissions are around 25 per cent below 2005 levels, while water transport emissions are 70 per cent higher, and air transport emissions are 300 per cent higher than 2005 levels for the Garnaut -10 scenario (Chart 6.33).

Chart 6.33: Contribution to transport mitigation
Change from reference scenario, Garnaut -10 scenario



Source: Treasury, BITRE and CSIRO.

Mitigation in the road transport sector in the CPRS -5 scenario is slightly less than in Garnaut -10 scenario despite a higher price on emissions. The difference is due to policy settings. In the CPRS -5 scenario, the road transport sector is exempted from emission pricing for three years, reflecting the Government's Green Paper commitment to provide a transitional period to allow motorists time to adjust to the scheme.

Output

Demand for private road transport falls, relative to the reference scenario, with the introduction of an emission price (Table 6.17 and Chart 6.34). Fuel costs are higher; vehicle sharing is greater; trips are fewer and/or distances travelled are shorter. Some substitution to public transport also occurs: passenger rail transport grows faster than in the reference scenario by around 0.2 per cent per year.

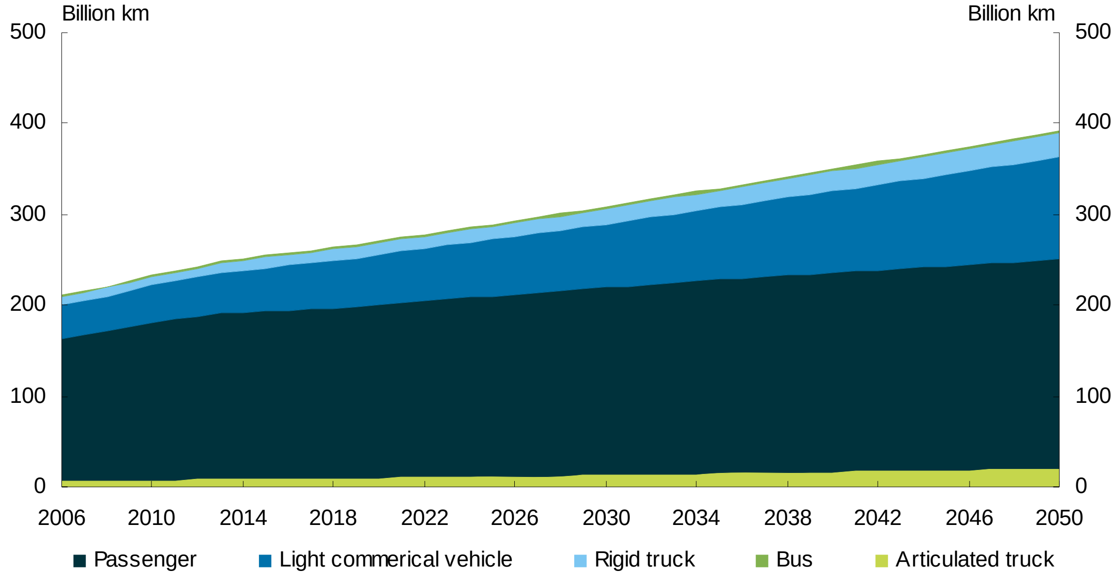
Output from the air transport falls by around -1.1 to -7.0 per cent in the policy scenarios relative to the reference scenario by 2050.

Table 6.17: Transport output
Change from reference scenario

	CPRS -5		CPRS -15		Garnaut -10		Garnaut -25	
	2020	2050	2020	2050	2020	2050	2020	2050
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Road								
Passenger	-0.9	-4.5	-1.2	-5.1	-1.8	-5.1	-3.0	-6.9
Freight	-0.3	-0.5	-0.1	0.8	-0.4	-0.3	-0.2	1.8
Rail								
Passenger	1.5	10.4	1.7	9.5	1.8	9.9	1.1	6.7
Freight	-0.6	-0.1	-0.9	-1.5	0.4	1.2	-0.5	-4.0
Water	-0.6	-1.8	-0.8	-2.5	-0.4	-1.6	-0.3	-2.5
Air	-1.4	-1.1	-2.2	-3.4	-1.3	-1.7	-3.6	-7.0

Source: Treasury estimates from MMRF.

Chart 6.34: Distance travelled by mode of road transport
Garnaut -10 scenario

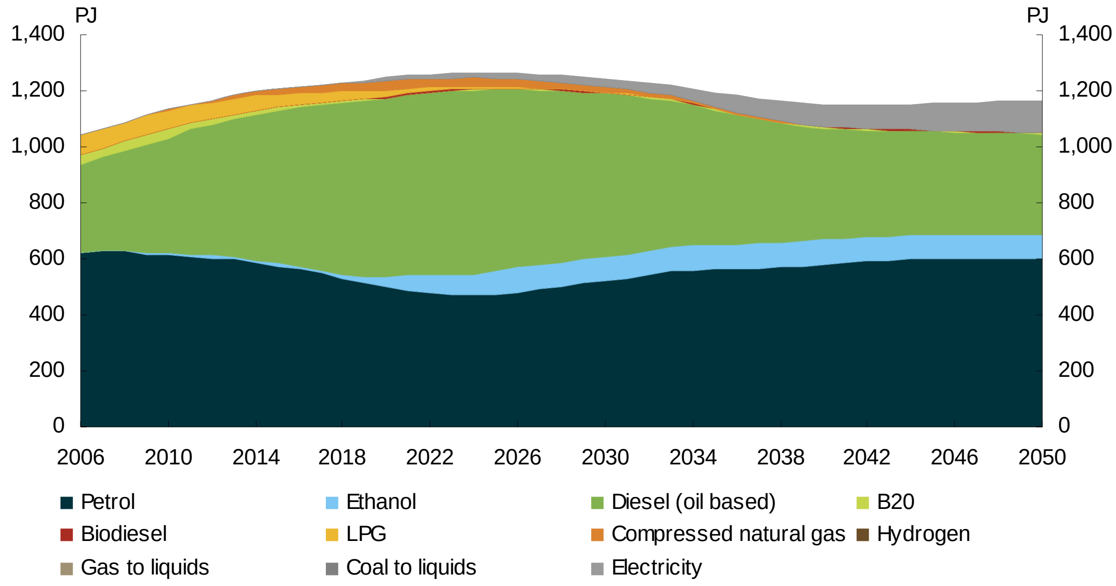


Source: Treasury, CSIRO and BITRE.

Transformation of the road transport sector

Fuel consumption falls relative to the reference scenario once emissions are priced. Lower fuel intensity and lower activity levels reduce total road fuel consumption in 2050 by around 20 per cent in the CPRS -5 scenario compared with the reference scenario. Traditional petrol fuel use falls most, while electric vehicles and hybrid electric cars boost electricity's share in the road transport sector to around 10 per cent in 2050.

Chart 6.35: Road transport fuel mix
CPRS -5 scenario



Note: B20 is diesel with 20 per cent biodiesel.
Source: CSIRO, BITRE and Treasury.

Fuel diversification is more limited in all the policy scenarios than in the reference scenario. An emission price makes non-conventional oil sources, such as coal-to-liquids and gas-to-liquids diesel, uncompetitive owing to their high life-cycle emissions.

6.5.6 Forestry and land-use change

Demand for low-emission goods and services increases, particularly where they substitute for higher emission commodities or where the emissions trading market creates a new source of revenue.

Both effects are important in the forestry sector. Consumers substitute towards wood products (a low-emission good, which can be used instead of other inputs in some processes). In addition, forests sequester carbon, generating credits for sale in an emissions trading scheme.

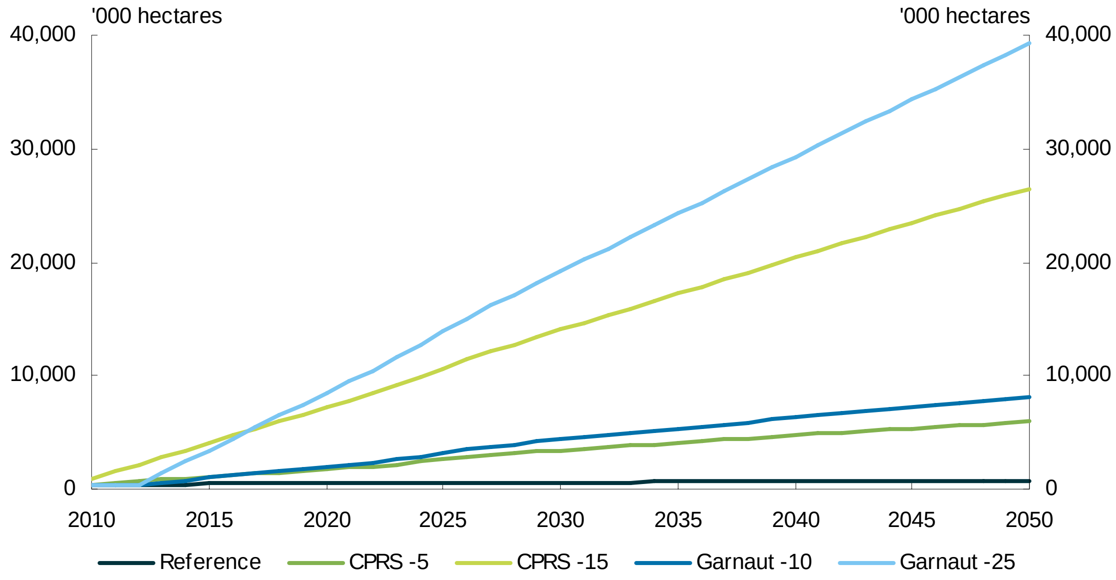
Carbon sequestration could offset substantial domestic emissions relatively cheaply. Realising a substantial part of this potential would greatly reduce the costs of climate change mitigation in Australia.[12]

Forestry's expansion may have flow-on effects for some agricultural sectors, particularly cattle and sheep grazing. These activities compete for land, so as forestry expands, livestock production contracts (relative to the reference scenario). This effect is even stronger in the lower stabilisation level scenarios, because the higher emission prices make forestry even more profitable than competing land uses.

Land under forestry

In all scenarios, substantial forestry or environmental plantations of 5-40 million hectares are established, from 2005 to 2050 (Chart 6.36).

Chart 6.36: Australian additional land under forestry



Note: New land under forestry is cumulative since 2005.
Source: ABARE, DCC, BRS.

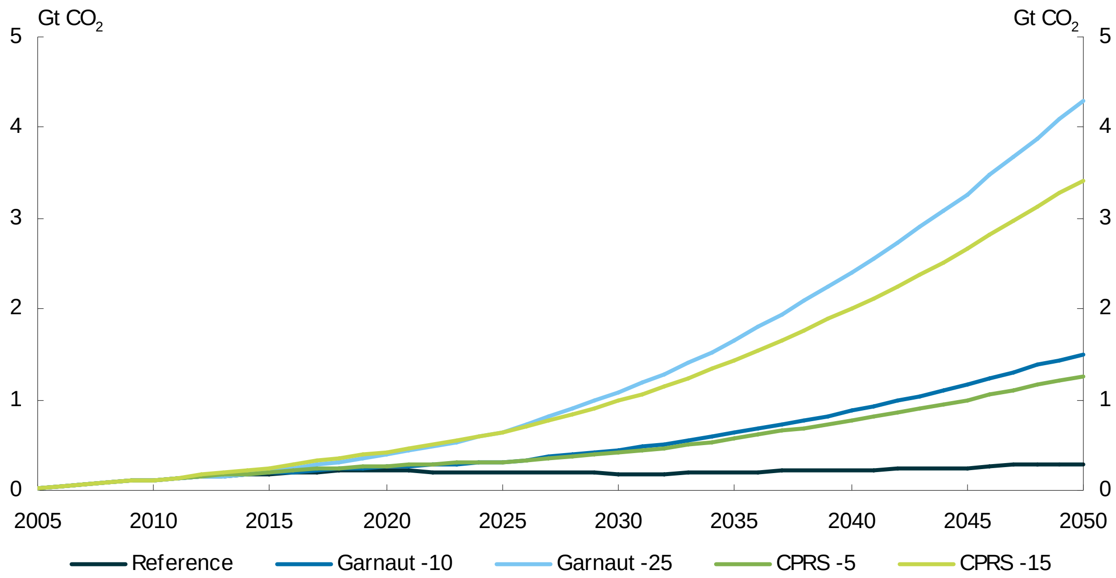
12 The *Carbon Pollution Reduction Scheme Green Paper* proposes allowing reforestation activities to opt-in to the scheme from its start in 2010 (DCC, 2008a).

The Garnaut -25 scenario sees around 40 million hectares of new forestry plantations established from 2005 to 2050, almost five times more than in the Garnaut -10 scenario. Over 80 per cent of these new plantings occur in Queensland and New South Wales, reflecting a change in the relative competitiveness of different land uses from a higher emission price. In the Garnaut -25 scenario, forestry delivers higher returns than other agricultural activities, such as grazing. By the time the emission price reaches the same level in the Garnaut -10 scenario (in the 2020s), agricultural land has appreciated in value, so prospective forestry investors face a much higher opportunity cost than they did in 2013. For the Garnaut -25 and CPRS -15 scenarios the majority of afforestation is environmental plantings.

Carbon sequestration

The growth in land under forestry provides a cumulative net carbon sink of 1.3-4.3 Gt CO_2 from 2005 to 2050 (Chart 6.37). Sequestration rates vary from year to year, depending on the amount of land planted, growth rates, harvesting and other factors.

Chart 6.37: Australian forestry sequestration



Note: Estimates are cumulative from 2005.
Source: ABARE, DCC, BRS.

Land-use change emissions in Australia continue at the rate of 44 Mt CO_2 per year until the introduction of emission pricing, then are assumed to decline gradually. While emissions from land use are not intended to be included in the Carbon Pollution Reduction Scheme, alternative policy instruments could be used to encourage emission reductions from this sector.

6.6 IMPACTS ON HOUSEHOLDS

Real household income continues to grow strongly. Households face higher prices for emission-intensive products, such as electricity and gas. However, the share of household income spent on these goods is likely to fall over time.

6.6.1 Aggregate impacts over time

Real household disposable income grows strongly over time in all policy scenarios. Real disposable per capita income grows at an average annual rate of around 1.0 per cent in the policy scenarios, compared to around 1.2 per cent in the reference scenario. As a result, real disposable income per capita is about 8-9 per cent higher than current levels by 2020, and about 50 per cent higher by 2050 (compared with 10 and 60 per cent in the reference scenario).

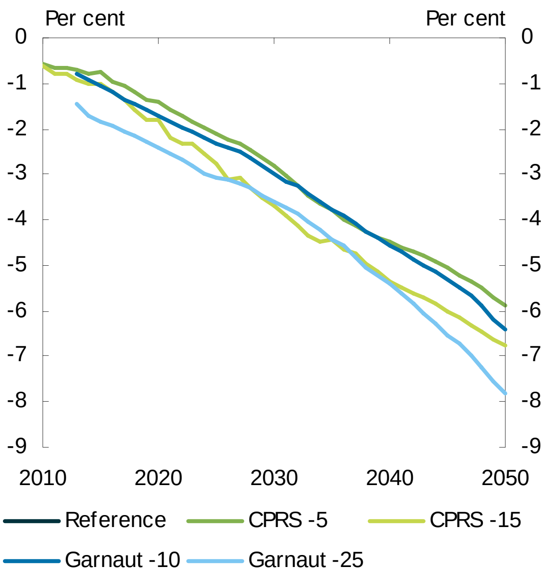
Household income growth slows mostly due to slower labour income growth. Although real returns to both capital and labour are reduced, labour income growth slows more than capital income. Capital is allowed to retire and the economy experiences capital shallowing. The modelling assumes that real wages adjust over the medium term to return the labour market to equilibrium.

The return of all remaining permit revenue as a lump-sum transfer to households, after the provision for shielding, partially offsets the reduction in household labour and capital income.

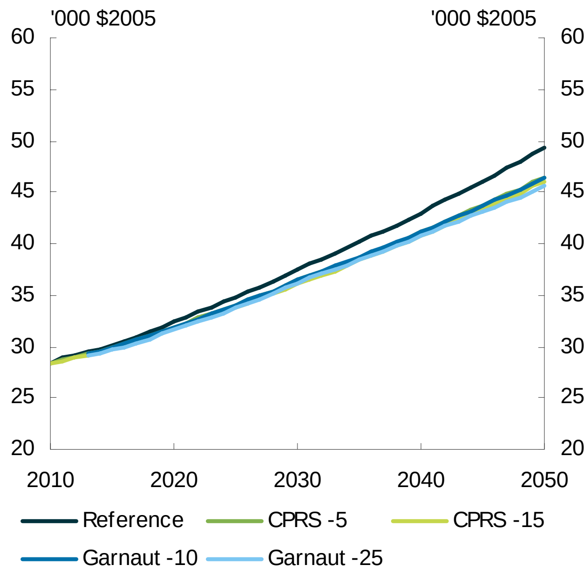
Aggregate household consumption moves in line with real household income and grows in all policy scenarios, although at a slower rate than in the reference scenario (Chart 6.38).

Chart 6.38: Private per capita consumption

Change from reference scenario



Level



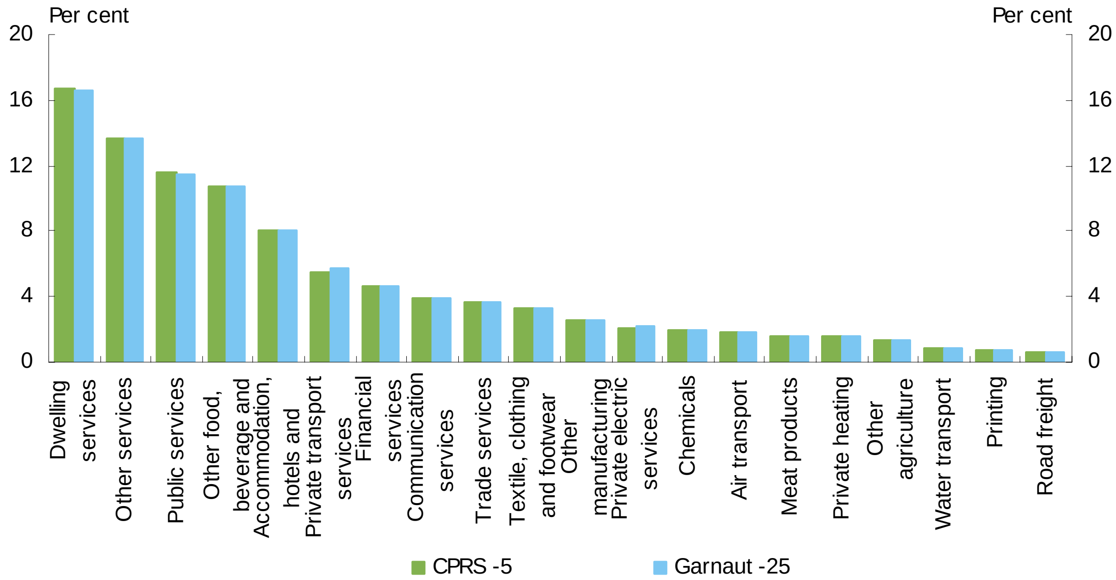
Source: Treasury estimates from MMRF

While aggregate consumption continues to grow, emission pricing changes the relative price of different consumer goods. The impact of emission pricing on particular goods and services will depend on the emission-intensity of the goods and how sensitive consumer demand is to price changes. If a good experiences a rise in relative prices, consumers tend to substitute away from this good. However, if substitution possibilities are limited (demand is inelastic) consumers may not change their demand by much, if at all, despite higher prices.

The largest relative price increases occur for emission-intensive goods such as road and air transport, electricity, and gas used for heating. For example, in the CPRS scenarios, real residential electricity prices increase by 35-50 per cent in 2045-2050, relative to the reference scenario, leading to a fall in electricity consumption of around 15 per cent. The relative prices of most products in the household basket fall, such as services, communication, accommodation and housing.

Households adjust their consumption patterns over time. By 2020, the variation in the price impacts from emission pricing across the policy scenarios is minimal. The Garnaut -25 scenario implies almost no additional change in the relative prices above those seen in the CPRS -5 scenario, except for a small set of emission-intensive products. As consumers substitute between consumption goods, away from those that experience price increases, and towards those that experience price falls, household expenditure shares do not change significantly across the scenarios (Chart 6.39).

Chart 6.39: Household expenditure shares in 2020



Source: Treasury estimates from MMRF.

6.6.2 Distributional impacts on introduction of emission pricing

Putting a price on emissions will make emission-intensive goods more expensive. Households that continue to consume more emission-intensive products face higher costs than households that change their consumption patterns. This has implications for the distributional impact of emission prices based on the initial emission-intensity of consumption by different household groups and their relative ability to alter consumption.

The distributional effects of emission pricing outlined in this section are based on the starting emission prices in the CPRS scenarios and update the preliminary analysis in the *Carbon Pollution Reduction Scheme Green Paper*. The Green Paper estimates were based on an indicative A$20 emission price in 2010. Some minor modelling enhancements and newly available data have since been incorporated.[13] However, flow-on effects from the Government's expanded Renewable Energy Target are not included.

The distributional analysis is based on estimates derived from linking models that have differing assumptions. The emission price from MMRF, which incorporates substitution effects and the

13 2004-05 ABS Input-output tables (Cat.no. 5209.0.55.001) and 2007-08 consumer price index expenditure class data.

return of permit revenue to the household sector, is inputted into PRISMOD. PRISMOD assumes full pass through of the emission price to households without allowing for substitution. Consequently, the distributional modelling tends to overestimate the impact of emission pricing on households. This is likely to be greatest in higher income households, as these households are expected to be more able to shift consumption towards less emission-intensive goods through product substitution.

The distributional modelling thus presents a 'morning-after' picture of the effects of putting a price on emissions and the corresponding increase in the price level. The distributional modelling does not explicitly factor in changes in emission prices over time and/or the price impact of the subsequent inclusion of additional sectors (such as the possible inclusion of agriculture from 2015).

In the CPRS scenarios (where emission pricing is introduced in 2010), a one-off rise in the price level of around 1-1.5 per cent is expected, with minimal implications for ongoing inflation (Box 6.11).

For the average household, emission prices in the CPRS scenarios lead to an extra $4-5 per week spending on electricity and $2 per week on gas and other household fuels in 2010.[14] This corresponds to increases in electricity prices of around 17-24 per cent, and a rise in gas and other household fuel prices by around 11-15 per cent. In the CPRS -5 scenario, most other commodity prices increase by an average of one per cent or less.[15]

The Government plans to offset the impact of emission prices on emission-intensive petroleum fuel products through cuts in fuel taxes, so the price of petrol does not increase when the scheme starts (DCC, 2008a).

Low-income households are disproportionately affected by emission prices as they spend a higher proportion of their disposable income on emission-intensive goods, such as electricity and gas (Tables 6.18 and 6.19). They are also less likely to be able to substitute towards low-emission products. For example, low income households may find it more difficult to purchase insulation, which would reduce consumption of gas or electricity for heating. In the CPRS -5 scenario, the average price impact for a single pensioner household in the bottom quintile is 1.3 per cent, while for a one-income household with no children in the highest quintile, the average price impact is 0.8 per cent.

The inclusion of agriculture from 2015 would produce a further increase in the price of many food products. This inclusion also is likely to have a disproportionate effect on lower-income households, as these households spend a higher proportion of their income on food products.

As outlined in the *Carbon Pollution Reduction Scheme Green Paper*, the Government is committed to helping households adjust to emission pricing, including by increasing benefit payments and other assistance to low-income households through the tax and payment system, and other assistance to middle-income households (DCC, 2008a). These measures, together with the automatic indexation of benefits to reflect changes in the CPI, will help minimise household impacts.

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14 These are estimated increases for those households who consume these commodities. The gas and other household fuels category also includes firewood, coal and kerosene.

15 These estimates are averages. Actual household expenditure may vary substantially (depending on household size, composition, preferences and energy sources).

The 'morning-after' impact analysis outlined in this section does not incorporate the Government's commitment to provide direct financial assistance to households, nor the mitigating impact stemming from the automatic indexation of transfer payments.

Table 6.18: Estimated price impacts by household type

CPRS -5 scenario in 2010

Household type – primary source of income	Household income quintile(a)					
	All	First	Second	Third	Fourth	Fifth
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
All	1.0	1.2	1.1	1.0	1.0	0.9
Two income household, no children(b)	0.9	**	1.2	1.0	0.9	0.9
Two income household, with children(b)	1.0	**	1.0	1.0	0.9	1.0
One income household, no children(b)	0.9	0.9	1.0	1.0	1.0	0.8
One income household, with children(b)	1.0	**	1.1	1.0	1.0	0.9
One income single person household(b)	1.0	**	1.1	1.0	1.0	1.0
Self-employed household	1.0	1.2	1.0	1.1	1.0	1.0
Household with primary income source from Commonwealth allowances (e.g New start Allowance, Youth Allowance)	1.2	1.2	1.2	**	**	**
Married pensioner household	1.1	1.2	1.0	**	**	**
Single pensioner household	1.3	1.3	1.2	**	**	**
Sole parent pensioner household	1.2	1.3	1.2	**	**	**
Part-pension and self-funded retiree households	1.0	1.0	1.0	1.0	1.0	0.9

(b) Income quintiles rank households from the lowest 20 per cent of disposable income to the highest 20 per cent. Modified OECD equivalence scales apply to household disposable incomes to allow for comparisons across households of different sizes.
(c) Principal source of income from wages and salaries.
** Represents those results for which the sample size is too small to produce statistically reliable results.
Source*:* Treasury.

Table 6.19: Estimated price impacts by household type

CPRS -15 scenario in 2010

Household type – primary source of income	Household income quintile(a)					
	All	First	Second	Third	Fourth	Fifth
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
All	1.4	1.6	1.5	1.4	1.3	1.3
Two income household, no children(b)	1.3	**	1.6	1.4	1.3	1.3
Two income household, with children(b)	1.3	**	1.4	1.4	1.3	1.3
One income household, no children(b)	1.3	1.3	1.4	1.3	1.4	1.2
One income household, with children(b)	1.4	**	1.5	1.4	1.3	1.3
One income single person household(b)	1.4	**	1.5	1.4	1.4	1.3
Self-employed household	1.4	1.6	1.4	1.5	1.4	1.4
Household with primary income source from Commonwealth allowances (e.g New start Allowance, Youth Allowance)	1.6	1.6	1.6	**	**	**
Married pensioner household	1.6	1.7	1.4	**	**	**
Single pensioner household	1.8	1.8	1.7	**	**	**
Sole parent pensioner household	1.7	1.8	1.7	**	**	**
Part-pension and self-funded retiree households	1.4	1.4	1.4	1.4	1.3	1.3

(a) Income quintiles rank households from the lowest 20 per cent of disposable income to the highest 20 per cent. Modified OECD equivalence scales apply to household disposable incomes to allow for comparisons across households of different sizes.
(b) Principal source of income from wages and salaries.
** Represents those results for which the sample size is too small to produce statistically reliable results.
Source: Treasury.

Spending on energy varies across regions, so the impact of emission pricing would be expected to also vary across regions. However, the Government's commitment to cut fuel taxes to offset the emission price impacts on fuel will ameliorate some of the differences between regions. The estimated average price impacts for households not located in a capital city are only slightly higher than for those located in a capital city (Tables 6.20 and 6.21).

Table 6.20: Estimated price impacts by region in 2010
CPRS -5

	Household income quintile(a)					
Area of usual residence(b)	All	First	Second	Third	Fourth	Fifth
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
All	1.0	1.2	1.1	1.0	1.0	0.9
Capital city	1.0	1.2	1.1	1.0	0.9	0.9
Balance of state	1.1	1.2	1.1	1.0	1.0	1.0
ACT/NT	1.0	1.3	1.1	1.1	1.0	1.0

(a) Income quintiles rank households from the lowest 20 per cent of disposable income to the highest 20 per cent. Modified OECD equivalence scales have been applied to household disposable incomes to allow for comparisons across households of different sizes.
(b) Capital city/balance of state breakdown is available for all states except ACT and NT.
Source*:* Treasury.

Table 6.21: Estimated price impacts by region in 2010
CPRS -15

	Household income quintile(a)					
Area of usual residence(b)	All	First	Second	Third	Fourth	Fifth
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
All	1.4	1.6	1.5	1.4	1.3	1.3
Capital City	1.4	1.6	1.5	1.4	1.3	1.3
Balance of state	1.5	1.7	1.5	1.4	1.4	1.4
ACT/NT	1.4	1.8	1.6	1.5	1.4	1.3

(a) Income quintiles rank households from the lowest 20 per cent of disposable income to the highest 20 per cent. Modified OECD equivalence scales have been applied to household disposable incomes to allow for comparisons across households of different sizes.
(b) Capital city/balance of state breakdown is available for all states except ACT and NT.
Source: Treasury.

Box 6.11: Mitigation policy and inflation

G-Cubed models the nominal economy, including price variables, while other models only generate results in real terms. As a result, G-Cubed indicates what might happen to the CPI and the GDP deflator following the introduction of emission pricing. In G-Cubed, the central bank responds to changes in consumer prices and output from desired rates by changing interest rates.

G-Cubed uses a modified Henderson-McKibbin rule for monetary policy. Changes in the interest rate are determined by:

- differences between the inflation rate and the monetary authorities' desired inflation rate;
- differences between the rate of GDP growth and what the model assumes is the economy's rate of growth of potential GDP; and
- for some developing economies, changes in the exchange rate from the desired level (reflecting the fixed exchange rates of, for example, China).

In this report, monetary authorities are assumed to be equally concerned about deviations in inflation and growth. For most regions, the growth effect dominates, leading the monetary authority to lower interest rates to stimulate the economy.

There is a one-off rise in consumer prices in 2010 when emission prices are introduced. In the CPRS -5 scenario, the rise in the CPI ranges from around 0.3 per cent in Japan and Europe to 1.4 per cent in the rest-of-the-world region.

In Australia, the CPI rises by 0.7 per cent in 2010 in the CPRS -5 scenario and by around 1.1 per cent in the CPRS -15 scenario. These initial price rises modelled in G-Cubed are broadly consistent with the estimated price rises modelled in PRISMOD. However, unlike PRISMOD, G-Cubed accounts for changes in consumer and firm behaviour.

After the initial spike, inflation continues to be slightly higher than the reference scenario. This is not purely a result of emission pricing, as the monetary policy chosen by the monetary authority in the model will affect ongoing inflation.

6.7

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CHAPTER 7: KEY FINDINGS AND FUTURE ANALYSIS

Key points

Australia's economy is well placed to respond to market-based mitigation policies.

With efficient policy settings, Australia can achieve its emission reduction objectives and maintain robust economic growth.

Real household incomes continue to grow with emission pricing. Households will face higher prices for emission-intensive products, however, the Government is committed to helping households adjust to Australia's low-pollution future.

Strong coordinated global action reduces the economic cost of achieving environmental objectives, reduces distortions in trade-exposed sectors, and provides insurance against climate change uncertainty. Where emission pricing gradually expands across the world, there are advantages to being an early mover.

If Australia prices emissions before its competitors do, some emission-intensive trade-exposed sectors could lose some competitiveness. Allocation of some free permits, as proposed by the Government, eases their transition. Fears of carbon leakage may be overplayed.

Accurately predicting which mitigation opportunities will prove most cost effective is impossible. Instead, broadly-based market-oriented policies, such as emissions trading, allow the market to respond as new information becomes available.

Australia's economy will respond to the emission price by restructuring. Most sectors will grow. Firms in a few industries face lower levels of output, and the consequent structural adjustment will require careful management.

This report has not found evidence that pricing emissions will compromise Australia's future energy security.

A key challenge for future economic analysis of climate change policies is to develop methods, models and capacity to allow more integrated analysis of the costs and benefits.

This report examines the macroeconomic, sectoral and distributional costs of climate change mitigation policies for the Australian economy. Economic modelling provides insights on the scale of the global effort and consequent economic transformation required to reduce the risks of dangerous climate change.

This study's rigorous analytical approach links global, national, sectoral and household models to generate consistent and integrated projections of economic activity and greenhouse gas emissions. The work done in preparing this report will improve the quality of future analysis, both within and outside government.

Some important gaps exist in Australia's current analytical tools and capacities. The Government plans to develop new tools to complement the existing suite of economic models, and strengthen Australia's analytical capacity to support ongoing international negotiations and implementation of domestic policies.

This chapter summarises the principal findings of the report and identifies priorities for future analysis.

7.1 Principal findings

The world and Australia can significantly reduce the risks of dangerous climate change and maintain robust economic growth.

They can do this by introducing efficient mitigation policies which price emissions. Mitigation costs fall as the policy coverage expands. If all sources of emissions across the globe are included, mitigation costs are minimised. This involves participation by all regions and all sectors to reduce emissions of all greenhouse gases.

Stabilising greenhouse gases at low concentrations requires global action: stabilisation at any level is not possible without mitigation action across all major emitters. If the world acts now, using efficient policy frameworks, it could achieve even low stabilisation levels at relatively low cost. Early strong global action keeps open the option of pursuing more ambitious stabilisation levels in the future, if that proves desirable, and provides insurance against the risks of serious and irreversible climate change.

Delaying action increases the risks and costs of achieving any given environmental goal.

The insurance value of pursuing very low global stabilisation targets (450 ppm and below) and strong united global mitigation action warrants further analysis (Garnaut, 2008). This issue is critical to current global climate change discussions, including negotiations on the post-2012 mitigation framework.

7.1.1 Implications for Australia in the global context

Australia's aggregate mitigation costs (as a share of GNP) are likely to be higher than the major developed economies, due to its large share of emission- and energy-intensive industries. The global mitigation policy framework therefore will be an important factor in the costs Australia faces.

A broader and deeper international emission market will help minimise the cost of achieving Australia's emission reduction goals, by creating access to lower cost mitigation opportunities in other regions, and minimising distortions associated with trade-exposed industries.

Full participation in international emissions trading would minimise the additional costs associated with more stringent national emission trajectories; strong links between Australia's Carbon Pollution Reduction Scheme and other robust, credible emission markets are crucial.

Comparisons of national emission reduction commitments for the post-2012 period must account for differences in the cost impacts across Annex B regions.[1] Australia, Canada and Russia will likely face higher aggregate economic costs than the United States, the European Union and Japan. Differentiation of national commitments could help offset these cost differences to some extent.

Assuming that global action is eventually forthcoming, economies introducing emission pricing early gain an advantage over the long term, and those that delay face higher costs later. Early action, including by developing economies, is clearly consistent with continued economic development: even for low stabilisation levels, all regions maintain economic growth.

Early mitigation action could ensure economic development supports prospects for long-term growth. For developing economies, delaying obligations could be a costly way to differentiate responsibilities, as delays could encourage further build-up of emission-intensive capital stock that later becomes a significant liability. Early action allows individuals and firms to plan their adjustment pathways and better manage changes in skills acquisition and capital stocks.

The relative costs of different international policy frameworks are crucial to current international negotiations and warrant further analysis.

7.1.2 National and trade implications

Economic reforms in Australia over the past three decades have created a flexible and adaptable economy, making it well placed to respond to price-based policies, such as the Carbon Pollution Reduction Scheme, and make the transition to a low-pollution future.

With efficient policy settings, Australia can achieve its emission reduction objectives and maintain robust economic growth. Efficient policies have broad coverage of emission sources and sinks, link to international permit markets, do not limit banking of permits for future use, and provide clear signals regarding future emission reduction targets.

Trade in permits is more efficient than achieving all required emission reductions domestically, as it allows mitigation to occur wherever it is cheapest. Trade does not compromise the environmental objective because Australia's 'excess' emissions are offset by lower emissions in economies that export permits.

Australia's comparative advantage will change in a low-emission world. Australia is likely to retain or improve competitiveness in some energy- and emission-intensive sectors, such as iron and steel, coal and livestock. Australia's competitiveness is likely to decline in other sectors where Australian production is relatively more emission-intensive than its competitors. Modelling suggests this is true for sectors such as aluminium and petroleum refining.

If Australia prices emissions before its competitors do, some emission-intensive trade-exposed sectors could lose some of their competitiveness. However, the results suggest fears of carbon leakage may be overplayed. The report finds little evidence of leakage at emission prices corresponding to all but the most stringent stabilisation goal examined.

1 Annex B of the Kyoto Protocol lists countries with quantified emission reduction commitments ('Kyoto targets'), and includes the members of the OECD and economies in transition (Russia and other eastern European nations).

The shielding arrangements proposed for emission-intensive trade-exposed sectors in the *Carbon Pollution Reduction Scheme Green Paper* could help ease the transition to a low-emission economy, and assist affected industries with the required structural adjustment.

Overall, shielding redistributes costs from shielded to unshielded sectors of the economy and amongst shielded sectors. The scale of costs will depend on the specific policy design. Maintaining clear mitigation incentives for shielded sectors is crucial. If the level of shielding is increased, or eligible sectors expanded, this would increase costs.

The costs associated with shielding highlight the importance of establishing an effective global mitigation framework. Broad participation in international emissions trading, sectoral agreements or equivalent measures could reduce competitiveness distortions stemming from national mitigation policies.

Slower growth in world demand for energy commodities, especially coal, will lower Australia's terms of trade. In response, the exchange rate (which acts as a buffer to changes in world demand) would be expected to depreciate, thereby helping to maintain the international competitiveness of many other export-oriented and import-competing industries, particularly manufacturing.

This report details possible structures of a low-emission Australian economy. The models approximate the short-term constraints in the real world economy, and cannot provide specific details of the transitional process in all sectors. Further analysis, focused on the short-term implications of mitigation policy, would complement this report.

The scenarios focus on market-based policies that price emissions. This approach helps isolate the effects of different emission reduction trajectories on the Australian economy. This report does not examine the role of policies such as support for research and development into low-emission technologies, and energy-efficiency standards. Where these policies tackle other market failures, such as the public good value of innovation, asymmetric information and split incentives, they could reduce the cost of achieving Australia's emission reduction objectives.

7.1.3 Other implications for sectoral activity

Opportunities to reduce greenhouse gas emissions exist in all sectors of the Australian economy.

The mix of mitigation activity (exactly how much occurs where, and when) is uncertain. An accurate prediction of what sectoral mix of changes in supply and demand will be the most cost-effective route to a low-pollution future is impossible. This underscores the importance of policies that create incentives for mitigation across all sectors without mandating where that mitigation occurs.

Pricing emissions will generate different costs and benefits across different sectors.

Firms in a few industries face lower levels of output compared with current levels. The consequent structural adjustment will require careful management of asset closures, worker retraining and regional planning. The Government is committed to providing additional support to assist affected workers and regions where required (DCC, 2008).

Electricity and transport together account for almost half of Australia's current emissions; by switching to more energy-efficient and low-emission technologies, they could reduce emissions substantially in coming decades. Further analysis of the short-term implications for the electricity supply industry is warranted. The Council of Australian Governments has asked the Ministerial Council on Energy to consider key energy sector issues raised by the Carbon Pollution Reduction Scheme.

Australia's low-emission electricity generation technology options and prospects include renewables (geothermal, wind, solar and wave) and carbon capture and storage. Consequently, the electricity generation sector should achieve large emission reductions over time, even if some technologies being explored do not prove commercially viable. This report has not found evidence that pricing emissions will compromise Australia's future energy security.

The future cost, performance and timing of carbon capture and storage will affect Australia's coal industry and coal-producing regions. Australia's aggregate mitigation costs will be lower if carbon capture and storage proves commercially viable, as this will help sustain global demand for coal, and therefore, the value of Australia's extensive coal deposits.

Strong, credible and long-term mitigation policy frameworks are likely to stimulate research, development and deployment of low-emission technologies, and help reduce future mitigation costs. Future emission price expectations, and therefore policy credibility, are crucial.

7.1.4 Implications for households

The initial impact on households will be through increases in electricity and gas prices. The CPRS scenarios show a one-off rise in the consumer price index (CPI) of 1-1.5 per cent. Price impacts on petrol and meat products will be deferred until later years through the effect of the fuel tax offset and initial exclusion of agriculture from the scheme. While the price impact of the scheme is estimated to be relatively larger for low-income households, these impacts will be offset by the Government's commitment to help households adjust.

Electricity and gas together account for a small proportion of household spending, and so, despite the price rise, will have only a small effect on overall household consumption. Over time, real household incomes continue to rise strongly.

7.2 Conclusion

This report brought together many of Australia's leading climate change economists to comprehensively analyse the potential effects of mitigation policies on the Australian economy. It rigorously examines and assesses the implications of policies to reduce greenhouse gas emissions for the Australian economy. The report is a key input to Government decisions regarding Australia's future emission pathway, and Australia's role in an effective global response to climate change.

This is a complex policy area, and the Government is drawing on many sources of advice and will consider the full range of costs and benefits of mitigation policy. The Government will consider public responses to this report before it makes its decision on Australia's emission targets for the medium term.

This report forms part of a much wider body of work on the economic impacts of climate change. This report looks only at the costs of mitigation, not the benefits. A critical challenge for future analysis is to develop methods, models and capacity that will allow a more integrated analysis of these costs and benefits.

Climate change analysis will remain a policy priority, informed by ongoing scientific and economic developments and the evolving international policy landscape.

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Annex A: Modelling framework

A.1 Introduction

No single existing model adequately captures the global, national, sectoral and household dimensions or focuses on all relevant aspects of mitigation policy in Australia. Previous Australian studies of mitigation policy focus on one or other of these dimensions — a particular sector (for example, electricity generation) in isolation from the broader national economy, or on the national economy but without a consistent global analysis. In contrast, this analysis uses a suite of models that together span global, national, sectoral and household scales, to simultaneously explore these four dimensions.

Treasury's climate change mitigation policy modelling includes three top-down, computable general equilibrium (CGE) models developed in Australia: Global Trade and Environment Model (GTEM); G-Cubed model; and the Monash Multi-regional Forecasting (MMRF) model. These CGE models are whole-of-economy models that capture the interactions between different sectors of the economy. GTEM and G-Cubed are models of the global economy; whereas, MMRF models the Australian economy with state and territory-level detail. The CGE models are complemented by a series of bottom-up sector-specific models for electricity generation, transport, land-use change and forestry (LUCF), with additional analysis for other industrial sectors.

This annex sets out the details of Treasury's modelling framework, including an overview of the CGE models and details on the sector-specific models.

A.2 Global / Economy-wide modelling

A.2.1 GTEM model overview

GTEM is a recursively dynamic general equilibrium model developed by ABARE to address policy issues with long-term global dimensions, such as climate change mitigation costs. It is derived from the MEGABARE model and the static GTAP model (Pant, 2007; Hertel, 1997; ABARE, 1996). The dimension of GTEM used in this report represents the global economy through 13 regions (including Australia, the United States, China and India) each with 19 industry sectors (Table A.1) and a representative household (for society). The regions are linked by trade and investment. Government policies are represented by a range of taxes and subsidies. The model also disaggregates three energy-intensive sectors into specific technologies: electricity generation, transport, and iron and steel. Some modifications have been made as part of the Treasury modelling program.

Key characteristics of GTEM

Regional households receive the region's gross national income and allocate it (in fixed proportion) to private and public consumption, and savings. Because of this feature and the learning and resource depletion effects, GTEM belongs to the class of Solow-Swan type growth models with endogenous sector-specific technical change. A limitation of the fixed savings rate assumption could be that the true cost of mitigation policy may be underestimated. For example, if an emission price reduces the rate of return on capital, this could reduce global savings and hence global investments, which in turn, could lower global GDP through reduced productive capacity. This limitation has been traded off against the need for simplicity in parameterisation and tractability of the model.

Household demand for private consumption goods responds to changes in income and relative prices. Household consumption behaviour is modelled by using a constant difference in elasticity of substitution function. This function has the property that the price and income elasticity of demand depend on the budget share and are, therefore variable, over time. Public consumption expenditure is allocated to commodities by maximizing a Cobb-Douglas utility function.

GTEM sectors produce output by employing four factors of production: land; labour; capital; and natural resources and material inputs. Labour and capital are perfectly mobile across sectors. Land is sluggishly mobile between agricultural and forestry sectors, in response to higher rental returns. Natural resources are used by the mining and forestry and fishing sectors. Capital accumulates by net investment and takes a year to install. Land supply is fixed. Supply of labour in the present application is exogenously given, and an unlimited supply of natural resources is available at a constant real price. These assumptions, together with the inter-factor substitutability, allow sectors to adjust instantaneously in response to changes in relative prices.

Three key energy-intensive sectors that employ multiple technologies to produce output are identified. These sectors are defined as technology bundle sectors, and include electricity generation, transport, and iron and steel. The sectors use the output of the respective technology bundle, and other commodities, in fixed proportions to distribute to the users. For example, various technologies generate electricity, which is used by the electricity sector with other inputs (proxy for transmission system), then it is distributed to end users. Technology bundles are modelled to make sure that only technically feasible combinations of inputs are used. As a default, input substitutions within a technology are not allowed — each technology uses its inputs in fixed proportions — while substitution between technologies is allowed. Outputs from each of the technologies are chosen to minimise the cost of producing a CRESH (constant ratio of elasticities of substitution, homothetic) aggregate of the outputs of all technologies.

GTEM models the demand and supply of electricity in Australia and the other GTEM regions, with a set of 12 established and emerging technologies (Table A.1). GTEM does not distinguish between peak and base-load electricity demand.

For non-technology bundle industries, several layers of substitution are possible. These industries can substitute between four energy commodities to produce an energy composite. This energy composite is then combined with a primary factor composite. At the final level, this energy-factor composite is combined with other intermediate inputs in fixed proportions to produce a single good. The inter-fuel and inter-factor substitutions and substitution between fuels and primary factors occur via a nested CES (constant elasticity of substitution) approach.

Mining sectors are subject to increasing costs, via an endogenous fall in labour and capital efficiency, as the cumulative level of extraction rises. This captures, in a stylised way, the resource depletion effect and causes prices of mining products, in particular fossil fuels, to rise over time.

A sophisticated handling of transport and electricity technologies, with endogenous productivity growth via learning by doing, a detailed technology portfolio including a suite of zero or near zero-emission technologies, and substitution across technologies, allows electricity generation and the transport sector to be gradually emission free, if market incentives are right. Parameters for the learning-by-doing functions are in Annex B.

Industries in GTEM alter their use of energy and other emission sources in response to relative price changes. Hence, the energy use by households and industries could be emissions free if they switch fully to electricity (and hydrogen) generated by zero-emission technologies.

Substitution between non-energy intermediate inputs in response to relative prices is not possible. GTEM, however, has a mechanism to model sector and input biased productivity changes that are consistent with a single region-wide input and sector-neutral productivity growth. GTEM uses this process to stylise the possible dematerialisation process that may take place, but it is not sensitive to policy changes. GTEM also allows improvements in energy efficiency via the biased allocation of the region-specific exogenous productivity growth over all inputs and sectors.

Fugitive emission response functions are incorporated into the model to enable mitigation of non-combustion emissions. Emission reductions from this source are assumed to be available to industry using the same production inputs. These functions proxy the reorganisation of existing production processes, or introduction of new technology, at the same cost as existing production. In that sense, there is no additional cost for these technologies. This feature of the model is explored in the sensitivity analysis.

Net emissions from land-use change and forestry are exogenously linked to GTEM. The implied assumption, therefore, is that forestry sequestration is possible without a call on factor inputs. This assumption results in an underestimation of mitigation cost, but the effect is expected to be modest as conservative assumptions have been used for land availability. The impact would be greatest in Indonesia, Other Asia and the Rest of World. The implications of having no forestry sinks are explored in the sensitivity analysis.

GTEM, like many other CGE models, maintains that all markets everywhere clear each year. As investment is not equal to capital depreciation and investments are not necessarily equal to savings in each region, capital accumulation and debt accumulation may continue year after year. Hence, the maintained equilibrium is not necessarily a steady-state equilibrium. Because of these features the model may display a dynamic momentum, provided the initial database is not in steady state. It is a suitable approach to analyse medium to long-term responses to a exogenous shock.

Most parameter values and the social accounting matrix (SAM) of GTEM currently are based on GTAP's version 6 database, with a base year of 2001 (Dimarannan, 2006). The emission database was developed at ABARE and contains estimates of six anthropogenic greenhouse gases — combustion and non-combustion carbon dioxide, methane, nitrous oxide, HFCs, PFCs and SF_6; all Kyoto gasses. Calibrations of additional GTEM specific parameters are described in Annex B.

Table A.1: Regions and sectors of GTEM

Regions	Industry sectors
Australia	Coal mining
United States	Oil mining
European Union	Gas mining
Japan	Petroleum and coal products
China	Electricity (with 12 technologies: coal, petroleum and coal products, gas, nuclear, hydro, wind, solar, biomass, waste, other renewables, coal CCS and gas CCS)
India	
Indonesia	Iron and steel (2 technologies, electric arc and blast furnace)
Other South and East Asia	Non-ferrous metals
Russia + CIS (a)	Chemical, rubber and plastic products
OPEC	Other mining
Canada	Non-metallic minerals
South Africa	Manufacturing
Rest of world	Air transport
	Water transport
	Other transport (5 technologies: non-road (rail), internal combustion engine, advanced internal combustion engine, hybrids and non-fossil fuel vehicles)
	Crops
	Livestock
	Fishing and forestry
	Food
	Services

(a) Commonwealth of independent states.
Source: GTEM.

The relatively high-level industry (commodity) aggregation could limit the degree of substitutions between commodities. This implies GTEM could not represent a decline in emission intensity in a sector (or commodity) due to compositional changes (with the exception of the three technology bundle industries). To the extent that this happens, emission projections from GTEM with such aggregations will be biased upwards. However, the calibration of the fugitive emission response functions takes some account of this factor. Such aggregation biases are unavoidable, given the computing and database limitations. The chosen aggregation reflects these tradeoffs.

All markets, including foreign exchange markets, are assumed to be in equilibrium in 2001. To the extent this assumption does not hold (financial turmoil was considerable in 2001), some exchange rates, such as Australia and the former Soviet Union (FSU), may be undervalued relative to the US dollar. This tends to result in higher emission intensity per dollar value of output when values are expressed in US dollars. This may overestimate these countries' loss of competitiveness following an emission price change. This effect moderates over time, as the Australian dollar appreciates against the US dollar. The implication of this assumption is greater for distribution costs across countries rather than aggregate mitigation costs.

Changes to the GTEM model

GTEM has been modified in three different levels — the structural level, the parametric level and the database level, to represent and simulate the policy scenarios presented in this report (Pant, 2007).

Structural changes

Modifications of GTEM at the structural level involve changes made in the investment demand function, the introduction of instruments to shield the emission-intensive and trade-exposed sectors (EITES) for a defined period at defined rates, and introduction of technology-bundle approach to modelling the other transport sector (land transport).

The investment demand function has been made sensitive to regional exposure to foreign debt. As regional debt rises, the risk premium rises, leading to a reduction in foreign investment. This in turn decreases the difference between investment and savings, so the rate of debt accumulation falls over the long term, relative to the case in which investments do not respond to changes in a regions debt exposure. This modification prevents uncontrolled escalation of foreign debt and better represents real-world risk adjustments in globalised investment markets over long timeframes.

An equation has been added in GTEM to represent the shielding framework for EITES, as outlined in the *Carbon Pollution Reduction Scheme Green Paper* (DCC, 2008). All of these sectors are shielded from the emission price on direct emissions, and from electricity price rises relative to the reference case from 2011-2025, except for the agriculture sectors, which are exempt until 2015 and shielded to 2025. To model this, direct emission intensities and electricity intensities of the outputs of GTEM sectors in 2007 have been applied for all future years to estimate the exposure of the EITES to the emission price. To estimate the applicable shielding rates, the share of the shielded sector, which could be a component, of the sectoral output, has been estimated for each GTEM sector, then the prescribed shielding rates have been multiplied by these shares. The shielding of EITES has been implemented by paying a production subsidy equal to the product of the declining shielding rate and the sum of the emission price on direct emissions and the increase in the cost of electricity relative to the reference case. To model the coverage, a binary coefficient has been used for each sector and region, which is assigned a value of unity if the sector is covered, and zero otherwise.

The technology bundle approach of GTEM has been extended to include the 'other transport' sector. Other transport is divided into non-road (which includes rail and pipelines) and four broad types of road vehicle technologies — conventional internal combustion engines, advanced internal combustion/partial hybrid engines, full hybrid vehicles and non-fossil fuel energy vehicles (such as fuel cell, electric or solar vehicles). Each production technique is represented by a Leontief production function, with capital and fuel inputs applied in fixed proportions. To achieve a given level of industry output, outputs from each production technology are chosen to minimise the aggregated production costs over all the techniques — using a CRESH aggregator function.

Endogenous technological change is modelled in emerging electricity and transport technologies via learning functions. The learning function on low emission technologies in the transport and electricity sectors is modelled so that technology costs decline in response to the global uptake of a technology.

Parametric changes

Mechanisms placed in GTEM endogenously change various elasticities of substitution to better represent the behaviour of infant technologies in the short term, and provide a the more mature technologies with a more elastic response in the longer term. To do this, the value of the CRESH parameter associated with each technology is linked with the inverse of its market share (or a large number such as 50) if the share is very small and the value of the parameter gradually declines as its market share increases over time: the smaller the market share of each technology, the higher the CRESH parameter and the higher the implied elasticity of substitution. This function is to capture the initial responses of infant technologies to given relative price changes. Once the technology matures, the price responsiveness falls. The functional form also produces higher elasticity of substitution parameters than previously used, even for mature technologies, to reflect their long-term flexibility. From 2001-2020, however, the elasticity parameters for each given technology share are scaled down to reflect stickiness in the short-term.

The fuel substitution parameter applied in the residential sector and across non-technology bundle industries changes over time. The parameter size (and therefore the responsiveness of fuel substitution to price changes) increases over time to reflect the long-term development of technologies that enables alternative fuels to be used, provided they are cost effective.

Emission response functions were parameterised in light of consultations with industry and Treasury's own research, including a global literature review, and to broadly represent intra-sectoral substitution opportunities. Similarly, learning functions were parameterised for the electricity and transport technology bundles, with different values for different technologies to reflect their potential for learning-related cost reductions.

The base year values of the elasticity of substitution between primary factors were adjusted so that the value-added share weighted sum of these parameters across sectors is unity in each region. This adjustment keeps the aggregate factor shares in regional value added stable over the longer term.

The base parameters of the household demand system were adjusted so that all cross-price elasticities of demand are positive and own price elasticities are negative. The parameters governing the income elasticity were adjusted so that in the long-term, developing countries did not have unrealistic consumption shares of necessities given that their per capita incomes are assumed to be much higher.

Database changes

Some database adjustments improved the performance of the model. The cost share of primary factors in the total cost of iron and steel, non-ferrous metals, chemicals rubber and plastics, other mining, non-metallic minerals, manufacturing, livestock and food sectors of former Soviet Union were unusually low in the initial database. The wage costs were increased for these sectors as shown in Table A.2. This increased the value of output of these sectors, and to maintain the balance in the SAM, the private household expenditure on these commodities was raised by the same amount. This led to an increase in the GDP of the former Soviet Union region by about $50 billion at 2001.

Table A.2: Database change: increase in wage bill for former Soviet Union

Sectors	$US billion at 2001 prices
Iron and steel	3.4
Non-ferrous metals	2.6
Chemical, rubber and plastic products	6.8
Other mining	0.4
Non-metal mining	4.1
Manufacturing	13.9
Livestock	4.6
Food	13.6

Source: Treasury.

Similarly, the cost of capital input was increased by reducing the cost of labour and land in the crops sector of Indonesia and other Asian regions. The share of land in total costs in these regions was significantly higher than in other regions, and led to unusual price impacts under a mitigation scenario. The increase in capital cost is $2 billion and $6 billion respectively. The cost of capital in the livestock sector of Indonesia was raised by just under $0.9 billion, offset by the adjusted cost of land. In all regions, to allow the modelling of land-use change, a small natural resources cost was reallocated as a land cost in the fishing and forestry sector.

In standard GTEM implementation, oil was considered as a fuel commodity and emissions were associated with oil use. This version adjusts the database so that oil is bought only by the petroleum and coal sector, and is a feed-stock which does not emit greenhouse gases. In short, oil has been removed from the set of fuel commodities and does not substitute with other fuels in response to price changes.

In the electricity technology bundle, capacity constraints were imposed on the wind and hydro technologies, and crops and forestry products were incorporated as feed-stock to biomass electricity generation.

A.2.2 G-Cubed model overview

G-Cubed models the global economy and is designed for climate change mitigation policy analysis.[1] An important characteristic of G-Cubed is that economic agents are partly forward-looking: they make decisions based not only on the present day economic situation, but also based on expectations of the future. G-Cubed has limited detail on technologies.

Modelling using the G-Cubed model was conducted in conjunction with the Centre for Applied Macroeconomics Analysis (CAMA) and the Treasury. A report from CAMA covering the joint modelling work is available on the Treasury website.

Key characteristics of G-Cubed

Economic agents are partly forward-looking: they make decisions based on the present economic situation, and expectations of the future.

Adjustment costs in capital are defined, so that structural adjustments take time to occur and impose greater costs on the economy, relative to models that assume capital is perfectly mobile.

The labour market does not adjust instantly to new conditions, but adjusts slowly as the nominal wage rate responds.

The theoretical macroeconomic specifications allow for insights across a broad variable set, such as exchange rates, inflation rates and human wealth. For example, savings rates across countries and the global economy adjust in response to the endogenous supply and demand for savings.

Energy efficiency is captured at a high level as the amount of energy used in the production process responds dynamically to any change in relative prices.

1 A technical description of the G-Cubed model is provided at McKibbin and Wilcoxen (1998) and at www.gcubed.com.

G-Cubed only allows limited technology detail. Technological change can be captured by adjustments to the amount of capital, labour and intermediate inputs that are required to produce a good. For example, the move to renewable technologies, such as wind and geothermal to produce electricity, can be captured by increasing the amount of capital and decreasing the need for fossil fuel input. No technology detail is specified exogenously; as the model finds the best mix of inputs, given the available prices and the starting point. However, the structure of G-Cubed does not easily allow for the production of energy from fossil fuels without emissions, although this could be approximated by changing emission coefficients or modifying of the production technology. An explicit technology for carbon capture and storage does not yet exist in the model.

Table A.3: Regions and sectors of G-Cubed

Regions	Industry sectors
Australia	Coal mining
United States	Crude oil and gas extraction
European Union	Gas utilities
Japan	Petroleum refining
China	Electric utilities
Rest of OECD	Mining
Former Soviet Union	Durable manufacturing
OPEC	Non-durable manufacturing
Other developing countries	Transportation
	Forestry and wood products
	Agriculture, fishing and hunting
	Services

Source: G-Cubed.

Changes made to the G-Cubed model

Changes to the standard G-Cubed model include: the addition of non-combustion emissions; a permit trading algorithm; adjustments for negative emissions; ability to model a mandatory renewable energy target; and the change to the model simulation starting year.

The addition of the non-combustion emissions to G-Cubed significantly enhances the model. The standard G-Cubed model incorporates emissions from combustion of fossil fuels only. With the addition of non-combustion CO_2, methane (CH_4) and nitrous oxide (N_2O), the model can better evaluate international climate change mitigation policy.

The permit trading algorithm is modelled as an outer loop of the model. The algorithm was used in the recent modelling by the IMF (International Monetary Fund, 2008). This algorithm takes the outputs of the model, calculates the permit trades, emissions and allocations, then creates a new shock file for the model with these adjusted permit trades. This loop is then run until the simulation converges.

In running simulations, Treasury has not used the normal reference case generation algorithm; instead, the 'cycle' mode of the model was activated for generating baselines. This mode allows Treasury to impose the reference scenario assumptions and ensure consistency with the GTEM reference scenario.

To model the CPRS, a number of small changes had to be made, including a lump-sum transfer from industry to allow for the modelling of shielding. An input tax on energy also was added to allow for the modelling of the mandatory Renewable Energy Target.

Due to the solution method and structure of G-Cubed, it is possible for sectors and regions to produce negative emission levels. This is not a desirable feature in the absence of a properly specified backstop technology, so an adjustment was implemented to take account of this.

The adjustment prevents negative emissions by stopping the growth of the emission price once zero emissions are reached. This adjustment is made on a sectoral level. Emissions from each individual sector are prevented from going negative. This adjustment is mainly intended to ensure that countries do not produce excessive negative emissions, then trade these for the emissions of other countries. Without the adjustment, other countries would not take on enough mitigation, and the country producing the negative emissions would have a wealth effect from the transfers.

The standard version of G-Cubed's database year is 2002; however, for the running of the simulations in this report, the database year was moved to 2006. This improves the jumping off point for the simulations.

G-Cubed has previously assumed 1.8 per cent as the long-term growth rate for labour productivity, which Treasury has modified to 1.5 per cent. This requires (for consistency) that the rate of time preference be modified from 2.2 to 2.5 per cent, to keep the underlying steady state real interest rate at 4 per cent.

A.2.3 MMRF model overview

The Monash Multi-Regional Forecasting (MMRF) model is a detailed model of the Australian economy developed by the Centre of Policy Studies (CoPS) at Monash University (Adams et al., 2008). MMRF has rich industry detail (with 58 industrial sectors) and provides results for all eight states and territories (Table A.4). It is also dynamic, employing recursive mechanisms to explain investment and sluggish adjustment in factor markets.

Modelling using the MMRF model was conducted in conjunction with CoPS and the Treasury. A report from CoPS covering the joint modelling with Treasury is available on the Treasury website.

Key characteristics of MMRF

MMRF determines regional supplies and demands of commodities through optimising behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital. Labour supply at the national level is determined by demographic factors, while national capital supply responds to rates of return. Labour and capital can cross regional borders so that each region's stock of productive resources reflects regional employment opportunities and relative rates of return.

The assumption of competitive markets implies equality between the basic price and marginal cost in each regional sector. Demand is assumed to equal supply in all markets other than the labour market (where excess supply conditions can hold). The government intervenes in markets by imposing ad valorem sales taxes on commodities. This places wedges between the prices paid by purchasers and prices received by producers — the basic price of the good or service. The model recognises margin commodities (for example, retail trade and road transport freight) which are required for each market transaction (the movement of a commodity from the producer to the purchaser). The costs of the margins are included in purchasers' prices but not in basic prices of goods and services.

MMRF recognises two broad categories of inputs: intermediate inputs and primary factors. Firms in each regional sector are assumed to choose the mix of inputs which minimises the costs of production for their level of output. They are constrained in their choice of inputs by a three-level nested production technology. At the first level, intermediate-input bundles, primary-factor bundles and other costs are used in fixed proportions to output. These bundles are formed at the second level. Intermediate-input bundles are combinations of international imported goods and domestic goods. The primary-factor bundle is a combination of labour, capital and land. At the third level, inputs of domestic goods are formed as combinations of goods from each of the eight regions, and the input of labour is formed as a combination of inputs of labour from the nine different occupational categories.

In each region, the household buys bundles of goods to maximise a utility function subject to a household expenditure constraint. The bundles are combinations of imported and domestic goods, with domestic goods being combinations of goods from each region. A Keynesian consumption function is usually used to determine aggregate household expenditure as a function of household disposable income.

Capital creators for each regional sector combine inputs to form units of capital. In choosing these inputs, they cost minimise, subject to technologies similar to that used for current production; the only difference is that they do not use primary factors. The use of primary factors in capital creation is implicitly recognised in the commodities used in capital creation.

MMRF adopts the ORANI specification of foreign demand. Each export-oriented sector in each state faces its own downward-sloping foreign demand curve. Thus, a shock that improves the price competitiveness of an export sector will result in increased export volume, but at a lower world price. By assuming that the foreign demand schedules are specific to product and region of production, the model allows for differential movements in world prices across domestic regions.

The latest version of MMRF incorporates a post-goods and services tax (GST) and contains a detailed treatment of government finances. The government finance module is based, wherever possible, on the structure adopted for the ABS Government Financial Statistics (Australian Bureau of Statistics, 2007). The module has three broad components:

- all of the main items of income for each jurisdiction, including income taxes, taxes on goods and services and taxes on factor inputs;
- all of the main items of expenditure for each jurisdiction, including gross operating expenses, personal benefit payments and grant expenses (which are both an item of expenditure for the federal government and items of income for each of the regional governments); and
- drawing together the changes in government revenue and government expenditure to report the net operating balance and the net lending or borrowing balance for each jurisdiction.

Physical capital accumulation

Investment undertaken in year *t* is assumed to become operational at the start of year t+1. Under this assumption, capital in industry *i* in state/territory *q* accumulates according to a standard accumulation relationship, with an allowance for depreciation. In MMRF, investors only take account of current rentals and asset prices when forming current expectations about rates of return (static expectations). Investment depends on expected rates of return relative to rates of interest; domestic savings is determined as a fixed share of household disposable income and the Government's budget position.

National labour market

For this report, the national real wage rate in MMRF is assumed to adjust over time to any policy shock, so that in aggregate, employment remains broadly unchanged. The adjustment is assumed to take about ten years.

Special features for greenhouse policy analysis

MMRF includes:

- an energy and gas emission accounting module, which accounts explicitly for each industry and region 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 mitigation measures in response to greenhouse policy measures.

MMRF tracks emissions of greenhouse gases at a detailed level. It breaks down emissions according to:

- emitting agent (the number of industries plus residential);
- emitting state or territory; and
- emitting activity.

The emitting activities are the burning of fuels (coal, natural gas or petroleum products). MMRF generally models non-combustion emissions as directly proportional to the output of the related industries.

MMRF contains a representation of the operations of the NEM. The NEM covers electricity supply in the NEM-regions: NSW, Victoria, Queensland, South Australia, Tasmania and the ACT. Final demand for electricity in each NEM region continues to be determined within the CGE-core of the model in the same manner as demand for all other goods and services. All of the electricity used in NEM-region *r* is purchased from the electricity supply industry in that region. Each NEM-supplier sources its electricity from the NEM. The NEM does not have a regional dimension: in effect it is a single industry that sells a single product (electricity) to each NEM-supplier. The NEM sources its electricity from generation industries in each NEM region. Thus, the electricity sold by the NEM to the electricity supplier in Queensland may be sourced from hydro generation in Tasmania. NEM demand for electricity generation is price-sensitive. Thus if the price of hydro generation from Tasmania rises relative to the price of gas generation from NSW, then NEM demand for generation will shift towards NSW gas generation and away from Tasmania hydro generation.

The explicit modelling of the NEM enables substitution between NEM regions and between different fuel types. It also allows explicitly for inter-state trade in electricity, without having to trace explicitly the bilateral flows. Note that WA and NT are not part of the NEM and electricity supply and generation in these regions continues to be determined on a state-of-location basis.

Changes made to MMRF

A number of modifications have been made to the model outlined above (Adams et al., 2008).

First, the industry structure of the model was reconfigured. In particular:

- the commodity petroleum and coal products was split into five commodities — petrol, diesel, LPG, aviation fuel (aviation turbine fuel and aviation gasoline) and all other coal products — produced by the petroleum and coal products industry to enable more accurate measurement of transport emissions within the MMRF model;
- the industry and commodity livestock was split into high-emission livestock (sheep and beef), low-emission livestock (chicken and pork) and dairy cattle;
- the pipeline transport industry was combined with the water and transport services industries and commodities; and
- biofuels was modelled as an output of the agriculture cropping industries.

Additional substitution possibilities were incorporated into the model to allow for additional economic responses to emission pricing. In particular:

- the meat and meat products industry was modified to allow it to enable price-based substitution between high- and low-emission livestock;
- a fuel bundle was introduced into household demand for private transport services to enable price-based substitution between petrol, diesel, LPG, biofuels and electricity; and
- technology bundles were introduced into the household demand for private transport services, corresponding to petrol vehicles, diesel vehicles, hybrid vehicles and electric vehicles, to enable price-based substitution between these vehicle types.

Table A.4: Sectoral aggregation in MMRF

Category	Sectors
Agriculture, forestry and fishing	Sheep and beef cattle
	Dairy cattle
	Other animals
	2 sectors: Agriculture services and fishing, forestry
	2 sectors: Grains, other agriculture
Mining	Coal mining
	Oil mining
	Gas mining
	3 sectors: Iron ore mining, non-ferrous ore mining and other mining
Manufacturing	Meat products
	Other food, beverages tobacco
	Textiles, clothing, footwear
	Wood products
	Paper products
	Printing
	Refinery (including petroleum and coal products)
	Chemicals
	Rubber and plastic products
	Non-metal construction products
	Cement
	Iron and steel
	Non-ferrous metals: alumina, aluminium and other non-ferrous
	Other manufacturing: metal products, motor vehicles and other manufacturing
Utilities	Electricity generation (6 sectors: coal; gas; oil; nuclear; hydro; other)
	3 sectors: Electricity supply, gas supply and water supply
Services	Construction services
	Trade services
	Accommodation, hotels, cafes and restaurants
	Communication services
	Finance and insurance services
	Property and business services
	Dwelling services
	Public services
	Other services
Transport	Road transport (2 sectors: passenger; freight)
	Rail transport (2 sectors: passenger; freight)
	Water, pipeline and transport services
	Air transport
Households(a)	Household consumption (3 sectors: electricity services; heating services; transport services).

(a) Sectors are named 'Private transport', 'Private heating' and 'Private electrical' in the MMRF model. They relate to the provision of services from the private stocks of motor vehicles, electrical equipment (not heating) and heating equipment only.
Source: MMRF.

Three dummy industries were also created in MMRF: for private transport services; private heating services; and private electronic equipment services. These dummy industries enable households to treat the energy sources and underlying capital equipment for these services as complements, rather than as substitutes, as is the case in the standard model.

- Modifications to the MMRF emissions database were also undertaken. In particular the input-output tables were uprated to the year 2005-06, and the emissions data bases aligned as closely as possible with the latest available emissions data, which is currently for 2005.

The model was also modified to allow it to capture the design features outlined in the *Carbon Pollution Reduction Scheme Green Paper*, in particular, the fuel tax adjustment and EITES shielding arrangements (DCC, 2008).

Marginal abatement cost (MAC) curves were also added to MMRF to capture the response of both fugitive and industrial process emissions in response to emission pricing. The set of industries covered by the MAC curves was expanded from those used previously in MMRF, and the parameterisation of these curves was adjusted. These are discussed in more detail in section B.8.7.

A.3 SECTOR SPECIFIC MODELLING

The CGE models are complemented by a series of bottom-up sector-specific models for electricity generation, transport, land-use change and forestry (LUCF). Detailed analysis of these emission-intensive sectors is useful in understanding the economy's likely response to climate change mitigation policy, particularly over the short to medium term.

Detailed analysis which relies on current views about technology is generally less robust over the long-term, as technology and other mitigation opportunities become more uncertain. As a result, bottom-up modelling of the transport and electricity sectors is limited to 2050. However, technology plays a much smaller role in LUCF emissions, so analysis of this goes to 2100.

A.3.1 Electricity sector modelling

McLennan Magasanik Associates (MMA) provides detailed bottom-up modelling of the Australian electricity generation sector with projections of electricity generation by technology and by state, fuel use, new investments and retirements, and electricity prices.

MMA's models are highly detailed and aim to closely represent actual market conditions including strategic bidding behaviour by individual generators and price setting operations of the market. The models take account of the economic relationships between individual generating plants in the system, with each power plant divided into generating units, with each unit defined by its technical and cost profiles. MMA models retirement for each unit based on age, existing commitments by operators, fuel supply and profitability, with new investment determined based on expected prices, demand and the behaviour of competitors.

A range of fuels and technologies are incorporated, including black and brown coal, natural gas, renewables (including hydro, biomass, solar, wind) as well as new technologies, such as carbon capture and storage, geothermal and wave. Electricity demand is modelled on an hourly and monthly basis, to capture the daily and seasonal fluctuations in energy use.

A report covering the modelling of the electricity sector is available on the Treasury website (McLennan Magasanik Associates, 2008).

A.3.2 Transport sector modelling

Australian transport sector modelling was conducted with CSIRO in conjunction with the Bureau of Infrastructure, Transport and Regional Economics (BITRE). CSIRO use a partial equilibrium model, the Energy Sector Model (ESM) of the Australian energy sector, which includes detailed transport sector representation (CSIRO, 2008). The ESM was co-developed by CSIRO and ABARE in 2006. The model has an economic decision-making framework based around the cost of alternative fuels and vehicles. It incorporates detailed information about technical fuel and vehicle technical characterisation.

The model evaluates the uptake of different technologies based on cost competitiveness, practical constraints in transport markets, current excise and mandated fuel mix legislation, greenhouse gas emission limits, each state's existing plant and vehicle stock, and lead times in the availability of new vehicles or plant.

Consumers (both individuals and firms) are assumed to minimise the cost of carrying out a given transport task, through their choices of vehicles and fuels. It is assumed that vehicles last for ten years. The mix of vehicle sizes is exogenous in the model, and for this project, the average vehicle size was assumed to decrease with increases in fuel costs. The availability of alternative technologies also depends, exogenously, on prices. The ESM supply-side exogenous assumptions are largely based on CSIRO's most recent research in conjunction with other major stakeholders (CSIRO, 2008).

A joint report from the BITRE and CSIRO covering details of the transportation sector modelling is available on the Treasury website.

A.3.3 Land use, land-use change and forestry

The Treasury commissioned modelling of the forestry sector from ABARE (for Australia) and from Lawrence Berkeley National Laboratory (for the rest of the world).

ABARE's modelling examines the impact of an emission price on land-use change in the Australian agriculture sector (ABARE, 2008). The framework used is spatially explicit, and involves analysing the opportunities for emission sequestration provided by LUCF on cleared agricultural land. These opportunities are determined when the net present value of returns from forestry investments are compared to the corresponding expected agricultural land value to estimate the potential area of clear agricultural land that is competitive for forestry within each spatial grid cell.

The Lawrence Berkeley National Laboratory use their GCOMAP model (Sathaye et al., 2005). GCOMAP simulates how forest land users respond to changes in prices in forest land and products, and to emission prices.

A report from ABARE covering details of Australia's forestry sector modelling is available on the Treasury website.

A.3.4 Other sectors

While other sectors were not specifically modelled they were analysed in both the reference and policy scenarios. Annex B outlines details of assumptions made on energy efficiency for specific sectors in the reference scenario. Also outlined in Annex B are assumptions made in the policy scenario for emission intensity reductions through marginal abatement cost (MAC) curves for fugitive and industrial process emissions.

A.4 Price Revenue Incidence Simulation Model (PRISMOD)

Modelling of the impact of the emission prices on households and the consumer price index was undertaken with Treasury's Price Revenue Incidence Simulation Model (PRISMOD). PRISMOD is a large-scale, highly disaggregated model of the Australian economy which captures the flows of goods between industries and final consumers. The data used in PRISMOD comprises the transactions and consumption patterns of 109 industry categories and seven categories of final demand. The 2008 version of the PRISMOD is based on data from the 2004-05 Input-Output Tables (ABS, 2008).

Key characteristics of PRISMOD include:

- the 2008 version of the model is based on 2004-05 input-output tables supplied by the ABS (ABS, 2008);
- the focus is on the inter-industry transmission of price changes. For example, it tracks how a change in the price of electricity impacts on all industries that purchase electricity, and on all industries that purchase from those industries, and on all purchasers of those industries and so on;
- quantities are held fixed: only price impacts are modelled. That is, businesses are assumed to continue to operate with exactly the same inputs, and produce exactly the same outputs, before and after the change being simulated;
- all cost and price impacts are passed on fully to final purchasers (such as, governments and households). That is, it is assumed that the imposition of an emission price will be passed through fully to domestic consumers and exports in the form of higher prices; and
- the model does not provide information as to the timing of price changes. All of the price impacts calculated by the model are 'long term in nature.

A.5 Price Revenue Incidence Simulation Model — Distribution (PRISMOD.DIST)

The distributional implication for households of emission pricing was analysed using Treasury's Price Revenue Incidence Simulation Model and Distribution Model (PRISMOD.DIST). This model is a static micro simulation model which can be used to examine the distributional effects of government policies on household income.

A.5.1 Key characteristics of PRISMOD.DIST

- The 2008 version of the model is based on data from the 2003-04 Household Expenditure survey (HES) (ABS, 2005).
- The HES data has been up-rated to 2007-08 using actual CPI item price movements. The totals for a variety of expenditure baskets are then projected to 2010-11 using CPI forecasts and projections.
- The HES data has been normalised to conform to the fifteenth series CPI weights to adjust for under-and over-reporting of certain expenditure items in the HES.
- Treasury's enhanced HES version of the NATSEM's STINMOD model has been used to re-weight the HES data for projected demographic changes.[2]
- The income and household type variables are also taken from STINMOD.

A.6 An integrated modelling framework

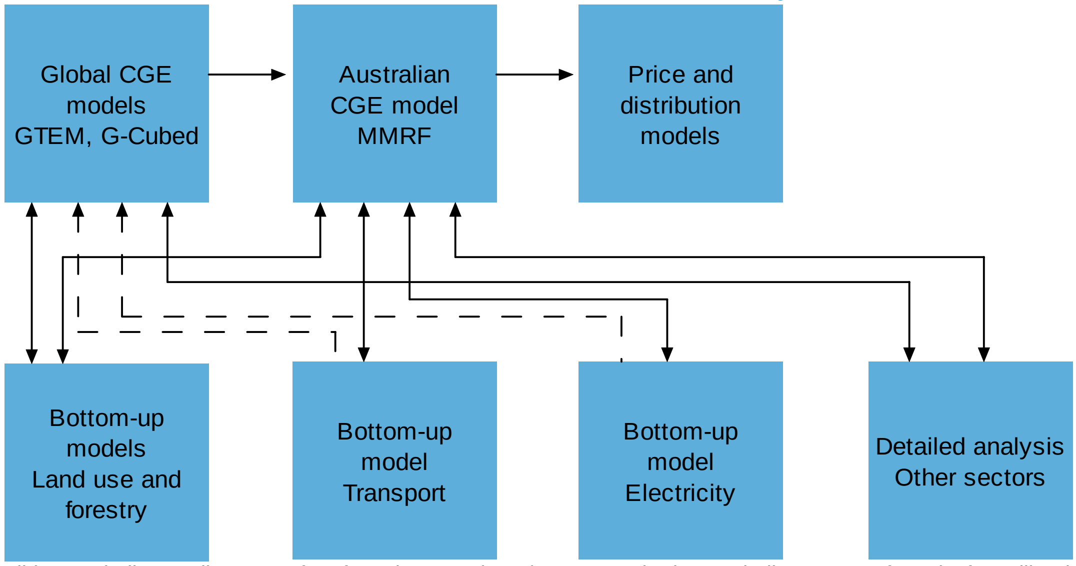
The results from each of these models are drawn together into an integrated set of projections that are broadly consistent at the macroeconomic level and sufficiently detailed in large emission-intensive sectors (Chart A.1).

Modelling of the global economy with GTEM and global land-use change and forestry with GCOMAP provides the international economic and emissions context for modelling of the Australian economy within MMRF, which in turn is informed by the bottom-up modelling of the electricity, transport and land-use sectors. G-Cubed is broadly calibrated to the GTEM reference scenario, and provides comparative cost estimates for the policy scenarios, strongly emphasising the macroeconomic adjustment process.

Linking economic models with different economic structures is not straight forward. The report team undertook significant research to ensure the suite of models were linked sensibly.

2 More information on NATSEM's version of STINMOD can be found at http://www.canberra.edu.au/centres/natsem/research-models/projects_and_models/stinmod.

Chart A.1: How the suite of models fit together



Note: Solid arrow indicates direct transfer of results as an input/output. Dashed arrow indicates use of results for calibration.

Using a suite of models provides a natural hedge against the inherent uncertainty of economic modelling. While input assumptions have been harmonised as much as possible across GTEM, G-Cubed and MMRF, the projections in the three models generated for Australia are not identical. The differences arise primarily from the different structures of the models, and these differences demonstrate the uncertainty surrounding modelling estimates.

To ensure that this report remains tractable, most Australian results are, in the first instance, from MMRF. However, where the Australian results determined in the global models differ significantly, or provide additional insights, these are provided for comparison. Similarly, the global results — including Australia as a region of the world — are from GTEM, with comparative analysis from G-Cubed. Where the bottom-up models provide insights, these results are given primacy.

Since MMRF is a multi-sectoral general equilibrium model of Australia, it takes world market conditions as given. This means that it does not determine endogenously the prices Australia faces in the world market, nor does it project the changes that may occur in demand for Australian exports. GTEM determines such prices and quantities, which are aggregated over all other regions using 'free on board' and 'cost insurance freight' value shares as weights. This required careful linking to ensure that the world demand curve determined within GTEM was inputted into MMRF in an appropriate way (Table A.5).

A partial-equilibrium representation of the export demand function faced by Australia for each GTEM commodity was derived. Responsiveness of the export demand to world price changes were estimated using GTEM parameters assuming that the rest of the world does not respond to supply-side changes that occurred in Australia. As the world economy responds to a given shock, such as the imposition of an emission price, the export demand faced by Australia shifts. A consistent measure of the shift in the export demand functions was derived and use as input into the MMRF model.

Table A.5: Concordance of GTEM and MMRF sectors

GTEM sector (19 sectors)	MMRF sector (58 sectors)
Livestock	Sheep and beef cattle
	Dairy cattle
	Other animals
Crops	3 sectors: Grains, other agriculture
Fishing and forestry	2 sectors: Agriculture services and fishing and forestry
Coal mining	Coal mining
Oil mining	Oil mining
Gas mining	Gas mining
Other mining	3 sectors: Iron ore mining, non-ferrous ore mining and other mining
Food	Meat and meat products
	Other food, beverages and tobacco
Manufacturing	Textiles, clothing, footwear and leather
	Wood, pulp and paper products
	Printing, publishing and recorded media
	Metal products
	Motor vehicles
	Other manufacturing
Petroleum and coal products	Refinery (including petroleum and coal products)
Chemical, rubber and plastic products	2 sectors: Chemicals and rubber and plastic products
Non-metalic minerals	Non-metal construction products
	Cement
Iron and steel	Iron and steel
Non-ferrous metals	3 sectors: Alumina, aluminium and other non-ferrous
Electricity	Electricity generation (6 sectors: coal; gas; oil; nuclear; hydro; other)
Services	3 sectors: Electricity supply, gas supply and water supply
	Construction services
	Trade services
	Accommodation, hotels, cafes and restaurants
	Communication services
	Finance and insurance services
	Property and business services
	Dwelling services
	Public services
	Other services
	Household consumption (3 sectors: electricity; heating; transport)
Other transport	Road transport (2 sectors: passenger; freight)
	Rail transport (2 sectors: passenger; freight)
Air transport	Air transport
Water transport	Water, pipeline and transport services

Source: Treasury from GTEM and MMRF.

GTEM also determines the global emission price that clears the global permit market. The equilibrium permit price trajectory was used as input into the MMRF model.

To ensure bottom-up electricity (and transport) supply-side information was correctly integrated within MMRF often required several iterations. Some models were relatively easy to link, as they took outputs from one model to provide additional detail. For example, PRISMOD was used to determine a highly disaggregated set of industry price impacts from a certain emission price. This information then was fed into PRISMOD.DIST which captured the distributional implications for households.

A.6.1 Electricity generation sector

MMRF was linked with the electricity bottom-up modelling commissioned from MMA. The demand for electricity was modelled in MMRF, with the MMA modelling providing the supply-side detail. MMRF also can model the supply of electricity (electricity generation is a 'technology bundle' industry in MMRF, with six aggregated technologies — coal, gas, oil, nuclear, hydro and non-hydro renewables); however, given the importance of the sector to understanding the Australian mitigation response, more detailed modelling was provided by MMA.

To marry MMRF modelling of the demand for electricity with the MMA modelling of the supply of electricity required a process of iteration. MMRF electricity demand was provided to MMA, together with the emission price. MMA then determined the response of the electricity sector to meet that demand. The MMA modelling then was integrated into MMRF by calibrating the technology shares, fuel efficiency, emission intensity of fuel use and wholesale price (with retail prices determined in MMRF). The new MMRF simulation then was re-run to generate a new level of demand, which was re-supplied to MMA. This process of iteration continued until there convergence between demand and supply.

MMRF electricity demand was divided by MMA into grid and off-grid and modulated into base-load, intermediate and peak demand. NEMCO assumptions for the peak-to-average demand ratio were used until 2018. These trends then were extrapolated until 2025, then the ratio was held constant at the level reached in 2025 for the remainder of the projection period. This assumption has implications for investment in the sector and the technology shares, with gas-fired generation typically more suitable than coal for generating peak demand.

A.6.2 Transport sector

The transportation sector of MMRF was linked with the bottom-up modelling commissioned from the CSIRO and BITRE. The demand for transport was determined jointly between MMRF and the BITRE's suite of transport demand models. With demand for road transport activities from the MMRF as an input, demand for individual fuels and vehicle types was determined using the bottom-up ESM model. The outputs from the ESM were used as input back into the MMRF model. An iterative feedback mechanism linked the MMRF and ESM models to ensure consistency of results. The ESM input and outputs are listed in Table A.6.

A.6.3 Land-use and forestry sector

The forestry sector of MMRF was linked with the bottom-up modelling commissioned from ABARE. Agricultural output prices and land prices were obtained from MMRF and were provided to ABARE, which then provided estimates for establishment rates of forestry plantations and the associated change in forestry sequestration. These estimates were incorporated into MMRF as exogenous inputs.

The global and regional emission price paths obtained from GTEM were provided to the GCOMAP model, which then provided estimates for the net change in emission stocks associated with land-use change and forestry. These then were incorporated into the world regions of GTEM and G-Cubed as exogenous inputs.

Table A.6: Inputs and Outputs of the Energy Sector Model (ESM)

ESM inputs	ESM outputs
Emission price	**Engine technology uptake by state**
	Internal combustion engine
Transport demand (from MMRF)	Hybrid
Private transport demand	Plug-in hybrid
Road passenger (including buses and taxis)	Full electric
Freight demand (including road and rail)	**Uptake by transport mode**
Fuel prices	Passenger, bus
From Treasury's oil price assumption	Light commercial vehicle
Electricity prices (from MMRF linked with MMA's model)	Articulated truck and rigid truck
Other exogenous assumptions	**Fuel consumption by fuel (and state)**
Fuel efficiency assumptions	Petrol
Technology cost assumptions	Diesel (from oil, coal or gas)
Fuel availability assumptions	Liquefied petroleum gas
Emission factors	Biofuels (biodiesel and ethanol blends)
Fuel and other vehicle operating costs	Electricity
Policy settings (such as ethanol targets)	Natural gas and hydrogen
Share of light, medium and heavy passenger vehicles	**Greenhouse gas emissions by state**

Source: CSIRO, 2008.

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ANNEX B: TREASURY CLIMATE CHANGE MITIGATION POLICY MODELLING ASSUMPTIONS

B.1 INTRODUCTION

The main assumptions used for the modelling of climate change mitigation policy are included in this annex.

Treasury has engaged widely with government, industry and other non-government stakeholders on the methodological approach to the modelling to gather information about input assumptions. These discussions were very important in determining the modelling framework and in forming model-input assumptions. These model-input assumptions also drew on research, previous global and Australian studies, and consultation with government, industry and domestic and international experts. Many of the assumptions used in the modelling exercise are uncertain, especially over the long timeframes being examined.

Treasury, where possible, applied a harmonised set of assumptions across the suite of models to ensure that projections have a common basis. However, due to the different model structures and aggregation, it was not always possible to harmonise all assumptions. For example, the MMRF model has more industry disaggregation than GTEM and G-Cubed, and thus requires more industry specific assumptions.

B.2 POLICY AND DESIGN FEATURES

The main policy intervention modelled is a cap and trade emissions trading scheme. This scheme is assumed to apply globally. Features of the scheme differ across the CPRS and Garnaut scenarios (Table B.1).

Table B.1: Key emissions trading scheme design features, policy scenarios

	CPRS scenarios	Garnaut scenarios
Start	2010	2013
Coverage	Agriculture emissions excluded until 2015; Australian land-use change excluded.	All emissions in all sectors.
International permit trade	Limited until 2020, then unlimited.	Unlimited from 2013.
International participation	Annex B countries from 2010; China and high-income developing countries from 2015; India and middle-income countries from 2020; global coverage from 2025.	Global coverage.

B.2.1 International assumptions

The two main issues in modelling international emissions trading are the international permit allocation framework and treatment of offset credits. Specifications for each participating region are broadly consistent with the assumed Australian settings.

International permit allocation

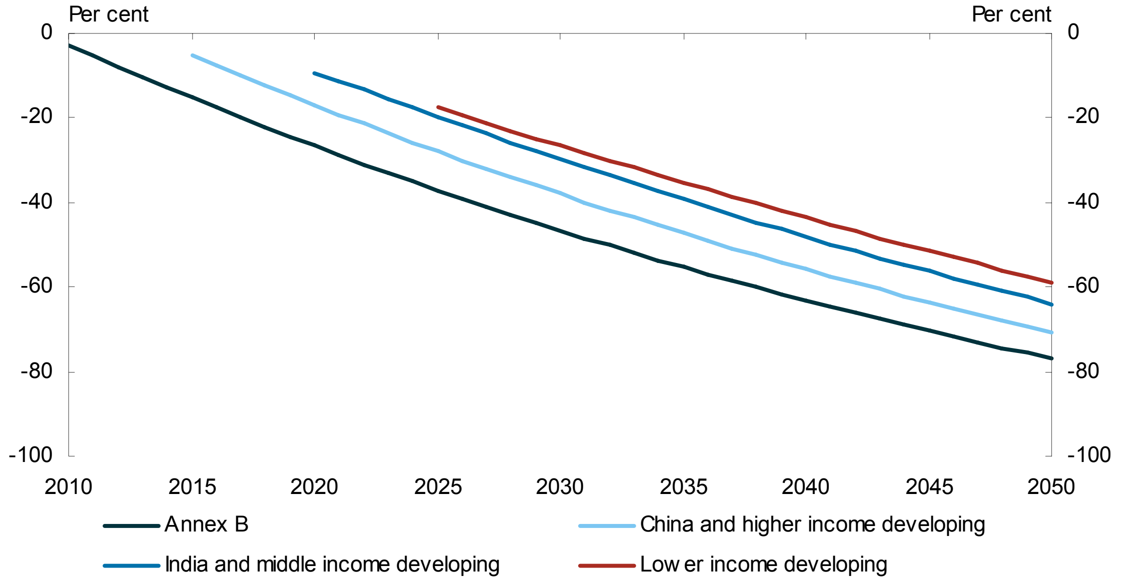
Within the models, the approach to international permit allocation determines the national emission targets and trajectories. The CPRS scenarios used a multi-stage allocation approach; the Garnaut scenarios use a differentiated contraction and convergence approach (Garnaut, 2008).

The multi-stage allocation approach

Under the multi-stage allocation approach, Australia's emission trajectory gradually diverges from the reference scenario, to be 5 per cent below 2000 levels in 2020 and 60 per cent below 2000 levels in 2050 in the CPRS -5 scenario; and 15 per cent below 2000 levels in 2020 and 60 per cent below 2000 levels in 2050 for the CPRS -15 scenario (Chart B.1). The same rate of divergence from reference scenario emissions is assumed for other regions. Emission allocations in Annex B countries start from their 2009 reference scenario emissions before diverging.

Emissions in non-Annex B countries diverge from their reference scenario levels in the year before they join the scheme. Emissions in economies not included in the trading scheme could theoretically diverge from their reference scenario levels through several mechanisms, including offset credits, positive spillovers from devolving low-emission technologies in Annex B countries; and relocation of emission-intensive trade-exposed sectors from Annex B countries. However, the modelling results suggest that the main difference between reference and policy scenario emissions for economies outside the scheme arises from the creation of offset credits. As a result, in the CPRS scenarios, allocations for non-Annex B countries start from reference scenario emissions levels, adjusted only for the assumed emission reductions from offset credits.

Chart B.1: Emission allocations by region
Per cent change from reference scenario, CPRS -5 scenario



Note: Non-Annex B regions start below reference scenario levels due to the effect of offset credits.
Source: Treasury.

Differentiation across regions was limited by the existing regional aggregation within the models. The regions corresponding to each group are shown in Table B.2.

Table B.2: Regional groupings in GTEM and G-Cubed
Multi-stage allocation approach

	GTEM	G-Cubed
Annex B	Australia, Canada, European Union, ormer Soviet Union, Japan, United States	Australia, European Union, former Soviet Union, Japan, other OECD, United States
China and higher income developing	China, OPEC, South Africa	China, OPEC
India and middle income developing	India, Indonesia, rest of South and East Asia	None
Lower income developing	Rest of world	Rest of world

The differentiated contraction and convergence approach

The differentiated contraction and convergence approach was developed for the Garnaut Climate Change Review, and used in the Garnaut scenarios. Under this approach, national allocations converge from current levels to an equal per capita allocation by 2050 (Chart B.2).

Fast growing non-Annex B countries are allowed 'head room' to increase their per capita emission allocations until they achieve a specified benchmark. The benchmark is based on the lowest per capita emissions over all Annex B countries. In implementing the allocation rule, however, the average of the European Union and Japan's allocation is used as the benchmark.

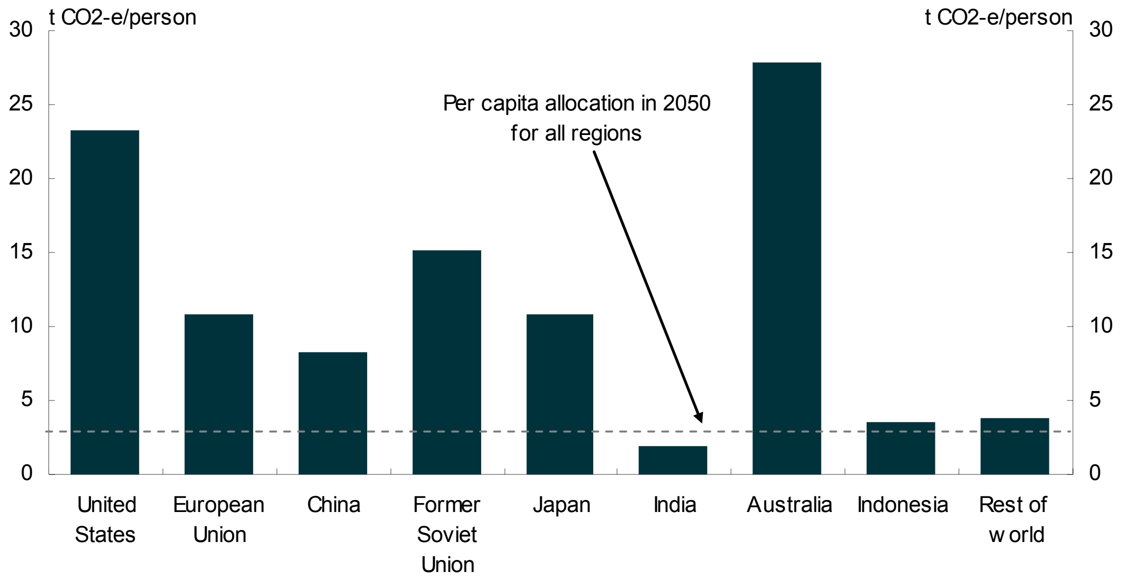
Other assumptions employed are:

- Annex B countries' allocations converge from their Kyoto targets; and

- the US allocation converges from reference scenario emissions, but is reduced at a more rapid rate; as a result, its cumulative allocation over the first 20 years is as if it had converged from its Kyoto target.

Chart B.2: Contraction and convergence approach

Per capita emissions in 2012, Garnaut -10 scenario



Source: GTEM; Treasury; Garnaut (2008a).

Offset credits

The CPRS scenarios assume economies outside the emissions trading scheme can generate offset credits for sale to Annex B countries, analogous to credits from Kyoto Protocol Clean Development Mechanism (CDM), but not necessarily restricted to this. This is not applied in Garnaut scenarios, as all economies take on national emission targets from 2013.

To implement offset credits in the global models GTEM and G-Cubed, assumptions were made about what the total quantity of credits was, where and how those credits were generated, and to whom those credits were sold (Table B.3).

In the short term, institutional capacity is likely to be an important determinant of where offset credits are generated. Credits from 2010 to 2014 therefore follow current patterns of CDM creation (UNEP, 2008). As the global emissions trading market and flexibility mechanisms evolve, credits are likely to be generated wherever low-cost mitigation is available. Credits from 2015 to 2019 therefore follow regional patterns of mitigation potential identified within the models.

Renewable energy and energy efficiency projects currently account for a large share of CDM credits, so these were used as the primary source of credits (UNEP, 2008). Mitigation from land-use change and forestry projects (including avoided deforestation) was not included until 2015, reflecting the institutional and accounting barriers to these projects in the short term.

Table B.3: Summary of offset credit assumptions

Year	2010 to 2014	2015 to 2019	2020 to 2024
Regions generating credits (GTEM)	China, OPEC, South Africa, India, Indonesia, other South and East Asia, rest of world	India, Indonesia, other South and East Asia, rest of world	Rest of world
Regions generating credits (G-Cubed)	China, OPEC, rest of world	Rest of world	Rest of world
Total credits generated (Mt CO_2e)	1,990	5,150	7,550
Source of credits	Renewable energy and energy efficiency projects	Renewable energy, energy efficiency and land use change and forestry projects	
Regions buying credits	All Annex B countries, allocated in proportion to their share of the aggregate abatement effort		
Price of credits	Prevailing global emission price		

B.2.2 Australian assumptions

Emission price

The global emission price for each of the four policy scenarios is estimated in the GTEM and G-Cubed models. The global price from GTEM is used as an exogenous assumption for the MMRF model, which estimates the Australian emission price given the global price and other assumptions. The Australian price from MMRF is used as an exogenous assumption for PRISMOD, which determines the distributional price impacts on households and industries.

Carbon pollution reduction scheme design

In the CPRS scenarios, the policy framework is based on the *Carbon Pollution Reduction Scheme Green Paper* (DCC, 2008b).

Table B.4: Carbon pollution reduction scheme design

Issue	Policy setting	Implementation in MMRF
Australia's emission trajectory	Determined by the international allocation assumptions.	
Coverage	All emission sources covered, except: * activity emissions from agriculture are excluded until 2015; and * emissions from land-use change are excluded (and remain subject to existing policies). Credit is available on a voluntary 'opt-in' basis for net increases in carbon stocks from forests on Kyoto-eligible land. Once in, credits can be generated from net increases, and permits must be acquitted for net losses in carbon stocks.	Agriculture comprises sheep and cattle, dairy, other animal and grains.
Banking and borrowing	Unlimited banking, no borrowing.	
Emission-intensive trade-exposed sectors (EITES)	EITES are shielded from the emission price for direct emissions and for emissions from electricity use ('CPRS costs'). From 2010 to 2019: * industries with an emission intensity of more than 2,000tCO_2e/$million revenue are shielded for 90 per cent of CPRS costs. * industries with an emission intensity of 1,500-2,000tCO_2e/$million revenue are shielded for 60 per cent of CPRS costs. Assistance per unit of output reduces by 3 per cent per year. Agricultural sectors are shielded from 2015, when they become covered by the scheme. From 2020 to 2024, assistance per unit of output phases out linearly. No shielding after 2025.	Industries over the 2,000 threshold are beef cattle, aluminium smelting, lime production, clinker production, sheep, dairy cattle, integrated steel manufacturing, and production of rice. Industries within the 1,500-2,000 group are production of pigs, ceramic product manufacturing, alumina refining, basic chemicals manufacturing, non-metallic mineral product manufacturing, pulp and paper manufacturing,

<table>
<tr><th>Issue</th><th>Policy setting</th><th>Implementation in MMRF</th></tr>
<tr><td></td><td>Shielding is calculated according to the formula:
$$A_{ia} = k_a \left[EI^d_{ia} \times O_{ia} \right] + k_a \left[EI^e_{ia} \times EF \times O_{ia} \right]$$
where
A_{ia} is the allocation of permits to industry I for emissions associated with activity a;
k_a is the assistance rate for activity a;
EI^d_{ia} is the direct emission-intensity baseline for industry I conducting activity a (that is, baseline level of direct emissions per unit of output for the activity)
EI^e_{ia} is the electricity-intensity baseline for indirect electricity emissions for industry i conducting activity a (that is, baseline level of electricity per unit of output for the activity);
EF is the electricity factor, which reflects the impact of the emission price on the price of electricity; and
O_{ia} is the output of activity a by industry i.</td><td>other non-ferrous metals smelting, and parts of oil and gas.
Shielding is implemented as an implicit subsidy. Calculations use 2005 values as the baseline for emission and electricity intensity. The electricity factor is calculated taking account of both the direct and general equilibrium effects of the carbon price.</td></tr>
<tr><td>International linkage</td><td>No export of Australian permits until 2015, unlimited thereafter.
Imports restricted to 50 per cent of the difference between reference scenario emissions and the national emission trajectory until 2020, unlimited thereafter.</td><td>CPRS -5 scenario:
* from 2010 to 2014, imports restricted to 6 per cent of the CPRS cap.
* from 2015 to 2019, imports restricted to 14 per cent of the CPRS cap.
CRS -15 scenario:
* from 2010 to 2014, imports restricted to 8 per cent of the CPRS cap.
* from 2015 to 2019, imports restricted to 20 per cent of the CPRS cap.</td></tr>
<tr><td>Fuel tax offset</td><td>Rate of excise duty changed to offset CPRS impact on fuel prices for:
* households, on-road business users, and agriculture and fishing from 2010 to 2012 (three years).
* heavy vehicles in 2010 (one year).
No offset for other fuel users.</td><td></td></tr>
<tr><td>Use of permit revenue</td><td>All permits are assumed to be auctioned, with auction revenue (net of revenue allocated to firms for shielding purposes) recycled as lump-sum payments to households.</td><td></td></tr>
</table>

Policy assumptions in PRISMOD

- Shielding arrangements use the definition of EITE industries to determine which industries in the ABS data will be shielded, and to what extent. These then are allocated a certain quantity of permits (based on their emission levels) at zero cost.

- Emissions from agricultural industries are excluded.

- The impact of the price increases on transport fuels is offset by a reduction in the excise tax. The excise tax is adjusted so that, after introducing the CPRS, the difference in the final purchaser's prices for liquid petroleum gas and gas and diesel fuels is zero. The excise tax on automotive petrol is adjusted by the same amount; this corresponds to a slight over-compensation for these fuels (so the increase in petroleum prices resulting from the CPRS is more than offset by the reduction in excise tax).

Electricity policy measures

The reference scenario assumes pre-existing policy measures remain in place, including the 9,500GWh/year Mandatory Renewable Energy Target (MRET), the Victorian Renewable Energy Target (VRET), the NSW and ACT Greenhouse Gas Abatement Scheme, and the Queensland 15 per cent Gas Scheme. No new mitigation policies, such as the planned increase in the Renewable Energy Target (RET) to 45,000GWh/year, the Carbon Pollution Reduction Scheme and the Australian Government's target to reduce emissions by 60 per cent from 2000 levels by 2050, have been included.

In the Garnaut scenarios, all pre-existing policy measures cease upon introduction of the emissions trading scheme.

In the CPRS scenarios, the expanded 45,000GWh RET is included. The target is assumed to increase linearly to 22,000 GWh in 2015, then linearly to 45,000GWh in 2020. The target is held constant at 45,000 until 2024, then phased out over the period to 2035. The Queensland 15 per cent Gas Scheme and the voluntary market program, Green Power, are assumed to remain in place. All other policy measures cease upon introduction of the CPRS.

B.3 Economic growth

Gross domestic product (GDP) in the reference scenario is a function of assumptions about labour supply and productivity.

B.3.1 World gross domestic product

Published forecasts for GDP are used where available. Forecasts are imposed for 2006 to 2009 using outcomes and forecasts from the IMF (2008), OECD (2007) and Consensus Economics (2008a; 2008b). Where country specific forecasts are not available, regional forecasts have been used.

Table B.5: World GDP (GTEM regions)
Annual average growth

	2005 to 2050	2050 to 2100
	Per cent	Per cent
United States	2.0	1.7
European Union	1.3	1.3
China	5.4	1.5
Former Soviet Union	2.8	1.7
Japan	0.5	1.2
India	6.2	2.8
Canada	1.8	1.5
Indonesia	5.1	2.2
South Africa	4.0	2.0
Other South and East Asia	3.7	2.1
OPEC	4.1	2.4
Rest of w orld	4.9	3.1

Note: See also international population and productivity section.
Source: Treasury; IMF (2008); OECD (2007); Consensus Economics (2008a; 2008b).

B.3.2 Australian gross domestic product

Table B.6: Australia's population, productivity and GDP
Annual average growth rates

Decade	Employment	Labour productivity	Real GDP
	Per cent	Per cent	Per cent
2000s	2.3	1.1	3.4
2010s	1.1	1.6	2.8
2020s	0.8	1.5	2.3
2030s	0.7	1.5	2.2
2040s	0.6	1.5	2.1
2050s	0.6	1.5	2.1
2060s	0.7	1.5	2.1
2070s	0.7	1.5	2.2
2080s	0.6	1.5	2.1
2090s	0.6	1.5	2.1

Source: Treasury and ABS.

B.3.3 Gross state product

Gross state product (GSP) is a function of assumptions about the distribution of population and industry across states.

Table B.7: Gross state product
Annual average growth rates

Decade	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
2000s(a)	3.0	3.2	3.8	2.7	4.6	2.9	4.3	2.9
2010s	2.6	2.8	3.2	2.2	3.2	2.0	2.8	2.6
2020s	2.3	2.3	2.7	1.6	2.4	1.7	2.3	2.2
2030s	2.2	2.1	2.6	1.6	2.4	1.7	2.6	2.1
2040s	2.0	2.0	2.4	1.4	2.3	1.5	2.7	1.9
2050s	2.0	2.0	2.3	1.4	2.3	1.5	2.7	1.9
2060s	2.1	2.1	2.3	1.5	2.3	1.6	2.6	2.1
2070s	2.2	2.1	2.2	1.5	2.3	1.6	2.5	2.2
2080s	2.1	2.1	2.2	1.4	2.3	1.6	2.4	2.1
2090s	2.1	2.0	2.2	1.4	2.2	1.6	2.4	2.1

(a) 2000s start in 2005-06, consistent with the base-year in the MMRF model.
Source: Treasury and ABS.

B.4 Population and participation

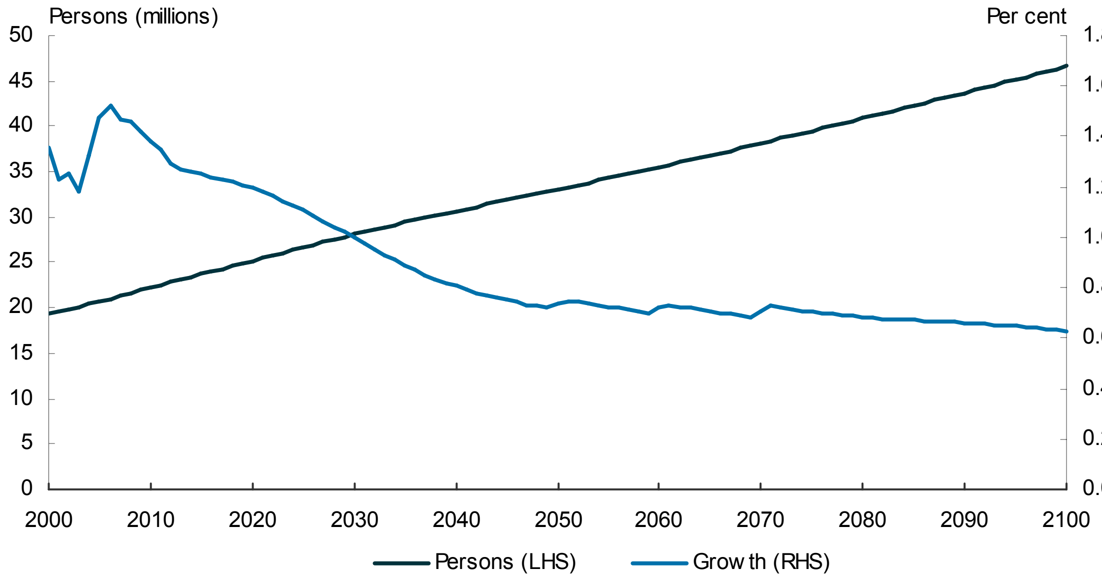
B.4.1 Australian population and labour force participation

Population projections are based on the framework used to develop the second *Intergenerational Report* — although input assumptions have been updated since the report's release in 2007. Since 2007 there has been additional information on future immigration trends. As a result, net overseas migration between 2012-13 and 2049-50 is assumed to be 150,000 people per year.

From 2050-51 to 2070-71 net migration is stepped up each decade to reach 200,000 people per year. Net migration is then kept constant at 200,000 to the 2100.

- A higher level of net migration beyond 2050 aims to reflect larger world and Australian populations, and increased requirements for skilled and unskilled workers as a result of the continued ageing of Australia's population.
- Labour force participation assumptions are consistent with the *Intergenerational Report* parameters; gender and age specific labour force participation rates remain stable from 2065.
- MMRF requires state population assumptions. State population ratios are taken from ABS projections (ABS cat. no. 3222.0 — *Population Projections, Australia, 2004 to 2101*, released on 14 June 2006) and scaled to be consistent with a higher estimated national aggregate population.
- The population estimates for Australia are higher than the UN projections for Australia, mainly due to recent changes in net migration assumptions not taken into account in the UN projections.

Chart B.3: Australian population



Source: Treasury and ABS.

Table B.8: State population

Decade	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
2000s(a)	1.1	1.4	2.0	1.0	2.1	0.8	1.7	1.5
2010s	1.0	1.2	1.8	0.7	1.8	0.5	1.6	1.2
2020s	0.9	1.0	1.6	0.5	1.4	0.3	1.5	0.8
2030s	0.7	0.8	1.3	0.2	1.1	0.0	1.5	0.7
2040s	0.6	0.6	1.1	0.1	1.0	-0.2	1.4	0.6
2050s	0.7	0.6	1.0	0.1	0.9	-0.2	1.3	0.6
2060s	0.7	0.7	0.9	0.0	0.8	-0.1	1.0	0.7
2070s	0.7	0.7	0.8	0.0	0.8	0.0	0.8	0.7
2080s	0.7	0.7	0.7	0.0	0.7	0.0	0.7	0.7
2090s	0.7	0.7	0.7	0.0	0.7	0.0	0.7	0.7

(a) 2000s start in 2005-06, consistent with the base-year in the MMRF model.
Source: Treasury and ABS.

B.4.2 International population and participation

World population projections to 2050 are taken from the United Nations (2006). This report provides total population and working age (15-64) populations for each country in five year intervals from 1950 to 2050. The median projection variant is used.

After 2050, growth rates for population are taken from United Nations (2004). Country-by-country growth rates are used to project population levels over the 50 years to 2100.

Growth rates are interpolated to produce year-by-year projections of population by country (both total and working age). These country projections then are aggregated into the country groups used in GTEM and G-Cubed.

Table B.9: Global population level and growth rates (GTEM regions)

	2005	2050	2100	2005 to 2050	2050 to 2100
	Population (millions)			Per cent, grow th	
United States	300	402	429	0.7	0.1
European Union	461	459	401	0.0	-0.3
China	1,320	1,418	1,202	0.2	-0.3
Former Soviet Union	279	243	200	-0.3	-0.4
Japan	128	103	84	-0.5	-0.4
India	1,134	1,658	1,577	0.8	-0.1
Canada	32	43	40	0.6	-0.1
Indonesia	226	297	275	0.6	-0.2
South Africa	53	62	60	0.4	-0.1
Other South and East Asia	380	513	493	0.7	-0.1
OPEC	219	399	452	1.3	0.2
Rest of w orld	1,961	3,564	4,056	1.3	0.3

Source: United Nations (2006); and Treasury.

International participation rates are assumed to remain constant over the projection period, so the growth of the labour force is projected using the growth of the working age population.

B.5 PRODUCTIVITY

B.5.1 Australian labour productivity

It is important for climate change mitigation modelling that the aggregate labour productivity assumption be built-up using sector productivity trends. Sectoral productivity trends are one of the principal determinants of the industry share of output. Industry shares of activity are an important determinant of the emissions intensity of the economy, and therefore, mitigation costs.

The mitigation modelling uses Treasury forecasts and budget projections for aggregate labour productivity growth until 2011-12 (Australian Government, 2008). Budget projections assume labour productivity growth of 1¾ per cent per year. This is based on 30-year trends from the ABS *National Accounts,* which indicate that aggregate labour productivity — expressed in terms of GDP per hour worked — for the Australian economy averaged around 1¾ per cent per year from 1975-76 to 2006-07.

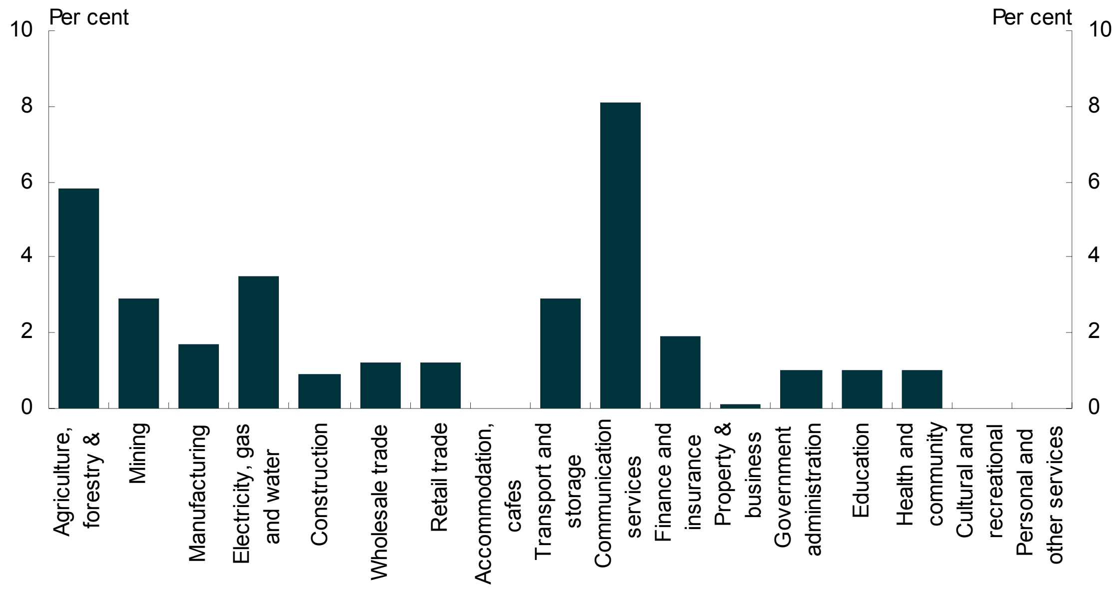
The CGE modelling suggests, that over time, as the composition of the Australian economy continues to shift towards services, aggregate Australian productivity growth will gradually drift down, purely due to the composition effect. The service industries generally have lower levels and rates of growth of measured sector-specific labour productivity than the rest of the economy. In the reference scenario, aggregate Australian labour productivity growth is assumed to gradually slow from 1¾ per cent to 1½ per cent per year over the ten years to the mid-2020s. This outcome, of 1½ per cent for long-term aggregate Australian labour productivity growth, is consistent with the long-term labour productivity growth assumption for the United States.

Aggregate labour productivity in MMRF is derived by adjusting the labour-augmenting technical change variable at an industry level. The dispersion of technical change across industry is based on historical estimates (Bagnoli, Chateau and Sahin, 2006).

The dispersion of labour-augmenting technical change across industry has not been uniform over the past 30 years. Chart B.4 shows the different growth rates by broad industry group from

1975-76 to 2006-07. These growth rates were estimated from ABS *National Accounts* and remove the effect of capital deepening on output. They were calculated by adjusting multifactor productivity (MFP) estimates by industry-level labour-income shares.

Chart B.4: Industry labour-augmenting technical change
Annual average growth from 1975-76 to 2006-07



Source: Treasury and ABS (2007).

Differences in industry growth rates imply changes in the level and composition of the Australian and state economies over time. Agriculture, manufacturing, communication, utilities, finance and insurance, wholesale, trade, transport and storage have historically grown faster than the national average over the last 30 years. Conversely, many service industries have grown more slowly than the national average. This pattern is similar across major developed economies.

After 2020, reflecting uncertainty about how persistent historical differences will be over the next century, the labour-augmenting technical change variable in market-sector industries converges to a constant rate by 2050. This constant rate is consistent with achieving aggregate labour productivity growth of 1½ per cent per year.

B.5.2 World productivity

Country-by-country growth in productivity (either output per worker or output per hour worked) is calculated using a conditional convergence framework. If a country has a productivity level below its 'potential', then it will have faster productivity growth as it catches up. Baumol (1986) and Barro and Sala-i-Martin (1992) discuss the economic framework for convergence in detail. Convergence (sometimes called 'catch-up') is a common assumption used for international growth in long-term projections, such as the *Special Report on Emission Scenarios* (IPCC, 2000).

The 'potential' for each country is assumed to be some percentage of the productivity level of the technological leader, assumed to be the United States. Productivity in the United States is assumed to adjust towards an assumed long-term growth rate (1½ per cent) in a gradual fashion from the end of history and GDP forecasts. The long-term growth rate assumption was selected after looking at the historical trends of productivity growth by industry, and the likely changes in the US industry structure. Official projections of long-term productivity growth are somewhat higher at 1.7 per cent (OASDI Trustees, 2008; Congressional Budget Office, 2008); but these projections do not take into account the likely shift towards industries with lower average rates of productivity growth.

The other key parameter for the world productivity projections is the rate of convergence. Given the lack of data for many non-OECD economies, trends that are commonly part of the development experience are assumed. The suggested rate in the literature is 2 per cent per year (Sala-i-Martin, 1996). Many studies using climate change models assume this rate, for example Bagnoli et al. (1996) and McKibbin et al. (2004).

- OECD productivity is calculated based on the per hour purchasing power parity (PPP) productivity from the Total Economy Database (The Conference Board/Groningen) January 2008 update. All OECD members as of January 2008 are included.
  - The US productivity growth rate is assumed to adjust towards its long-term growth rate of 1½ per cent in a gradual fashion, from the end of history and GDP forecasts. This gives a level of US productivity for all years.
- Non-OECD productivity is calculated based on the working age population. GDP per capita (in PPP terms) is taken from the December 2007 update of the World Bank International Comparison Project, and adjusted to per working age population using the population assumptions. Where data on the GDP level is unavailable from the International Comparison Project update, the most recent update of the Maddison international PPP data (August 2007) is used. This is done for 50 economies, making up around 4 per cent of world GDP.
- A conditional convergence framework is applied, with the conditional convergence level allowed to differ by country.
  - High-income OECD members (those with a productivity level of greater than 70 per cent of the US level) are assumed to converge to a level of productivity relative to the US equal to the average level over the last 5 years of history (to abstract from cyclical effects). This generally has the effect of causing the country to grow at the same rate as the United States.
  - High-income non-OECD economies (those with a productivity level of greater than 70 per cent of the US level) are assumed to converge to a level of productivity relative to the US equal to their starting point. This generally has the effect of causing the country to grow at the same rate as the United States.
  - Low-income economies (those with a productivity level of less than 70 per cent of the US level) are assumed to converge to 70 per cent of the US productivity level.
  - Productivity growth is smoothed, so each country takes some time to go from its recent rate of growth to its convergence path.
  - Growth in China up to 2030 has been further adjusted, based on judgements by the Garnaut Review of Climate Change of the likely growth path; see Garnaut (2008) and Garnaut et al. (2008).

Table B.10: Productivity level to the US level (GTEM regions)

	Productivity level relative to the United States		
	2005	2050	2100
United States	100	100	100
European Union	67	73	75
China	9	50	58
Former Soviet Union	18	39	52
Japan	74	76	76
India	5	24	45
Canada	82	83	84
Indonesia	7	26	47
South Africa	18	41	54
Other South and East Asia	15	30	49
OPEC	24	38	52
Rest of w orld	11	24	44

Note: GDP per adult population, US=100. Convergence and GDP calculations have been performed at a country, not regional level. OPEC in particular shows seemingly less convergence than other economies — this is a result of OPEC being a mix of economies with high productivity (for example, Qatar) that do not converge, mid-income economies (for example, Saudi Arabia) that converge more slowly, and low-income economies (for example, Yemen).

B.5.3 World sectoral labour productivity

The productivity and population assumptions give the total change in output for the economy. To implement these assumptions in the international models (G-Cubed and GTEM), some assumption has to be made about the way this increase in productivity (or efficiency) is distributed between industries. Since capital stock accumulates endogenously and the supply of other factors are given in the model, the model calculates the value of a productivity variable to be consistent with the exogenous trajectory of regional outputs.

Aggregate labour productivity has been distributed across industries in each economy on the basis of historical performance, consistent with the aggregate productivity. Productivity growth rates across sectors are based on historical averages calculated from the Groningen Growth and Development Centre database and the OECD. Table B.11 shows the relative growth rates of different sectors in key economies used in the GTEM model.

Table B.11: Sectoral labour productivity distribution

	Relative grow th rates betw een sectors						
Industry	United States	EU25	China	FSU(a)	Japan	India	Canada
Coal mining	1.00	1.00	1.30	0.50	0.50	1.50	1.00
Oil mining	1.00	1.00	0.75	0.50	0.50	1.00	1.00
Gas mining	1.00	1.00	0.75	0.50	0.50	1.00	1.00
Petroleum and coal	1.00	1.00	0.75	0.50	0.50	1.00	1.00
Electricity	1.25	1.00	0.75	0.50	0.50	0.50	1.25
Mining and chemicals	1.25	1.00	1.00	1.00	1.50	1.00	1.25
Manufacturing	1.25	1.50	1.00	1.00	1.50	1.00	1.25
Road transport	1.50	2.00	2.00	1.00	2.00	2.00	1.50
Water and air transport	0.75	1.00	0.50	0.50	1.00	0.50	0.75
Crops	0.75	1.50	1.00	1.00	0.50	0.50	0.75
Livestock	0.75	1.50	1.00	1.00	0.50	0.50	0.75
Fishing and forestry	0.75	1.50	1.00	1.00	0.50	0.50	0.75
Food	1.40	1.50	1.00	1.00	1.00	1.00	1.40
Services	1.00	1.00	0.75	0.75	1.00	0.75	1.00

(a) Former Soviet Union. GTEM industries have been aggregated where distribution of sectoral productivity is the same.
Source: Treasury.

Table B.11 (cont): Sectoral labour productivity distribution

Industry	Relative growth rates between sectors					
	Australia	Indonesia	Southern Africa	Other South East Asia	OPEC	Rest of world
Coal mining	1.00	1.40	1.00	1.00	1.00	1.00
Oil mining	1.00	0.75	1.00	0.75	1.00	1.00
Gas mining	1.40	0.75	1.00	0.75	1.00	1.00
Petroleum and coal	1.40	0.75	1.00	0.75	1.00	1.00
Electricity	1.40	0.75	1.00	0.75	1.00	1.00
Mining and chemicals	0.80	1.00	1.00	1.00	1.00	1.00
Manufacturing	1.00	1.00	1.00	1.00	1.00	1.00
Road transport	2.00	2.00	2.00	2.00	2.00	2.00
Water and air transport	1.40	0.50	1.00	0.50	1.00	1.00
Crops	1.00	0.75	1.00	0.50	1.00	1.00
Livestock	1.00	0.50	1.00	0.50	1.00	1.00
Fishing and forestry	2.00	0.50	1.00	0.50	1.00	1.00
Food	1.00	0.50	1.00	0.50	1.00	1.00
Services	1.00	0.75	1.00	0.75	1.00	1.00

Note: GTEM industries have been aggregated where distribution of sectoral productivity is the same.
Source: Treasury.

As an example of how to interpret this data, note in the EU-25 road transport labour productivity grows twice as fast as coal sector labour productivity. The same comparison cannot be made between sectors, For example, mining and chemicals productivity in the EU-25 and China are not be equal; 'average growth' (that is, equal to 1.0) in each is determined by aggregate labour productivity.

Due to structures in the G-Cubed model, it was not possible to use differentiated labour productivity growth rates across economies, so the relative productivity pattern for Australia was used for all regions.

B.5.4 Weights used for gross world product

The market exchange rate (MER) is the rate of exchange between currencies in foreign exchange markets in the 'real world'. In contrast, purchasing power parity (PPP) exchange rates are a hypothetical exchange rate that adjusts for differences in prices levels across economies. Under a PPP exchange rate, one Australian dollar could buy the same amount of goods and services in any economy: no more, no less.

The MER/PPP debate in climate change modelling is about which exchange rate is more appropriate for converting different economies' GDP into a single currency (usually US dollars) to make economic comparisons and growth projections. It is argued that the choice of measurement could have significant impacts for the validity of economic growth projections and energy use, and hence, projections of future climate change (Castles and Henderson, 2003). The price levels expressed in common MER currency terms are typically higher in developed economies than in developing economies. Economic activity levels in the developing economies tend to appear lower than they actually are. As a result, current cross-country differences in income per capita levels tend to be over-estimated when MERs are used to convert GDP into a common currency. The use of MER exchange rates, together with the assumption of conditional convergence in relative per person income levels, could lead to over-stated economic growth in developing economies and consequently, excessive growth in energy demand and emission levels.

It is practical to use PPP data for this modelling report as the national and trade accounts in the CGE models used are specified using MER. However, the issues that arise from using MER data are lessened through careful analysis and implementation of assumptions. The initial productivity projections are derived using PPP exchange rates, and sector productivity growth rates are specified based on historical trends (Bagnoli, Chateau and Sahin, 2006). Using historic sector productivity assumptions tends to result in faster tradable sector productivity than non-tradable sector productivity. This difference, combined with the conditional convergence framework, typically lead to an appreciation of the real exchange rate over time, and a convergence between MER and PPP exchange rates ('Baumol-Balassa-Samuelson effect').

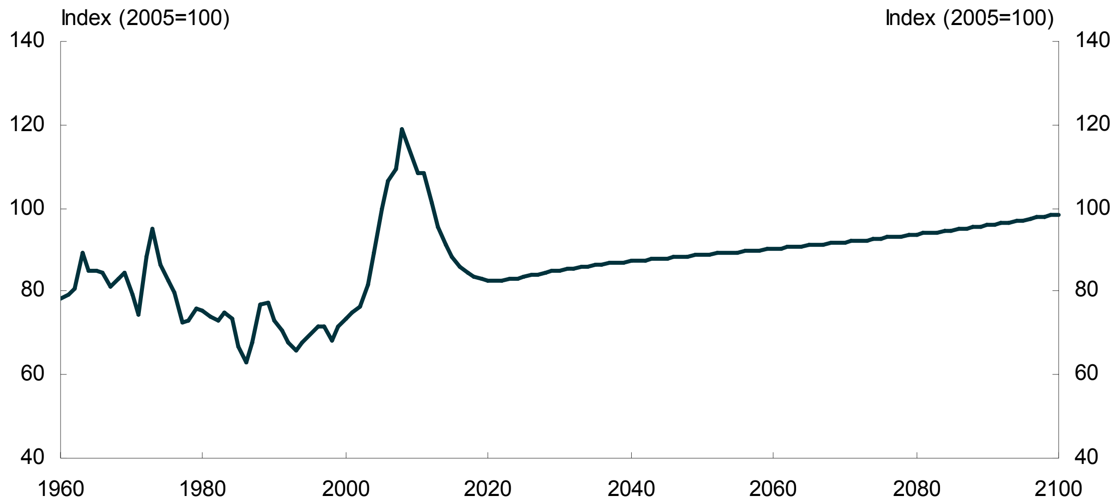
B.6 TERMS OF TRADE AND ENERGY PRICE ASSUMPTIONS

B.6.1 Australia's terms of trade

Australia's terms of trade (the ratio of export prices to import prices) are imposed on the MMRF model until 2020-21. In the short term, Treasury forecasts are used, then, in line with the methodology used in recent federal budgets, a two-year step down in the terms of trade is imposed. Beyond 2011-12, Australia's terms of trade are assumed to continue to decline gradually over the 10 years to 2021-22, as key commodity prices (coal, oil, gas, iron ore, non-iron ore, other mining, diesel, chemicals, rubber and plastic, steel and other metals) continue to fall towards levels that reflect longer term demand and supply conditions. After 2021-22, Australia's terms of trade are determined within the MMRF model.

In MMRF, export prices reflect the interaction of MMRF's industry supply schedules and the position of the world demand curves for Australia's exports. The position of the world demand curves for Australia's exports, which is exogenous in MMRF, is drawn from GTEM information.

Chart B.5: Australia's terms of trade

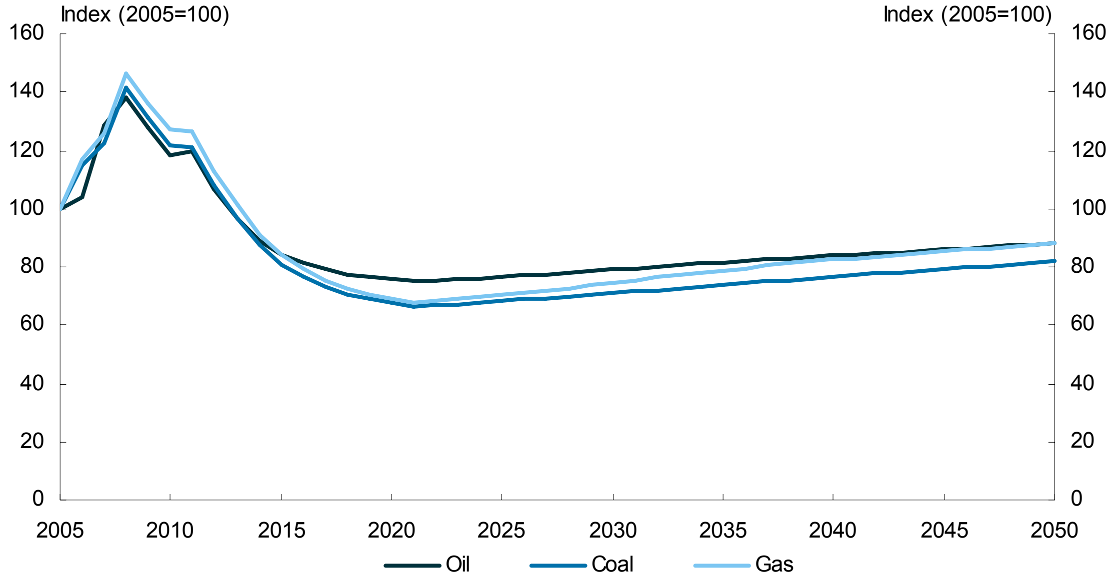


Source: Treasury.

B.6.2 Energy commodity price assumptions

Global energy prices are projected to rise gradually over time, consistent with International Energy Agency (IEA) projections, as in the *World Energy Outlook 2007*. As continued growth in demand forces the exploitation of more marginal resources, the rising marginal cost of extraction for these commodities pushes up their price.

Chart B.6: Energy commodity price assumptions
Foreign currency — 2005-06 dollars



Source: Treasury; IEA, 2007b.

Resource cost curves

In GTEM, movements in the international prices for key energy commodities, including oil, coal and gas, are assumed to broadly follow movements in IEA projections. Costs of extracting resources increase as output expands as low cost resource supplies are used up, requiring use of more primary factors (capital and labour) per unit of resource. Table B.12 shows the percentage decline in labour and capital efficiency in natural resource intensive sectors per doubling of cumulative extraction of the resources (resource depletion effect).

Table B.12: Change in factor efficiency per doubling in the level of extraction

	Coal	Oil	Gas	Other mining
	Per cent	Per cent	Per cent	Per cent
United States	2.9	12.8	10.6	3.2
EU-25	2.9	12.8	13.4	3.2
China	4.9	9.8	17.8	3.2
Former Soviet Union	1.7	9.8	17.8	3.2
Japan	11	24	46.2	3.2
India	4.9	3.4	2.6	3.2
Canada	5.7	9.8	16.2	3.2
Australia	5.7	12.8	6.4	3.2
Indonesia	0.7	18.6	25.5	3.2
South Africa	0.7	12.8	24	3.2
Other South East Asia	0.7	11	23	3.2
OPEC	0.7	10.4	14.6	3.2
Rest of world	3.3	6.6	12.9	3.2

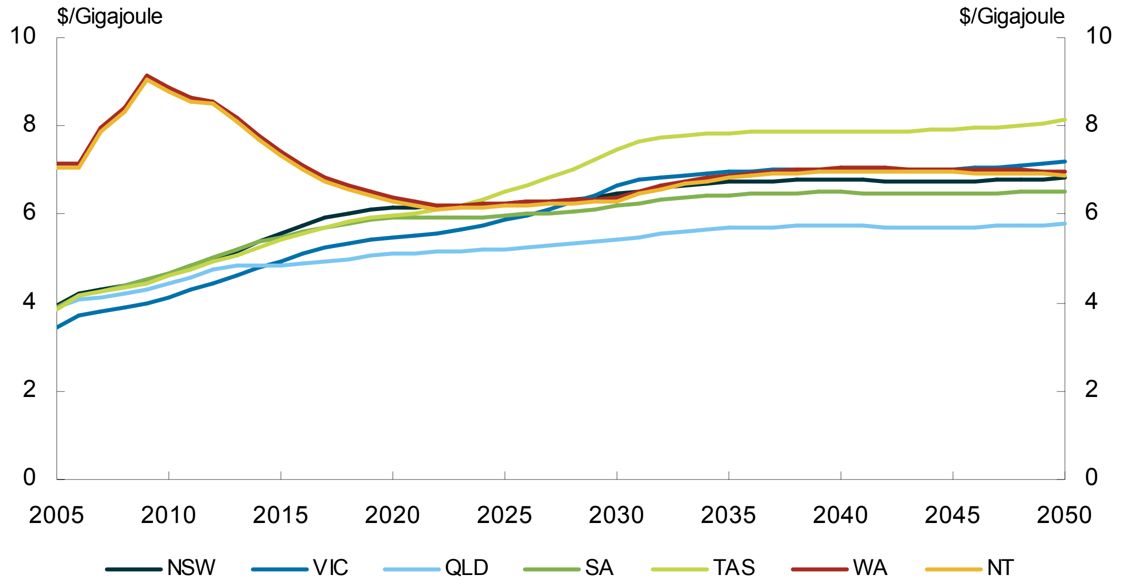
Note: A positive number means that more factors are required per unit of extracted resource.
Source: Treasury and GTEM database.

B.6.3 Fuel costs for electricity generation

MMA combined Australian energy price assumptions with electricity industry-specific information to determine the fuel prices faced by Australian electricity generators.

- Once existing contracts expired for black coal (non-mine mouth), world energy price movements affected new coal contracts. Brown coal and mine mouth black coal prices were assumed to be unaffected by world energy price movements.
- South eastern gas supplies are assumed to be gradually depleted over the next 20 years, with gas increasingly sourced from Queensland. In addition, LNG facilities are assumed to be developed in Queensland, with a moderate degree of LNG penetration assumed, reaching 10 Mtpa LNG capacity. Consequently, east coast gas prices are assumed to converge to international gas prices in 2029-30. Differences in gas transmission costs amongst states, reflecting distance from fuel sources, mean that fuel prices are not equalised across states.
  - Domestic average gas prices are modelled by assuming that gas contracts turn over at a rate of 10 per cent of contracts per year, and that new contracts are influenced by world prices.

Chart B.7: Domestic Australian gas prices



Source: MMA.

B.6.4 Australian oil and gas supply constraints

The MMRF model incorporates assumptions about energy resource supply constraints, drawing on ABARE (2008), Geoscience Australia (2007 and 2008) and the BP statistical review of world energy (2007). No constraints have been imposed on the availability of energy resources in G-Cubed or GTEM.

It is assumed in MMRF that oil production in Australia ceases around 2030, and gas production ceases in South Australia around 2020, and in Victoria around 2030. Supply constraints in the model are imposed through scrapping existing capital.

ABARE reports that Australia has over 100 years worth of reserves of black coal and over 500 years worth of reserves of brown coal at current rates of production; therefore no constraints on coal production were imposed (ABARE, 2008).

B.7 Structural change

B.7.1 Intermediate input assumptions

Industry use of intermediate inputs in MMRF and GTEM is assumed to change over time.

The assumed changes in MMRF are based on historical decomposition analysis by Giesecke (2004). The estimates in MMRF were validated within Treasury, using a data set provided by the Centre for Integrated Sustainability Analysis at the University of Sydney. Reflecting uncertainty about the persistence of historical trends over the next century, the intermediate input change assumptions are assumed to decline linearly to zero between 2020 and 2050. The change in the intermediate input usage is implemented in MMRF in a cost-neutral manner, so total factor productivity remains unchanged.

As shown in Table B.13, the use of energy-intensive commodities is assumed to decline. This autonomous energy efficiency improvement (AEEI) reflects historical trends and analysis by the IEA and ABARE. In contrast, the intermediate use of services by business is assumed to continue to increase. For example, the demand for business services is assumed to increase by 1.5 per cent per year over the next 10 years.

Table B.13: Intermediate input usage in MMRF[(a)]

Annual average growth , per cent

Commodities	2006 to 2010	2011 to 2020	2021 to 2030	2031 to 2040	2041 to 2050	2051 to 2100
Sheep and cattle	-0.3	-0.2	-0.2	-0.1	0.0	0.0
Dairy cattle	-0.3	-0.2	-0.2	-0.1	0.0	0.0
Other animals	-0.3	-0.2	-0.2	-0.1	0.0	0.0
Forestry	-0.5	-0.5	-0.4	-0.2	-0.1	0.0
Coal mining(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Gas mining(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Other mining	-1.5	-1.5	-1.2	-0.7	-0.2	0.0
Meat products	0.5	0.5	0.4	0.2	0.1	0.0
Textiles, clothing and footw ear	-2.0	-2.0	-1.5	-0.9	-0.3	0.0
Wood products	-0.2	-0.2	-0.2	-0.1	0.0	0.0
Paper products	-0.2	-0.2	-0.2	-0.1	0.0	0.0
Printing	-0.4	-0.4	-0.3	-0.2	-0.1	0.0
Gasoline(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Diesel(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
LPG(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Air fuel	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Other fuel(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Chemicals	-0.7	-0.7	-0.5	-0.3	-0.1	0.0
Rubber and plastic products	0.5	0.5	0.4	0.2	0.1	0.0
Non-metal construction products	-0.5	-0.5	-0.4	-0.2	-0.1	0.0
Cement	-0.3	-0.3	-0.2	-0.1	0.0	0.0
Iron and steel	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Aluminium	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Other metals manufacturing	-0.1	-0.1	-0.1	0.0	0.0	0.0
Metal products	-0.1	-0.1	-0.1	0.0	0.0	0.0
Other manufacturing	-0.5	-0.5	-0.4	-0.2	-0.1	0.0
Electricity supply(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Water supply	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Construction	0.5	0.5	0.4	0.2	0.1	0.0
Trade	0.5	0.5	0.4	0.2	0.1	0.0
Accommodation and hotels	-1.5	-1.5	-1.2	-0.7	-0.2	0.0
Road transport: passenger	0.7	0.7	0.5	0.3	0.1	0.0
Road transport: freight	0.7	0.7	0.5	0.3	0.1	0.0
Rail transport: passenger	0.4	0.4	0.3	0.2	0.1	0.0
Rail transport: freight	0.4	0.4	0.3	0.2	0.1	0.0
Air transport	0.5	0.5	0.4	0.2	0.1	0.0
Communication services	1.0	1.0	0.8	0.5	0.1	0.0
Financial services	0.5	0.5	0.4	0.2	0.1	0.0
Business services	1.5	1.5	1.2	0.7	0.2	0.0

(a) Annual rate of change of use of the commodity identified per unit of output of all industries.
(b) Energy commodities have economy-wide energy-efficiency term applied. See energy efficiency section. Excluded commodities have no intermediate input efficiency shocks applied.
Source: Treasury and Centre of Policy Studies.

Table B.14: Intermediate input efficiency, GTEM
Annual average growth

	2002 to 2100
	Per cent
United States	0.3
EU-25	0.3
China	0.5
Former Soviet Union	0.6
Japan	0.3
India	0.7
Canada	0.2
Australia	0.4
Indonesia	0.3
South Africa	0.6
Other South East Asia	0.3
OPEC	0.4
Rest of w orld	0.7

Source: Treasury.

Table B.14 shows the average annual efficiency improvement across all intermediate inputs from 2002 to 2100. In the United States, intermediate input efficiency improves by around 0.31 per cent per year from 2002 to 2100.

B.7.2 Household taste shifts

Household taste shifts account for any additional change in consumption, after accounting for changes in incomes and relative prices. Projection assumptions are based on historical decomposition analysis by the Centre of Policy Studies (Adams et al., 1994; Dixon and Rimmer, 2002; Giesecke, 2004). In addition, Treasury has undertaken a decomposition analysis in the MMRF model, based on consumption categories in the national accounts.

The projected household taste shifts suggest a continuation of the long-term trends towards service commodities and away from basic commodities. Reflecting uncertainty about how persistent household trends will be over the next century, the taste shifts terms are assumed to decline to zero in a linear fashion between 2020 and 2050.

Table B.15: Household taste shocks in MMRF
Annual average growth, per cent

Commodities	2006 to 2010	2011 to 2020	2021 to 2030	2031 to 2040	2041 to 2050	2051 to 2100
Biofuels	1.0	1.0	0.8	0.5	0.1	0.0
Forestry	-1.5	-1.5	-1.2	-0.7	-0.2	0.0
Coal mining	-0.6	-0.6	-0.5	-0.3	-0.1	0.0
Paper products	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Printing	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Chemicals	0.8	0.8	0.6	0.4	0.1	0.0
Water supply	-0.5	-0.5	-0.4	-0.2	-0.1	0.0
Trade	0.5	0.5	0.4	0.2	0.1	0.0
Accommodation and hotels	0.5	0.5	0.4	0.2	0.1	0.0
Air transport	1.5	1.5	1.2	0.7	0.2	0.0
Communication services	3.0	3.0	2.3	1.4	0.4	0.0
Financial services	0.5	0.5	0.4	0.2	0.1	0.0
Business services	1.0	1.0	0.8	0.5	0.1	0.0
Public services	2.3	2.3	1.8	1.0	0.3	0.0
Other services	1.0	1.0	0.8	0.5	0.1	0.0
Private transport	-0.5	-0.1	0.0	0.0	0.0	0.0
Private electricity	0.5	0.5	0.4	0.2	0.1	0.0

Note: Excluded commodities have no taste shocks applied.
Source: Treasury and Centre of Policy Studies.

B.8 ENERGY EFFICIENCY

Energy efficiency improves when less energy is required to produce the same amount of output. Energy efficiency can improve when the price of energy rises relative to other inputs or from technological improvements, including better use of existing technologies, the replacement of existing technologies with newer technologies, or improvements in new technology through research and development and learning by doing.

Assumed energy efficiency improvements in the modelling will affect the level of energy use and hence emissions. The three CGE models used by Treasury, GTEM, G-Cubed and MMRF treat energy efficiency differently depending on the model's structure.

B.8.1 Economy-wide energy efficiency

While CGE models can capture price-induced improvement in energy efficiency internally, if they allow for substitution in consumption and production choices, where they do not fully capture those substitution opportunities, they incorporate underlying energy efficiency improvements using a simple autonomous energy-efficiency improvement (AEEI) parameter. The AEEI parameter specifies the rate of annual energy-efficiency improvement, but not the source.

Arriving at estimates for the value of the AEEI is difficult given the uncertain evolution of energy efficiency over very long timeframes. While history provides a guide, available data is often aggregated, which obscures trends in energy efficiency with other factors such as structural changes in the economy. The reference scenario for Australia, assumes a constant economy-wide AEEI parameter of 0.5 per cent for all sectors outside the electricity and transport sectors, reflecting available estimates of historical energy efficiency by ABARE (2003) and the IEA (2004 and 2007a). For other regions, GTEM uses 0.5 per cent per year, except for some specific sectors such as: transport, iron and steel, non-metallic minerals, non-ferrous metals, and chemicals, rubber and plastics. These assumptions are outlined in Tables B.16 and B.18 to B.22. In its modelling of the Australian transport sector, the CSIRO also makes fuel efficiency assumptions (Table B.17).

B.8.2 Sector-specific energy efficiency

Transport energy-efficiency improvements

World transport efficiency assumptions

Transport energy-efficiency improvements in the 'other transport' sector in GTEM are based on ABARE (2006). The other transport sector includes rail and road transport technologies.

The fuel efficiencies of the different economies reflect a variety of trends. The increased uptake of variable valve controls and changes in fuel use (for example to diesel) tends to increase fuel efficiency. The improvement in fuel efficiency in North America is assumed to be slower than in some other developed regions as consumers prefer larger, less fuel efficient vehicles (ABARE, 2006). As discussed in Chapter 6, Australia is expected to see an increase the share of diesel fuel over the projection period.

Table B.16: Transport sector energy-efficiency assumptions
Annual average growth, 2005 to 2100

	Rail	ICE	Advanced ICE	Hybrid	Non-fossil fuel
	Per cent	Per cent	Per cent	Per cent	Per cent
United States	0.6	0.3	0.5	0.6	0.6
European Union	0.6	0.4	0.4	0.7	0.7
China	0.6	0.5	0.7	1.0	1.0
Former Soviet Union	0.6	0.5	0.7	0.7	0.7
Japan	0.6	0.3	0.4	0.6	0.6
India	0.6	0.8	0.9	1.2	1.2
Canada	0.6	0.3	0.5	0.6	0.6
Australia	0.6	0.7	0.8	0.9	0.9
Indonesia	0.6	0.6	0.8	0.7	0.7
South Africa	0.6	0.8	0.6	0.9	0.9
Other South and East Asia	0.6	0.9	1.2	1.1	1.1
OPEC	0.6	0.8	0.8	1.1	1.1
Rest of w orld	0.6	1.0	0.8	1.0	1.0

Note: ICE refers to internal combustion engines, and non-fossil fuel vehicles include electric and hydrogen cars.
Source: ABARE and Treasury.

Australian transport energy efficiency assumptions

The CSIRO assumes petrol engine vehicles to be 25 per cent more efficient and diesel engines to be 14 per cent more efficient from 2006 to 2050, independently of changes related to fuel type and hybrid drivetrain, (CSIRO, 2008). Details of CSRIO's Australian road transport technology assumptions can be found in BITRE and CSIRO (2008).

Table B.17: CSIRO fuel efficiency improvements
Average annual growth, 2006 to 2050

	Petrol	Diesel	LPG	NG	B100	B20	E85	E10	H2	GTLD	CTLD
Passenger	Per cent										
Light	0.7	0.3	0.8	0.8	0.5	0.3	0.9	0.7	1.0	0.3	0.3
Medium	0.7	0.3	0.8	0.8	0.4	0.3	0.9	0.7	1.0	0.3	0.3
Heavy	0.7	0.4	0.8	0.8	0.4	0.3	0.9	0.7	1.0	0.3	0.3
LCVs											
Light	0.7	0.3	0.8	0.9	0.5	0.3	0.9	0.7	1.0	0.3	0.3
Medium	0.7	0.3	0.8	0.9	0.4	0.3	0.9	0.7	1.0	0.3	0.3
Heavy	0.7	0.4	0.8	0.9	0.5	0.3	0.9	0.7	1.0	0.3	0.3
Trucks											
Rigid	0.7	0.3	0.8	0.8	0.5	0.3	0.9	0.7	1.0	0.3	0.3
Articulated	0.7	0.3	0.5	0.5	0.5	0.3	0.6	0.7	0.6	0.3	0.3
Buses	0.7	0.3	0.8	0.9	0.5	0.3	0.9	0.7	1.0	0.3	0.3

Note: NG refers to compressed natural gas; B100 and B20 are different blends of biodiesel; E85 and E10 are different ethanol blends; H2 is hydrogen; GTLD is gas-to-liquid fuels; and CTLD are coal-to-liquid fuels.
Source: CSIRO, 2008.

Other sector energy efficiency assumptions

The non-ferrous metal sector includes aluminium, nickel, copper, lead and gold. Energy efficiency improvements for the aluminium sector are assumed to vary significantly between regions (Table B.18). The main determinant of efficiency improvements in the non-ferrous metals sector in GTEM is the assumed increase of scrap aluminium rather than technological advancement (Fisher et al., 2006). Early in the projection period, the United States is expected to shut down most of its primary aluminium smelting plants and produce aluminium solely from scrap. Australia and other major exporting regions, however, are assumed to have little scrap available. These regions are assumed to have significantly less efficiency improvements than the United States. Efficiency improvements in this sector largely reflect composition shifts within the sector, not uniform improvements over all sub-sectors within the aggregate sector.

Table B.18: Non-ferrous metals energy-efficiency shocks
Average annual growth

	2005 to 2100
	Per cent
United States	1.7
European Union	1.7
China	1.1
Former Soviet Union	0.7
Japan	0.6
India	0.8
Canada	0.7
Australia	0.5
Indonesia	1.5
South Africa	0.8
Other South and East Asia	0.7
OPEC	0.7
Rest of w orld	0.8

Source: ABARE and Treasury.

To test the sensitivity of the mitigation cost estimates to this assumption, a sensitivity scenario was undertaken. Non-ferrous metal energy-efficiency shocks were uniformly applied to all economies, at 0.5 per cent growth per year. Australia's exports of non-ferrous metals increased very slightly in the reference scenario as a result. However, this sensitivity scenario indicated changing this assumption had no material effect on the Australian and non-ferrous metal sector results under mitigation policy.

Table B.19: Non-metallic mineral energy-efficiency shocks
Average annual growth

	2005-2050
	Per cent
United States	0.7
European Union	0.6
China	1.0
Former Soviet Union	0.9
Japan	0.4
India	0.9
Canada	0.9
Australia	0.4
Indonesia	0.7
South Africa	0.4
Other South and East Asia	0.6
OPEC	0.6
Rest of w orld	0.5

Source: ABARE and Treasury.

Table B.20: Chemical, rubber and plastics energy efficiency shocks
Average annual growth

	2005 to 2010	2010 to 2020	2020 to 2030	2030 to 2100
	Per cent	Per cent	Per cent	Per cent
United States	0.5	0.5	0.5	0.6
European Union	0.5	0.5	0.5	0.5
China	0.5	0.5	0.5	0.5
Former Soviet Union	0.4	0.4	0.4	0.5
Japan	0.5	0.5	0.5	0.5
India	0.6	0.6	0.5	0.5
Canada	0.4	0.5	0.5	0.5
Australia	0.4	0.4	0.5	0.5
Indonesia	0.4	0.4	0.5	0.5
South Africa	0.4	0.5	0.5	0.5
Other South and East Asia	0.4	0.4	0.5	0.6
OPEC	0.4	0.4	0.5	0.5
Rest of w orld	0.5	0.5	0.5	0.6

Source: ABARE and Treasury.

Iron and steel energy efficiency (GTEM)

As part of the modelling in GTEM, assumptions have been made on improvements in energy efficiency in the iron and steel industry. Annual average efficiency improvements are based on the US Energy Information Administration National Energy Modelling System (NEMS), which underlies the EIA's Annual Energy Outlook. In GTEM, iron and steel is a technology bundle industry with two discrete technologies — blast furnace and electric arc furnace (recycled steel from scrap steel). The assumed improvements in energy efficiency for blast furnace and electric arc furnace processes are outlined in Tables B.21 and B.22 respectively.

Table B.21: Blast furnace

Average annual growth

	2005 to 2010	2010 to 2020	2020 to 2030	2030 to 2100
	Per cent	Per cent	Per cent	Per cent
United States	0.5	0.3	0.3	0.8
European Union	0.4	0.3	0.3	0.4
China	0.9	1.0	1.0	0.7
Former Soviet Union	0.5	0.9	0.9	0.7
Japan	0.3	0.3	0.3	0.5
India	1.1	0.9	0.8	1.0
Canada	0.2	0.3	0.3	0.5
Australia	0.4	0.3	0.3	0.7
Indonesia	0.0	0.0	0.0	0.5
South Africa	0.6	0.8	0.8	1.2
Other south and east Asia	0.3	0.5	0.5	0.4
OPEC	0.5	0.3	0.3	0.9
Rest of w orld	0.6	0.8	0.8	0.9

Source: ABARE and Treasury.

Table B.22: Electric Arc

Average annual growth

	2005 to 2010	2010 to 2020	2020 to 2030	2030 to 2100
	Per cent	Per cent	Per cent	Per cent
United States	0.9	0.7	0.7	0.9
European Union	0.8	0.6	0.6	0.7
China	1.0	1.3	1.3	1.0
Former Soviet Union	0.6	1.3	1.4	0.8
Japan	0.5	0.6	0.6	0.8
India	1.3	1.3	1.3	1.3
Canada	0.4	0.7	0.7	0.6
Australia	0.7	0.7	0.7	0.9
Indonesia	1.2	1.2	1.2	1.4
South Africa	0.7	1.3	1.3	1.5
Other South and East Asia	0.5	0.7	0.8	1.2
OPEC	1.0	0.9	0.9	1.0
Rest of w orld	0.6	1.2	1.3	1.2

Source: ABARE and Treasury.

B.9 TECHNOLOGY ASSUMPTIONS

B.9.1 Electricity technology assumptions

Table B.23 describes the key electricity sector input assumptions used by MMA.

Table B.23: Technology characteristics, MMA

Fuel/technology	Thermal efficiency 2010 per cent	Thermal efficiency 2011 to 2050 per cent per year	Capital costs 2010 $/kW sent out	Capital cost de-escalator 2010 to 2020 per cent per year	Capital cost de-escalator 2021 to 2050 per cent per year
Black Coal					
Supercritical coal (dry-cooling)	38	0.48	1,879	0.5	0.5
Ultrasupercritical coal (USC)	41	0.48	2,255	0.5	0.5
Integrated gasification combined cycle (IGCC)	39	1.20	2,673	1.5	1.0
IGCC w ith carbon capture (CC)	32	1.30	3,688	1.5	1.0
USC w ith CC and oxyfiring	30	0.58	2,997	1.0	0.5
USC w ith post-combustion capture	28	0.58	3,044	1.5	0.5
Brown Coal					
Supercritical coal w ith drying	35	0.48	1,972	0.5	0.5
Supercritical coal	33	0.48	2,289	0.5	0.5
Ultra supercritical coal w ith drying	37	0.48	2,366	1.0	0.5
IGCC w ith drying	37	1.20	2,788	1.0	1.0
Integrated drying gasification combined cycle (IDGCC)	37	1.20	2,732	1.5	0.5
IGCC w ith CC and drying	30	1.30	3,886	1.5	0.5
IDGCC w ith CC	32	1.30	3,026	1.5	0.5
Co-firing w ith biomass or gas in supercritical plant	35	0.48	2,169	0.5	0.5
Post-combustion capture w ithout drying	28	0.58	3,155	1.5	0.5
Post-combustion capture w ith drying	26	0.58	3,248	1.5	0.5
Natural gas					
Combined cycle gas turbined (CCGT) - small	49	0.60	1,467	0.5	0.5
CCGT - large	53	0.60	1,334	0.5	0.5
Cogeneration	72	0.60	1,740	0.5	0.5
CCGT w ith CC	46	0.70	2,001	1.0	0.5
Renewables					
Wind			2,134	0.5	0.5
Biomass - Steam			2,598	0.5	0.5
Biomass - Gasification			2,784	1.5	1.0
Concentrated solar thermal plant			4,176	1.5	1.0
Geothermal - Hydrothermal			2,227	1.0	1.0
Geothermal - Hot Dry Rocks			4,200	1.5	0.5
Concentrating PV			4,640	1.0	1.0
Hydro			2,320	1.0	0.5

Source: MMA.

There is uncertainty surrounding future technology costs, particularly in relation to technologies that have not yet been deployed. See ACIL Tasman (2008) for a review of capital cost estimates. The Treasury assumptions were developed, taking account of the broad macroeconomic assumptions from the national and global modelling. Comparisons of these assumptions with overseas estimates are not straight forward owing to different environmental regulatory standards, which are not needed in Australia.

Thermal efficiency

The thermal efficiency of a fossil fuel power plant is the ratio of electricity generated to energy input. Assumptions on thermal efficiency improvements for Australia were provided by MMA. Table B.24 shows thermal efficiencies when the plants operate at maximum capacity. As plants do not always operate at maximum capacity, the average thermal efficiency is typically lower than those shown. After 2050, thermal efficiencies are assumed to increase slightly for coal and gas, reflecting a continuation of efficiency improvements from 2030 to 2050.

Assumptions on electricity generation efficiencies are based on information received from ACIL Tasman and MMA. It is assumed the thermal efficiency of new fossil fuel electricity and heat generation plants improves over time. These assumptions apply to new power plants. The thermal efficiency of the average plant in the capital stock improves as a combination of technology advancement and replacement of old capital with new.

Table B.24: Thermal efficiency of new power plants in electricity generation in GTEM

	Coal			Gas		
	2002	2050	2100	2002	2050	2100
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
United States	35.6	47.0	54.6	40.3	61.3	65.7
European Union	35.1	41.2	44.6	48.1	55.2	58.0
China	31.6	43.3	50.3	46.5	63.1	69.8
Former Soviet Union	31.3	33.3	35.4	38.1	41.1	42.3
Japan	37.1	45.5	50.3	45.1	60.1	65.8
India	27.7	47.5	56.8	41.6	64.5	69.9
Canada	38.2	44.9	48.6	46.2	57.9	60.2
Indonesia	27.8	47.2	57.6	32.9	63.1	69.7
South Africa	38.5	46.8	54.3	39.4	65.0	70.4
Other South and East Asia	33.8	46.3	54.8	37.3	61.7	68.1
OPEC	39.0	49.0	58.6	31.9	63.4	70.1
Rest of w orld	32.7	47.1	56.3	41.5	60.9	65.3

Source: ABARE, ACIL Tasman, MMA.

Capital costs

Two main factors drive capital costs over time in MMA: metal prices and technological progress. MMA assume that 25 per cent of capital costs reflect commodity costs.

Treasury provided cost indices for key metals (steel and aluminium) for the reference and policy cases. The metal costs are consistent with the macroeconomic assumptions, such as the terms of trade, including the expected unwind in metal costs as supply responds to high levels of demand. Metal prices are higher in the policy scenarios owing to the cost of emissions associated from metal production.

MMA assume that capital costs decline over time for all technologies owing to general capital productivity improvements. Table B.23 shows the annual rate of capital cost de-escalation.

GTEM assumes that additional global deployment of renewable technologies leads to faster rates of cost decline for these technologies. To capture the impact of global deployment on Australia, additional capital cost reductions were applied on Australian renewable technology capital costs. These were developed by comparing renewable cost declines in GTEM and applying the *additional* rate of cost decline to MMA modelling.

B.9.2 Learning rates

Learning-by-doing is when technology costs fall due to greater use of a technology, such as incremental innovations. Changes to learning rates alter the rate at which these improvements occur.

Non-renewable and biomass technologies use feedstock, labour and capital to produce electricity, while renewable, including hydro, technologies use only labour and capital as inputs. The efficiency with which new technology uses capital and labour is assumed to increase over time as the scale of these technologies increases.

The GTEM parameters of the learning function were calibrated, given the pathways of the fossil fuel prices and the possibility of substitution between the technologies, to produce shares of each technology that were broadly in line with the MMA analysis and other published results. Learning rates for GTEM were only assumed for new technologies and were broadly constant across all regions. The learning rates for GTEM based on the doubling of the cumulative global output are shown below.[1]

- Wind: 1.9 per cent
- Solar: 3.3-4 per cent
- Other renewables: 2.5 per cent
- Coal carbon capture and storage: 0.7 per cent
- Gas carbon capture and storage: 1.5 per cent

In addition to these learning effects, renewable technologies also benefit disproportionately from overall sector-specific factor productivity growth because primary factors are the only input to these technologies, while for non-renewable technologies the costs of feedstocks, such as coal, are significant.

B.9.3 Constraints

Exogenous assumptions and constraints in the MMA modelling include:

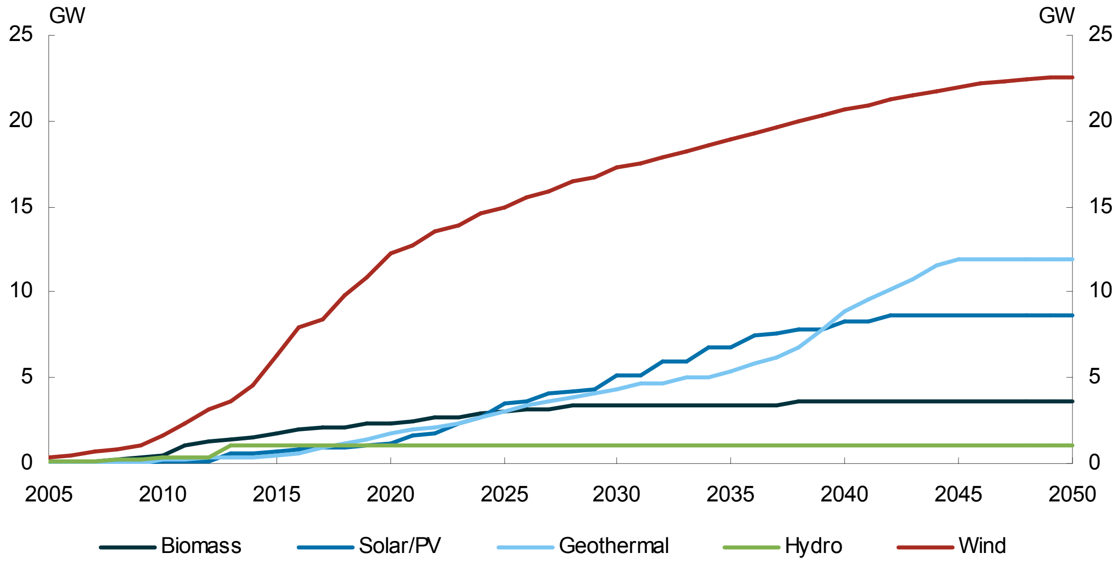
- the impact of the 2006-07 drought is assumed to disappear by 2012 — for instance, hydro dam levels are assumed to be replenished;
- new entry of power plants that are currently not planned was constrained until 2011 for peaking gas, 2012 for baseload gas, and 2013 for coal; and
- limits were placed on the rate of takeup and total takeup of renewable energy capacity reflecting resource availability, and engineering and technical constraints (including constraining wind capacity to no more than 25 per cent of a region's peak demand). Chart

1 Under the GTEM formulation of learning rates, cost reductions depend on cumulative global *output* of electricity from a specific technology. This is different to the more common formulation where cost reductions depend on cumulative global installed *capacity*. Accordingly, the GTEM learning rates are not directly comparable with many estimates in the literature.

B.8 shows the assumed cumulative limits on wind, solar/PV, hydro, biomass and geothermal takeup.

Checks ensured that the amount of carbon projected to be geo-sequestered by carbon capture and storage did not exceed estimates of available storage space (Bradshaw, 2005; Langford, 2005).

Chart B.8: Cumulative renewable capacity constraints — MMA



Note: The charts shows the maximum additional post-2005 capacity that can be installed each year, if it is economical.
Source: MMA.

Exogenous assumptions and constraints in the GTEM modelling are:

- the expansion of hydro electricity is constrained to reflect remaining unexploited hydropower resources. For China, India, Indonesia, other Asia and the rest of the world, hydro electric uptake is unconstrained to 2020, and fixed thereafter. For other regions (except Australia), hydro electric production is assumed to be fixed (based on the assumption that all profitable hydro resources already have been used) from 2001. For Australia, however, hydro electric production is exogenously shocked, based on MMA analysis;
- generation of wind electricity by region is constrained, based on estimates of wind resources (IEA, 2000; de Vries, 2007); and
- checks ensured that the amount of carbon projected to be geo-sequestered by carbon capture and storage did not exceed estimates of available storage space (IPCC, 2005).

B.9.4 Carbon capture and storage

There is a range of views on the viability, cost and timing of carbon capture and storage technology (IEA, 2008; Greenpeace, 2008). Carbon capture and storage technology, combined with coal and gas electricity generation, is assumed to be available on a commercial scale in the main policy scenarios. A sensitivity scenario also was run to test the implications of carbon capture and storage being unavailable. See Chapter 5.

The approach to modelling carbon capture and storage in MMA and GTEM differed, reflecting the level of detail in the respective models and the inherent uncertainty surrounding a technology that has yet to be demonstrated on a commercial scale. In MMA modelling, carbon capture and storage was assumed to be available for various black coal, brown coal and gas technologies. Power plants can be either purpose-built carbon capture and storage, or built 'capture ready', with carbon capture and storage installed when the carbon price is sufficiently high. Retrofitting existing power plants with carbon capture and storage was also an option. In contrast, GTEM only models purpose-built carbon capture and storage operations and has a single technology for coal and gas. However, the rates of carbon capture and storage takeup in GTEM were cross-checked in light of possible retrofitting.

In the MMA modelling of the Australian electricity sector and GTEM modelling of the world electricity sector, carbon capture and storage was assumed to be available as a generation option from 2020. This assumption is consistent with assumptions in similar modelling exercises in Australia.[2] However, the actual timing of carbon capture and storage technology deployment was determined by the model, based on economic considerations including the availability of the technology, the relative cost of carbon capture and storage with non-carbon capture and storage alternatives, the requirement for new power plant to meet current and expected future electricity demand and the emission price. Across the full range of scenarios modelled by MMA, the earliest year carbon capture and storage can be deployed ranges from 2026 to 2033, with the emission price in that year ranging from $45 to $80 per tonne of CO_2-e for coal and around $100 per tonne of CO_2-e for gas (MMA, 2008).

MMA assumes that carbon capture and storage technologies capture 85 per cent of emissions before 2050, with this capture efficiency stepped up to 90 per cent after 2050. GTEM assumes a constant 90 per cent capture efficiency throughout the period.

MMA modelling assumes carbon capture and storage capital costs are around 30-40 per cent higher for coal and 50 per cent higher for gas compared to non-carbon capture and storage options. Capturing and compressing carbon requires energy use and, as a result, the sent out efficiency of a power plant with carbon capture and storage is assumed to be around 20 per cent for lower coal generation and 14 per cent lower for gas generation.

MMA models the storage of captured carbon by state. Depending on the proximity of sequestration and the point of emission, extensive pipelines may be required. Existing gas distribution infrastructure could facilitate this but if new pipes are required the modelling assumes the fixed cost of building those pipes is paid by generators. However, these fixed costs are not paid upfront, but as an annual fee which is part of generator's variable cost of transporting and storing carbon. Generators therefore pay for the fixed cost of building pipelines over the life of the carbon capture and storage operation. This variable cost ranges from $10 to $20 a tonne, depending on the state.

B.9.5 Nuclear

Nuclear is assumed to continue to be available in regions where it is currently deployed (and not available elsewhere, including in Australia). No specific constraints were imposed; nuclear

2 Concept Economics (2008), CRA International (2008) and Energy Supply Association of Australia (2006) assumed 2020 as the earliest year for CCS. MMA (2006) assumed 2021 and Allen Consulting Group assumed 2022.

resources and emerging technology were assumed to be able to meet demand for nuclear electricity.

B.9.6 Reference scenario reductions in non-combustion emission intensity

Reductions in emissions per unit of output (emission intensity) were imposed in all CGE models based on assumptions from Australian and world sources (DCCa, 2008a; Weyant and Chesnaye, 2006).

Table B.25: Reductions in non-combustion emission intensity in GTEM

Average annual growth from 2005 to 2050 by sector and gas

	Coal CH_4 Per cent	Non-metallic minerals, CO_2 Per cent	Livestock CH_4/N_2O Per cent	Crops N_2O Per cent	Gas CH_4 Per cent	Oil CH_4 Per cent
United States	-1.4	-0.3	-0.8	-0.8	0.0	0.0
European Union	-1.7	-0.3	-0.8	-0.5	-0.6	0.0
China	-0.7	-0.4	-0.8	-0.3	-1.1	-3.2
Former Soviet Union	-1.0	-0.3	-0.8	-1.2	-2.4	-0.9
Japan	0.0	-0.3	-0.8	-0.5	-1.4	-4.5
India	-3.6	-0.3	-0.8	-0.3	-1.4	-4.1
Canada	0.0	-0.4	-1.1	-2.0	0.0	0.0
Australia	-1.7	0.0	-1.1	-1.5	0.0	0.0
Indonesia	-3.6	-0.3	-0.8	-0.4	-1.4	-4.2
South Africa	-1.0	-0.3	-0.8	-0.5	-1.7	-4.5
Other South and East Asia	-3.6	-0.3	-0.8	-0.4	-1.5	-4.1
OPEC	-3.8	-0.3	-0.8	-0.2	-0.2	-3.2
Rest of w orld	-3.0	-0.3	-0.8	-0.5	-0.4	-2.5

Note: Negative number denotes an improvement in emissions intensity. G-Cubed emission intensity reductions calibrated to be consistent with GTEM.
Source: Treasury; DCC, 2008a; Weyant and Chesnaye, 2006.

Table B.26: Reductions in non-combustion emission intensity in MMRF

Average annual growth

Industry sectors	2005 to 2020 Per cent	2021 to 2050 Per cent
High enteric livestock	4.5	4.5
Dairy cattle	1.7	1.7
Other animals	0.9	0.9
Grains	0.1	0.1
Biofuels	0.3	0.3
Other agriculture	-4.6	-4.6
Forestry	0.9	0.9
Coal mining	0.1	0.1
Oil	0.4	0.4
Gas mining	0.0	0.0
Iron ore mining	0.1	0.1
Non-Ferrous ore mining	0.1	0.1
Chemicals	0.1	0.1
Non-metal construction products	0.2	0.2
Cement	1.0	1.0
Iron and steel	0.6	0.6
Aluminium	0.8	0.8
Gas supply	0.8	0.8
Road transport: passenger	0.4	0.4
Other services	0.2	0.2
Private electricity	0.1	0.1

Source: Treasury and DCC (2008a).

B.9.7 Marginal abatement cost curves

Introduction of an emission price induces industries to reduce the emission intensity of their production; they attempt to reduce the volume of greenhouse gases emitted for each unit of production. One common way to represent and model this reduction, especially when the models do not allow for substitution between intermediate inputs of production, is with marginal abatement cost (MAC) curves. This method is used in the GTEM and MMRF models.

In the current modelling, MAC curves have the functional form:

$$\Lambda = \begin{cases} \boldsymbol{e^{-\alpha(t+1)^{\gamma}}} \ \textbf{if } \Lambda > \textbf{min}\,\Lambda, \\ \textbf{min}\,\Lambda; \end{cases}$$

Where:

Λ is an index of the emissions factor relative to the reference year;

t is the carbon price;

α is set to 0.03 unless otherwise noted;

Min Λ is the minimum emissions intensity of output possible; and

γ sets the speed of adjustment of emissions intensity in response to a carbon price, a higher γ represents a faster adjustment.

The parameters γ and min Λ are selected to model the selected industry as best as possible based on sector-specific information on technology and production possibilities. The MAC curves are non-linear in nature and results can be sensitive to the solution methods used by the models.

Marginal abatement cost curves in GTEM

The MAC curves used in GTEM were derived to fit the functional form listed above to the global level data from the EMF-21 data set by Weyant and Chesnaye (2006). The MAC curves in GTEM are applied only to fugitive/industrial process emissions, that is, only to emissions that are not the consequence of combustion of energy.

Table B.27: GTEM fugitive/industrial process emission MAC curve parameters

Sector	γ	minΛ
Coal	0.90	0.1
Gas	0.80	0.1
Oil	0.75	0.1
Landfill/solid w aste	0.85	0.1
Livestock	0.60	0.1
Crops	0.45	0.1
Fertilizer use	0.45	0.1
Non-ferrous metals	0.80	0.1
Non-metallic minerals	0.60	0.1

Source: Treasury; and EMF 21 (2006).

Marginal abatement cost curves in MMRF

Industrial process MAC curves

The MAC curves for fugitive emissions used in MMRF were constructed using a combination of the EMF-21 data set by Weyant and Chesnaye (2006), consultation with McLennan Magasanik Associates and consultation with industry stakeholders. This process yielded a set of MAC curves tailored to Australian industries.

Table B.28: MMRF industrial process emission MAC curve parameters

Sector	γ	minΛ
Livestock	0.50	0.1
Crops	0.56	0.1
Coal	0.70	0.1
Oil	0.55	0.1
Gas	0.63	0.1
Non-ferrous ore mining	0.50	0.1
Paper products	0.50	0.1
Refinery	0.55	0.1
Chemicals	0.90	0.1
Non-metal construction	0.50	0.1
Cement	0.89	0.1
Steel	0.90	0.1
Aluminium	0.90	0.1
Gas supply	0.64	0.1
Trade	0.99	0.1
Accommodation and hotels	0.99	0.1
Road transport: passenger	0.99	0.1
Other services	0.99	0.1
Private transport	0.99	0.1
Private electricity	0.99	0.1

Source: Treasury; EMF21 (2006); MMA; and Industry consultation.

Combustion MAC curves in MMRF

The MMRF model does not currently capture the potential for fuel switching, that is, substitution between say coal and gas within each sector. Fuel switching is a feature of the GTEM and G-Cubed models. In the MMRF model MAC curves were applied to combustion emissions in the industrial (non-transport) sectors, to capture the notion that industrial combustion emissions will fall in response to rising carbon prices.

The MAC curve for each type of fuel was calibrated to reflect possible use of using carbon capture and storage technology (as in the electricity generation sector) or to reflect the decarbonisation of the transport sector through the electrification of transport.

Table B.29: MMRF combustion emission MAC curve parameters

Fuel	α	γ	minΛ
Coal	0.000001	2.75	0.1
Gas	0.000001	2.33	0.1
Gasoline	0.000006	2.05	0.1
Diesel	0.000007	2.05	0.1
LPG	0.000006	2.07	0.1
Air fuels	0.000007	2.05	0.1
Other fuels	0.000007	2.05	0.1

Source: Treasury.

B.10 LAND-USE AND FORESTRY ASSUMPTIONS

B.10.1 Forestry

Detailed modelling of the forestry sector can be problematic within CGE models. Owing to this sector's importance to both Australian and global responses to emission pricing, more detailed, bottom-up modelling of the forestry sector was commissioned from ABARE (for Australia) and from Lawrence Berkeley National Laboratory (for the rest of the world).

The Australian estimates are based on the Kyoto Protocol Article 3.3 emissions accounting framework. Specifically, Article 3.3:

- includes only new forests established on land not forested in 1990;
- requires the reporting of all greenhouse gases;
- excludes harvest wood products; and
- includes the 'short rotation' harvest sub-rule, to protect individual stands from returning a negative outcome until the end of the Kyoto period.

The global emission estimates are more consistent with the United Nations Framework Convention on Climate Change (UNFCCC). The differences largely reflect availability of data. The main differences between the carbon accounting in international forestry modelling and in the Kyoto reporting adopted for Australia are:

- inclusion of all identified managed native forests and plantations (even if cleared after 1990);
- reporting of all carbon including harvested wood products; and
- inclusion of the no sub-rule mechanism.

Australia

For Australia, the supply of land available for use in agricultural and forestry sectors is assumed to be fixed. ABARE models the allocation of land between forestry and agricultural sectors using a spatial modelling framework.

ABARE's modelling examines the impact of an emission price on land-use change in the Australian agriculture sector. The framework is spatially explicit, and involves analysing the opportunities for carbon sequestration provided by land-use change and forestry on cleared agricultural land. These opportunities are determined by comparing the net present value of returns from forestry investments with the corresponding expected agricultural land value to estimate the potential area of clear agricultural land in each spatial grid cell that is competitive for forestry.

The assumed percentage changes each year to the returns to agriculture and timber from 2007 to 2100 are based on MMRF reference scenario projections. These changes are applied to both agricultural land values; and the returns and costs associated with timber plantations.

Three types of forestry activity were assumed to be available: softwood and hardwood timber plantations and environmental (carbon sequestration) plantations. All types have establishment costs, but environmental plantings do not have transport or harvesting costs, and are assumed not to incur ongoing management costs. These costs are presented in Table B.30.

The cost assumptions relating to the establishment, harvesting and transport of timber plantations and environmental plantings are based on data from NSW Department of Primary Industry (Roberts, 2007) and ABARE estimates. These costs are assumed to remain constant in the analysis, but are discounted at a rate of 7 per cent each year. Further, the cost assumptions are based on large-scale investments and may differ considerably from small-scale operations.

Table B.30: Cost assumptions, 2007 prices

		Timber plantations	Environmental plantings
Establishment	\$/ha	2,500	2,000
Management	\$/ha	180	0
Harvesting	\$/m^3	22	0
Transport	\$/m^3.km	0.123	0

Source: ABARE estimates; Roberts, 2007.

The assumed return from traditional timber production is calculated using the average mill-door log price in each state. These mill-door log prices are assumed to range from \$42/m^3 to \$71.5/m^3 in 2007 (Table B.31). The variation is due to the differences in the demand and supply of softwood and hardwood timber across states. Only one price is estimated for hardwood (broadleaved) and softwood (coniferous) logs. However, these prices are a good approximation of the expected return from native and forest plantations in Australia between 2000-01 and 2006-07 (ABARE, 2008). Mill-door log prices by state and species are derived from ABARE forest industry survey data.

The ABARE analysis uses a broad definition of available agricultural land and assumes a 100 per cent takeup of sequestration opportunities. Factors other than economic viability, including water availability and environmental restrictions, may make some land unsuitable for afforestation and therefore reduce the sequestration potential.

Table B.31: Assumed mill-door price by type in the reference scenario, 2007 prices

	Hardwood	Softwood
	\$/m^3	\$/m^3
New South Wales	54.5	52
Victoria	62.8	59.6
Queensland	54.5	66.8
South Australia	62.8	61.9
Western Australia	71.5	59.6
Tasmania	60.6	61
Northern Territory	67.3	42

Source: ABARE, 2008.

The ABARE modelling is supplemented by estimates from the Department of Climate Change of net carbon sequestration for plantations occurring between 1990 and 2006, and adjustments to account for the 'short rotation' harvest sub-rule over the Kyoto period.

B.10.2 Emissions from Australian land use and land use change

There is no economic modelling of Australian land use and land-use change. Emissions from this sector are exogenously imposed in the models. Land-use emissions for Australia largely represent emissions from clearing regrowth as part of agricultural management rather than clearing for new land.

In the reference scenario, emissions from land clearing were assumed to remain at 44 Mt CO_2-e per year throughout the projection period, based on a simple extrapolation from projections in the most recent national emission projections (DCC, 2008). Under the policy scenarios, land clearing emissions are assumed to decline linearly to 24 Mt CO_2-e in 2050 and to zero in 2100.

B.10.3 Emissions from global land use and land use change

International land use and forestry estimates were commissioned from the Lawrence Berkeley National Laboratory, and are based on their GCOMAP model. See Sathaye et al. (2006) for details.

The GCOMAP model establishes a level in the reference scenario for land use, without emission prices, for 2000 to 2100. It then simulates the response of forest land users (farmers) to changes in prices in forest land and products, and emerging emission prices. The aim is to estimate ow much more land area land users would plant than in the reference scenario, or prevent from being deforested, in response to emission prices. The model then estimates the net changes in carbon stocks while meeting the annual demand for timber and non-timber products.

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GLOSSARY

Abatement	Reduction of greenhouse gas emissions, or enhancement of greenhouse gas removal from the atmosphere by sinks.
Allocation	In the modelling, an economy's allocation of emission rights is determined by the assumed international emission reduction agreement.
Annex B countries	Annex B of the Kyoto Protocol lists countries that have a quantified greenhouse gas emission limitation or reduction commitment in the period 2008–12.
Anthropogenic greenhouse gases	Greenhouse gases released due to human activities.
Banking	The ability to hold permits for use in the future.
Borrowing	The use of future permits to meet current obligations under an emissions trading scheme.
Bottom-up model	A detailed, sector specific model, often with engineering detail. This report uses bottom-up models for the electricity generation, transport and land-use change and forestry sectors.
Carbon capture and storage (CCS)	Technology to capture and store greenhouse gas emissions from energy production or industrial processes. Captured greenhouse gases have the potential to be stored in a variety of geological sites.
Carbon dioxide (CO_2)	A naturally occurring gas. It is also a by-product of burning fossil fuels and biomass, other industrial processes and land-use changes. It is the main greenhouse gas that affects anthropogenic changes to the earth's temperature.
Carbon dioxide equivalent (CO_2-e)	A standard measure that takes account of the different global warming potentials of greenhouse gases and expresses the cumulative effect in a common unit.
Carbon leakage	An increase in global emissions, arising from the relocation of emission-intensive production activity in response to the introduction of an emission price.
Carbon price	See emission price.
Carbon sinks	Natural or man-made systems that absorb and store carbon dioxide from the atmosphere, including plants, soils and oceans.
Clean Development Mechanism (CDM)	A mechanism under the Kyoto Protocol through which developed countries may undertake greenhouse gas emission reduction or removal projects in developing countries, and receive credits for doing so. They then may apply these credits to meet their own mandatory emissions targets.
Climate change	As defined by the UNFCCC, a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability over comparable time periods.
Computable General Equilibrium (CGE) model	A CGE model is a whole-of-economy model that captures the interactions between different sectors of the economy.
Contraction and convergence approach	An approach to international emission allocation where initial national allocations reflect actual emission levels at the start of the scheme, but over time, converge to an equal per capita basis. This approach is assumed in the Garnaut scenarios.
Coverage	The scope of an emissions trading scheme. Covered sectors are liable for their emissions under the scheme.

CPRS scenarios	Two policy scenarios in this report were modelled based on the Government's *Carbon Pollution Reduction Scheme Green Paper.* These scenarios are CPRS -5 and CPRS -15.
Deforestation	The conversion of forested land to an alternative, non-forest use.
Economic model	Economic models mathematically represent how the economy operates and how various agents respond to changing signals.
Emission	Release of greenhouse gases into the atmosphere.
Emission intensity	The ratio of emissions to output. Emission intensity can refer to both the emissions per unit of sectoral output (for instance the emission-intensity of electricity generation) and the emissions per unit of economy-wide output (which usually refers to GDP).
Emission permit	The right to release a specified quantity of greenhouse gas under an emissions trading scheme.
Emission price	The cost of releasing greenhouse gases into the atmosphere. Often referred to as the carbon price.
Emission-intensive, trade exposed (EITE) industries	Industries that either are exporters or compete against imports (trade exposed) and produce significant emissions in their production of goods.
Emissions trading scheme	A scheme that creates a market for emission rights by limiting the total amount of emissions. Market participants then buy and sell rights to emit greenhouse gases.
Fuel switching	The substitution of one type of fuel for another, for example the use of natural gas instead of coal. Fuel switching changes the emission intensity of energy production because the carbon content of fuels varies.
Fugitive emissions	Greenhouse gases that are released in the course of oil and gas extraction and processing, through leaks from gas pipelines, and as waste methane from black coal mining.
Garnaut scenarios	Two policy scenarios in this report were modelled for the Garnaut Climate Change Review. These scenarios are Garnaut -10 and Garnaut -25.
Gigatonne (Gt)	One billion (10^9) tonnes.
Gigawatt hour (GWh)	A unit of energy equal to one billion watt hours.
Global warming potential	A system of multipliers devised to enable the comparison of the warming effects of different gases. For example, over the next 100 years, a gram of nitrous oxide in the atmosphere is currently estimated as having 310 times the warming effect as a gram of carbon dioxide.
Greenhouse gases	Gases that cause global warming and climate change. The major greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).
Gross domestic product (GDP)	The total market value of all goods and services produced in an economy.
Gross national product (GNP)	GDP adjusted for international transfers of income. GDP measures what an economy produces; GNP measures what an economy can afford to buy.
Gross output	The value of an industry's output — the value of inputs produced by other industries used in the production process (intermediate inputs) plus gross value added and any taxes, less subsidies on production. Gross output is a measure of turnover or activity.
Gross value added (GVA)	GVA measures the returns accruing to the owners of the primary factors, such as land, labour and capital used in the production process, plus taxes less subsidies on production. GDP is the sum of GVA across industries.

Hotelling rule	Derived from resource economics, the Hotelling rule explains the growth in the price of finite resources. In this report, the emission price follows a Hotelling rule, whereby it grows at the real interest rate from a specified starting level.
Intergovernmental Panel on Climate Change (IPCC)	Established in 1988, the IPCC surveys worldwide scientific and technical literature and publishes assessment reports that are widely recognised as the most credible existing sources of information on climate change. The IPCC also works on methodologies and responds to specific requests from the UNFCCC's decision-making bodies.
Kyoto Protocol	An international treaty negotiated under the auspices of the UNFCCC. It entered into force in 2005. Among other things, the protocol sets binding targets for the limitation of greenhouse gas emissions by individual developed countries to be met within the first commitment period of 2008–12.
Land use, land-use change and forestry	A reporting category comprising agriculture emissions (land use), and emissions from deforestation (land-use change) and carbon sequestered through reforestation (forestry).
Learning by doing	Reductions in technology costs due to greater use of a technology, such as through incremental innovation.
Marginal cost of mitigation	The cost of reducing emissions by one additional unit.
Market exchange rate (MER)	The rate of exchange between currencies in foreign exchange markets in the real world. Also see purchasing power parity exchange rate.
Market failure	A situation where the market is not able to provide an efficient level of production and consumption of goods and services, including natural resources or ecosystem services. In the climate change context, market failure arises because those emitting greenhouse gases do not bear all the risks of adverse climate change impacts from emissions, but share them across the world.
Megatonne (Mt)	One million (10^6) tonnes.
Megawatt hour (MWh)	A unit of energy equal to one million watt hours.
Mitigation	A human intervention to reduce the sources of or enhance the sinks for greenhouse gases.
Mitigation cost	The proportional decline in economy-wide activity that occurs as a result of reducing emissions. This is distinct from the marginal cost of mitigation which refers to the cost of reducing a unit of emissions. Regions which have a high marginal cost of mitigation do not necessarily have high mitigation costs.
Multi-stage approach	An approach to international allocation where the number of economies participating in global mitigation gradually expands. This approach was assumed in the CPRS scenarios.
Nominal emission price	The emission price in current dollars (that is, including the effects of inflation).
Policy scenario	A projection of the future path of the global and Australian economy if policies to reduce emissions are introduced.
Purchasing Power Parity (PPP) exchange rates	Hypothetical exchange rates that adjust for differences in prices levels across countries. Under a PPP exchange rate, one Australian dollar buys the same amount of goods and services in every country: no more, no less. Also see market exchange rate.
Real emission price	The emission price in constant dollars (that is, without the effects of inflation).
Reference scenario	A projection the future path of the global and Australian economy if no new policies to reduce emissions are introduced. The reference scenario is a point of departure to explore the possible implications for the global and Australian economy of policies to reduce greenhouse gas emissions. The reference scenario does not include any impacts of climate change on the economy.

Scenario modelling	Scenario modelling is an assessment of what *could* happen in the future, given the structure of the models and input assumptions. It is not a prediction of what *will* happen in the future.
Sensitivity scenario	A modelling scenario that tests the impact of changing particular assumptions in the reference or main policy scenarios.
Sequestration	The removal of atmospheric carbon dioxide, either through biological processes (for example, photosynthesis in plants), or geological processes (for example, storage of carbon dioxide in underground reservoirs).
Stabilisation	Refers to the stabilisation of the atmospheric concentration of greenhouse gases in the atmosphere. This occurs when the amount of greenhouse gases released into the atmosphere matches the earth's capacity to absorb greenhouse gases.
Terms of trade	The ratio of the price of an economy's exports to the price of its imports. The terms of trade are said to improve if that ratio rises.
Terawatt hour (TWh)	A unit of energy equal to one trillion (10^{12}) watt hours.
United Nations Framework Convention on Climate Change (UNFCCC)	An international treaty adopted after the Rio Earth Summit in 1992 and aimed at achieving the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

List of boxes, charts and tables

Boxes

CHARTS

TABLES