STRONG GROWTH, LOW POLLUTION

MODELLING A CARBON PRICE

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FOREWORD

The science of climate change is compelling, the threat is real and the economic and environmental benefits of mitigation are tangible.

The need for action to prevent climate change is clear. This Government has put forward a comprehensive plan to introduce a carbon price for Australia.

The Treasury modelling has been prepared to inform policy design and public discussion about carbon pricing. Treasury modelled a range of scenarios which explore different environmental targets and design features in a carbon pricing scheme. The modelling provides important insights into the economic impacts of carbon pricing at global, national, sectoral and household levels.

The world is moving to act. At the Copenhagen and Cancun conferences, we saw the world step up with pledges to take action to put the world on a path to reduce the risks of dangerous climate change. Australia must contribute its fair share to this world action.

The Government is committed to taking action in a fair and effective way. Pricing carbon through a market mechanism provides incentives for emission reductions to occur where they are cheapest. As the Productivity Commission found, when firms and consumers make the decisions, rather than governments, the costs of reducing emissions are lower. A carbon price is the most economically responsible, fair and effective way to tackle climate change.

Building on modelling completed by the Treasury in 2008, this report presents one of the largest and most complex economic modelling projects undertaken in Australia. It provides a comprehensive analysis of the implications of carbon pricing on the economy, at a global, national, regional and sectoral level. The modelling draws on experts from within Treasury, across Australia and around the world, and represents a robust and comprehensive analysis of carbon pricing for Australia.

The Treasury modelling finds the costs are modest to cut pollution and transform our economy to cleaner energy sources. A carbon price will ensure the Australian economy continues to prosper while we cut emissions to reduce the risks of dangerous climate change. Incomes and jobs continue to grow under a carbon price, with the majority of the economy experiencing only a very modest slowing in growth.

The Treasury modelling also finds the world will face higher long-term costs if we defer action to reduce the risk of dangerous climate change. We must act now to protect our future economy, future environment and future generations.

This report will form an important part of the community debate over carbon pricing over the coming months. Given the long lead times in commissioning detailed modelling of the electricity generation and other sectors, it was necessary to settle on the broad architecture of the global scenarios in late 2010 and the starting prices for the economy-wide modelling analysis in early 2011.

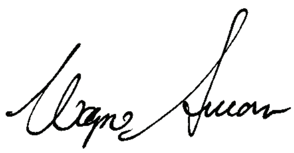
As a consequence, the economy-wide modelling presents scenarios with starting carbon prices in 2012-13 of A$20 and $30 /t CO_2-e, growing at 5 per cent per year plus inflation before moving to a flexible price. The $20 core policy scenario has a slightly lower carbon price path over the first 3 years than agreed by the Multi-Party Climate Change Committee (MPCCC), which is for a $23/t CO_2-e starting price, growing at 2 ½ per cent per year plus inflation. As it is a separate modelling exercise, with shorter lead times, the modelling of household impacts reflects the agreed starting carbon price of $23/t CO_2-e in 2012-13.

The Government's plan has been negotiated with the MPCCC, which agreed on a comprehensive set of measures to tackle climate change. The Government is separately proposing additional transition and abatement measures, which are separately identified in the policy documentation and fiscal costings. These measures include support for jobs in the coal and steel industries and inclusion of heavy on-road transport in the carbon price coverage from 2014-15.

The economy-wide modelling contained in the modelling report does not include all elements of the final policy package as agreed by the MPCCC. For example, in addition to the slightly lower start price, the core policy scenario assumes unlimited international permits over the entire period, a binding 100 per cent facility allocation cap and applying an effective carbon price to heavy on-road vehicles from 2014-15.

Even so, it is expected that the outcome of any updated modelling would closely match the results of the core policy scenario.

Once again, this is one of the most comprehensive modelling exercises ever conducted in Australia. The report provides extensive details on the assumptions and frameworks used, with full details provided on the Treasury website.



The Hon. Wayne Swan, MP
Deputy Prime Minister and Treasurer

The Hon. Greg Combet, MP
Minister for Climate Change and Energy Efficiency

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CONTENTS

Abbreviations and Acronyms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
AEEI	Autonomous energy efficiency improvement
AEMO	Australian Energy Market Operator
ALPF	Australia's Low Pollution Future
APC	Average propensity to consume
ASEAN	Association of Southeast Asian Nations
B100	100 per cent biodiesel
B20	A blend of 20 per cent biodiesel with 80 per cent conventional diesel
BITRE	Bureau of Infrastructure, Transport and Regional Economics
BP	British Petroleum
BTA	Border Tax Adjustment
CAIT	Climate analysis indicators tool
CC	Carbon capture
CCC	Committee on Climate Change (UK)
CCGT	Combined cycle gas turbine
CCP	Climate change policy
CCS	Carbon capture and storage
CCSP	Climate Change Science Program (United States)
CDM	Clean development mechanism
CER	Certified Emission Reductions
CFI	Carbon Farming Initiative
CGE	Computable general equilibrium (model/s)
CH_4	Methane
CNG	Compressed natural gas
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CoPs	Centre of Policy Studies (Monash University)
CPI	Consumer price index
CPRS	Carbon Pollution Reduction Scheme
CRESH	Constant ratio of elasticities of substitution, homothetic

CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCCEE	Department of Climate Change and Energy Efficiency
DEFRA	Department of Environment, Food and Rural Affairs (United Kingdom)
E10	A blend of 10 per cent ethanol and 90 per cent petrol
EGS	Engineered geothermal systems
EIA	Energy Information Administration
EITE	Emission-intensive trade-exposed
EITEs	Emission-intensive trade-exposed sectors
EMF	Energy Modelling Forum
EPA	Environmental Protection Agency (United States)
EPRI	Electric Power Research Institute
ESM	Energy Sector Model
ETS	Emission Trading Scheme
EU25	European Union — 25 countries
g	Gram
G-Cubed	Global general (equilibrium) growth model
GCOMAP	Generalised Comprehensive Mitigation Assessment Process
GDP	Gross domestic product
GEMPACK	General Equilibrium Modelling Package
GFC	Global Financial Crisis
GGAS	Greenhouse Gas Reduction Scheme (New South Wales)
GLOCAF	Global Carbon Finance Model
GNE	Gross national expenditure
GNI	Gross national income
GNP	Gross national product
GSP	Gross state product
GST	Goods and services tax
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
HDI	Household disposable income

HES	Household Expenditure Survey
HFC	Hydrofluorocarbon
HGWP	High global warming potential
IEA	International Energy Agency
IGCC	Integrated gasification combined cycle
IGR	Intergenerational Report
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
L/K ratio	Labour to capital ratio
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LRET	Large-scale Renewable Energy Target
LUCF	Land use change and forestry
LULUCF	Land use, land use change and forestry
MAC	Marginal Abatement Cost
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MARKAL	Market Allocation (model)
MEGABARE	Model developed by ABARE of the global economy
MFP	Multifactor productivity
MMRF	Monash Multi-Regional Forecasting (model)
Mt	Megatonne
MW	Megawatt
MWh	Megawatt hour
N_2O	Nitrous oxide
NATSEM	National Centre for Social and Economic Modelling
NBN	National Broadband Network
NEM	National Electricity Market
NEMS	National Energy Modelling System (United States EIA)
NPV	Net present value
NZIER	New Zealand Institute of Economic Research
OCGT	Open Cycle Gas Turbine
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
ORANI	Model of the Australian economy

PAGE	Policy Analysis of the Greenhouse Effect
PC	Productivity Commission
PFC	Perfluorocarbon
PJ	Petajoule
ppm	Parts per million
PPP	Purchasing power parity
PRISMOD	Price Revenue Incidence Simulation Model
PRISMOD.DIST	Price Revenue Incidence Simulation Model and Distribution Model
PV	Photovoltaic
ROAM	ROAM Consulting
ROW	Rest of world
SAM	Social accounting matrix
SF_6	Sulfur hexafluoride
SKM MMA	SKM MMA, part of the Sinclair Knight Merz Group
SRES	Small-scale Renewable Energy Scheme
STINMOD	Static income model
t	Tonne
TWh	Terawatt hour
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WACC	Weighted Average Cost of Capital

Overview

Key points

The Australian economy and the global economy both continue to grow strongly at the same time as we cut pollution to reduce the risks of dangerous climate change.

Early global action is cheaper than delayed action. Every year of delay adds to the eventual cost of action as it locks in more emission-intensive industry and infrastructure, and defers new investment in low-emission technology, industry and jobs.

Pricing carbon will drive structural change in the economy, moving resources towards less emission-intensive industries. Many of Australia's industries will maintain or improve their competitiveness in a carbon constrained world.

The structural change in the economy driven by a market-based carbon pricing mechanism will be modest compared to other changes facing the economy, such as those driven by the high terms of trade, demographic change or changing consumer tastes.

Modelling of scenarios with two different starting carbon prices in 2012-13 (A$20 and A$30 per tonne of carbon dioxide equivalent) shows the economy continues to grow strongly, while cuts to carbon emissions are deep.

Growth in real national income per person slows by about one-tenth of one percentage point per year under carbon pricing, with real incomes around $9,000 higher in 2020 in today's dollars.

Jobs will continue to grow under carbon pricing. By 2020, national employment is projected to increase by 1.6 million jobs, with or without a carbon price.

Household consumption continues to grow over time, although households face higher prices for emission-intensive products, such as electricity and gas. The impact on overall price levels is modest.

The analysis provides information on only one element necessary for evaluating climate change policy: the costs of taking action. To form policy judgements, this modelling analysis needs to be evaluated alongside the detailed analysis of the economic, environmental and social impacts of climate change itself and the benefits of reducing global emissions.

The modelling is robust to a range of assumptions. Sensitivity analysis shows that the aggregate economic costs are similar across a range of plausible assumptions.

The level of Australia's real income per person in 2020 is now expected to be higher after allowing for carbon pricing than was expected without a carbon price in the 2008 modelling. The key economic outcomes from the current modelling are similar to the analysis published in 2008.

Introduction

Evidence that the globe is warming is unequivocal, and has become stronger since the 2008 modelling exercise. There is clear scientific advice that the climate is changing, that greenhouse gas emissions from human activity are a major cause and that we can avoid the worst impacts by reducing emissions.

As global emissions rise, the stock of emissions in the atmosphere grows. Since the industrial revolution, when fossil fuel combustion began driving economic growth, global atmospheric concentrations of greenhouse gases have increased markedly. The current concentration of carbon dioxide, the most significant anthropogenic greenhouse gas, is estimated to be around 390 parts per million (ppm), far exceeding the range of variation over the past 800,000 years. Without action to reduce emissions, concentration levels are estimated to rise to around 1,500 ppm carbon dioxide equivalent (CO_2-e) by 2100, resulting in high risks of large-scale irreversible climate change.

This report examines different scenarios in which Australia and the world take action to reduce emissions so atmospheric concentrations of greenhouse gases are stabilised at levels that reduce the risks of dangerous climate change. It updates and expands on the analysis undertaken for the Government's *Australia's low pollution future: the economics of climate change mitigation* released in October 2008.

The analysis provides information on only one element necessary for evaluating climate change policy: the costs of taking action. To form policy judgements this modelling analysis needs to be evaluated alongside the detailed analysis of the economic, environmental and social impacts of climate change itself and the benefits of reducing global emissions; that analysis has been provided elsewhere (Garnaut, 2008; Pearman, 2008; Stern, 2007; OECD, 2009; OECD, 2010; and CCSP, 2007). The strong consensus emerging from this work is that the costs of inaction far outweigh the costs of action on climate change.

The Treasury has once again undertaken a comprehensive modelling exercise using a suite of models comparable to that undertaken in 2008 to inform discussion about the costs of taking action on climate change. The impacts of carbon pricing are assessed at the international, national, state, industry and household levels.

Two international global action scenarios, assuming the world takes action to stabilise greenhouse gas concentration levels at around either 550 ppm or 450 ppm by around 2100, provide a credible and realistic backdrop to examine the impact of pricing carbon in Australia.

The core policy and high price scenarios assume that Australian emissions will face different prices (A$20 and A$30) from 1 July 2012, which rise at a fixed rate each year, before the introduction of a flexible price cap-and-trade scheme on 1 July 2015.

Australia's national emission reduction targets of at least 5 per cent below 2000[1] levels by 2020 and 80 per cent below 2000 levels by 2050 are modelled. As part of a plan to secure a clean energy future, the Australian Government has adopted a stronger long-term target for cutting pollution. The Government's 2050 target represents a fair contribution by Australia to the global

1 All results in this publication, unless otherwise indicated, are in Australian financial years, ending 30 June of the year quoted.

goal of holding temperature increases to less than 2 degrees Celsius, and is consistent with the target adopted by countries such as the United Kingdom.

The key message from the modelling is that the economy continues to prosper while emissions are reduced.

This report adds to the large body of analysis that shows that the economic cost of taking action to reduce emissions is modest, if action starts sooner rather than later (OECD, 2008; OECD, 2009). Delayed action only raises the eventual economic costs.

The Australian economy is flexible and able to adapt to carbon pricing, just as it has evolved in light of other economic developments. It will adjust over time to a low-emission world through changes in technology, processes, production inputs and consumer choices. As the economy transitions, the impact of carbon pricing on economic growth declines.

The modelling is robust to a range of assumptions. Sensitivity analysis shows that the aggregate economic costs are similar across a range of plausible assumptions.

As the world takes action

The broad sectoral trends in the global economy continue as the world acts on climate change. The services sector continues to comprise a growing share of the global economy, and agriculture and energy-intensive industries continue to comprise declining shares. However, reducing global emissions requires a shift away from the production of emission-intensive goods towards low-emission goods, combined with a general decline in the emission intensity of production across all sectors.

Under both global action scenarios, the world economy will continue to prosper, with average annual growth slowed by only around 0.1 of a percentage point over the period to 2050 while reducing emissions to stabilise greenhouse gas concentration levels at around either 550 ppm or 450 ppm of CO_2-e by around 2100. Even with strong action on climate change, the global economy grows strongly with world output more than 3.5 times higher by 2050 than today.

The medium global action scenario assumes countries implement the less ambitious end of their mitigation pledges made in the Cancun Agreements and Copenhagen Accord, and stabilise greenhouse gas concentrations at 550 ppm by around 2100.

The ambitious global action scenario reflects a potential trajectory that gives around a 50 per cent chance of achieving the global goal of holding the average temperature increase to less than 2 degrees Celsius. Greenhouse gas concentrations are stabilised at 450 ppm by around 2100.

Delaying mitigation action at the global level would increase climate change risks, lock in more emission-intensive industries and infrastructure, and defer cost reductions in low-emission technology. This would increase the cost of achieving environmental goals.

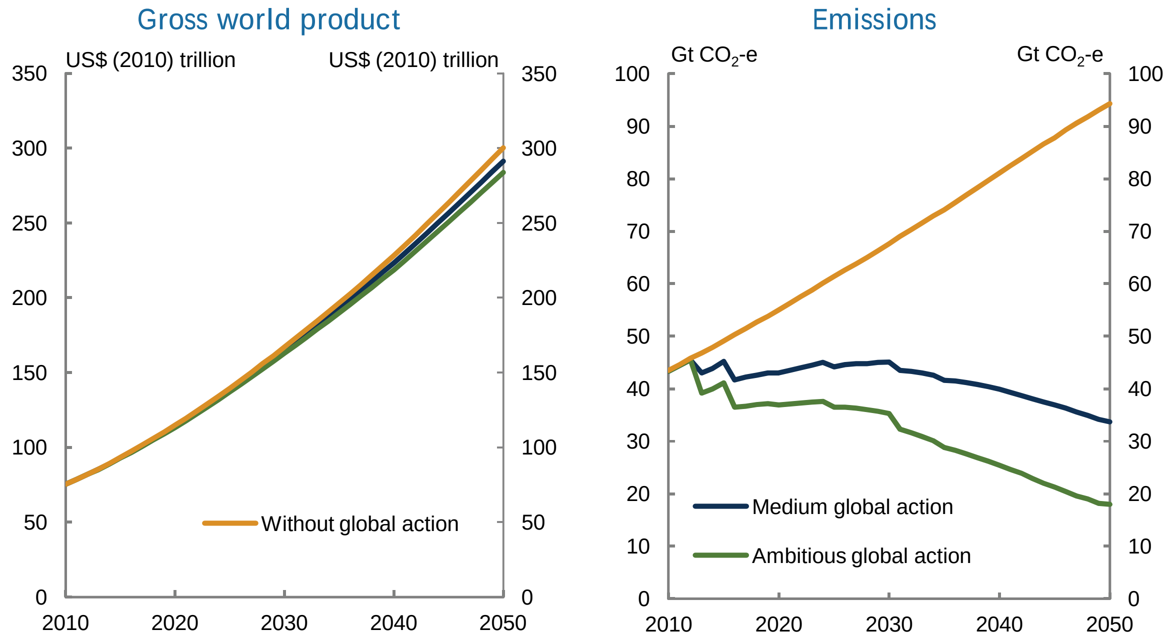
Delay brings initial benefits, but every year of global delay adds to the eventual economic and social cost of tackling climate change. Delaying global action by 3 years adds around 20 per cent to the first year global mitigation cost. Delaying entry by a further 3 years adds a further 30 per cent to the first year mitigation cost.

World carbon prices are expected to be around A$29 in 2016, if the world takes action to stabilise greenhouse gas concentration levels at 550 ppm of CO_2-e. If the world takes action to stabilise concentration levels at 450 ppm of CO_2-e, world prices are expected to be A$61 in 2016. These price ranges are slightly lower than in previous Treasury modelling, with higher world prices offset by an initially higher Australian dollar.

World carbon prices are predicted to be slightly higher than in the 2008 modelling for more ambitious action. Delayed and less coordinated international action on climate change pushes up world prices needed to achieve the same environmental outcome, raising mitigation costs. While the global financial crisis slowed emissions growth in developed countries, growth in developing countries' emissions is now projected to be stronger, pushing up world price estimates. Projections of higher energy prices lead to lower world carbon prices as a partial offset.

Independent of Australian action, world action to reduce emissions has a small negative impact on the Australian economy, through reduced demand for our exports, including energy exports such as coal and gas. If the world acts to achieve a 550 ppm stabilisation goal, this is expected to reduce Australia's gross national income (GNI) growth by less than 1/20th of one percentage point per year over the period to 2050.

Chart 1: Gross world product and emissions



Source: Treasury estimates from GTEM.

Before domestic carbon pricing

The global action scenarios model the path of our economy before accounting for the impacts of a domestic price on carbon. They separate the impact of the domestic carbon price from the other forces at work in our economy.

The global action scenarios tell a story of an economy that will continue to grow, generating jobs and income growth. It is also a story of an economy that is already managing ongoing and substantial structural change from factors like demographic change and the high terms of trade.

Gross national income per person is expected to grow at an annual rate of 1.2 per cent to 2050. While aggregate growth is projected to be strong, growth across sectors and industries will vary, with strongest growth in absolute terms in the services sector and strongest growth in percentage terms in mining and related sectors over the next decade.

Also over the next decade, the output of the services sector — industries like education, health, finance, professional services, information and communication technology, recreation, retail and wholesale — increases by around a third, owing to the growing demand from a more prosperous Australia and its surrounding region.

The manufacturing sector grows at a slower rate than the rest of the economy — around ½ per cent annually to 2020 — as Australia's economy continues the long-term shift towards services and the relative decline of manufacturing. This long-term decline is expected to be reinforced by the effects of the sustained high terms of trade and high exchange rate. While the manufacturing sector will be larger in absolute terms by 2020, its share of GDP will continue to fall from its peak, when it accounted for one quarter of our 1950s economy.

Mining output grows at a real annual rate of around 6 per cent and construction output by 4 per cent to 2020.

While Australia's terms of trade are now expected to remain higher for longer, boosting the level of incomes, they are still expected to fall gradually from their current 140 year high as the global supply of key Australian export commodities expands.

The level of Australia's GNI per person in the reference scenarios is expected to be around 4 ½ per cent higher in 2020 than in the previous 2008 modelling. Growth in GNI per person over the period is expected to be around 1.2 per cent per year, slower than growth in GDP, reflecting the expected fall in the terms of trade.

With domestic carbon pricing

The Australian economy will continue to prosper while cutting carbon emissions.

Pricing carbon results in deep cuts in domestic greenhouse gas emissions relative to the global action scenarios. It breaks the link between economic growth and emissions growth, so large cuts in emissions do not result in large economic costs. Through a market-based mechanism, individuals and firms are encouraged to adopt cleaner technology and substitute from more to less emission-intensive production, goods and services.

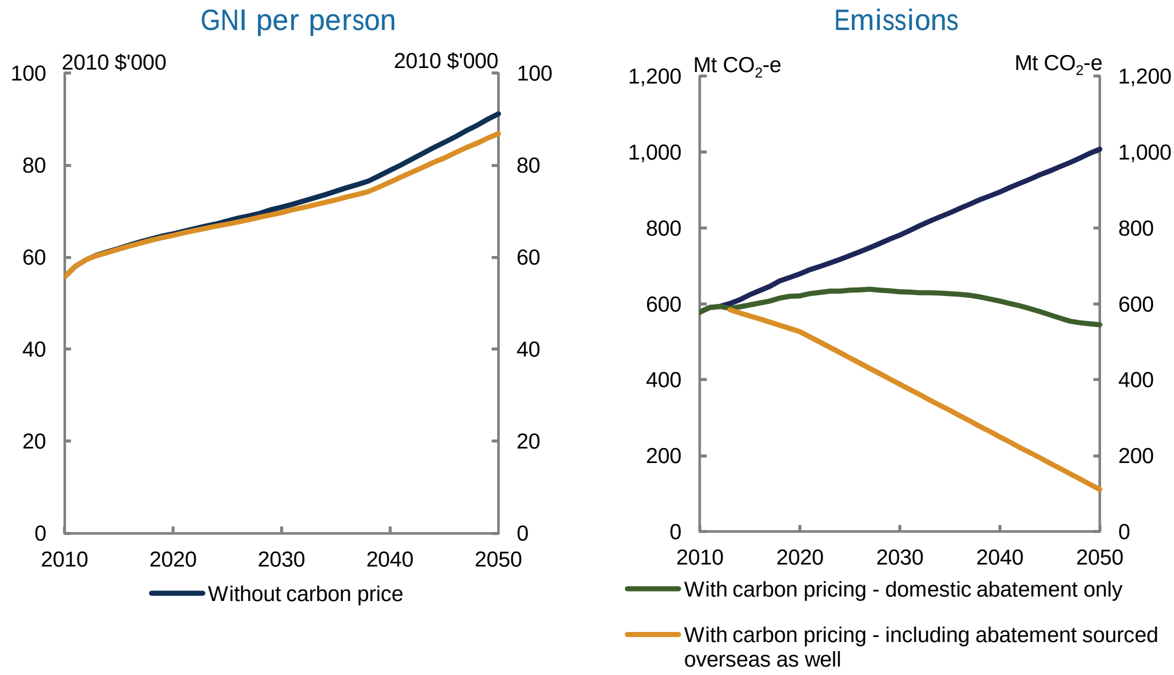
Australia's GNI per person grows strongly under both carbon price scenarios — core policy and high price — at rates marginally below those expected without carbon pricing.

In the medium global action scenario, where the world takes action to limit greenhouse gas concentrations to 550 ppm, but with no Australian carbon price, Australian GNI per person is around 60 per cent higher and emissions are 74 per cent higher by 2050 than today. In contrast, with carbon pricing, Australia's GNI per person is at least 56 per cent higher than today and emissions fall by around 80 per cent (with just over half the reduction occurring within Australia, and the remaining reduction being sourced from overseas).

Pricing carbon is expected to slow Australia's average GNI per person growth by less than 0.1 of a percentage point per year in the core policy scenario. Real GNI per person is expected to increase from today's levels by around $9,000 per person to 2020 and more than $30,000 per person to 2050.

Employment is projected to grow strongly with a carbon price. In the core policy scenario, around 1.6 million jobs are projected to be created to 2020 and a further 4.4 million to 2050. With a carbon price, growth in real wages, household consumption and investment slows slightly, consistent with the aggregate slowing in the economy.

Chart 2: GNI per person and emissions



Source: Treasury estimates from MMRF.

Projections of any sort, particularly those over long timeframes, are inherently uncertain. The sensitivity analysis in this report shows the high level results are robust to a range of plausible alternative assumptions. The high level results are also consistent with a large body of analysis that suggests that the economic cost of taking action to reduce emissions is modest, if action starts sooner rather than later (OECD, 2008; OECD, 2009). Uncertainty about the modest economic costs of mitigation is not a reason to delay climate change action.

Decoupling growth and emissions

Australia's abatement task is substantial. Without a domestic carbon price, Australia's emissions are projected to increase along a strong upward trajectory. Australia's emissions reach 679 Mt CO_2-e in 2020 (22 per cent above 2000 levels) and 1,008 Mt CO_2-e in 2050 (82 per cent above 2000 levels) for a 550 ppm global stabilisation target. To meet the Australian Government's unilateral emission reduction targets, the abatement task is 159 Mt CO_2-e in 2020. This excludes abatement from the Carbon Farming Initiative, as without a domestic carbon price, CFI abatement is exported or used in voluntary markets and therefore cannot be counted towards Australia's abatement task.

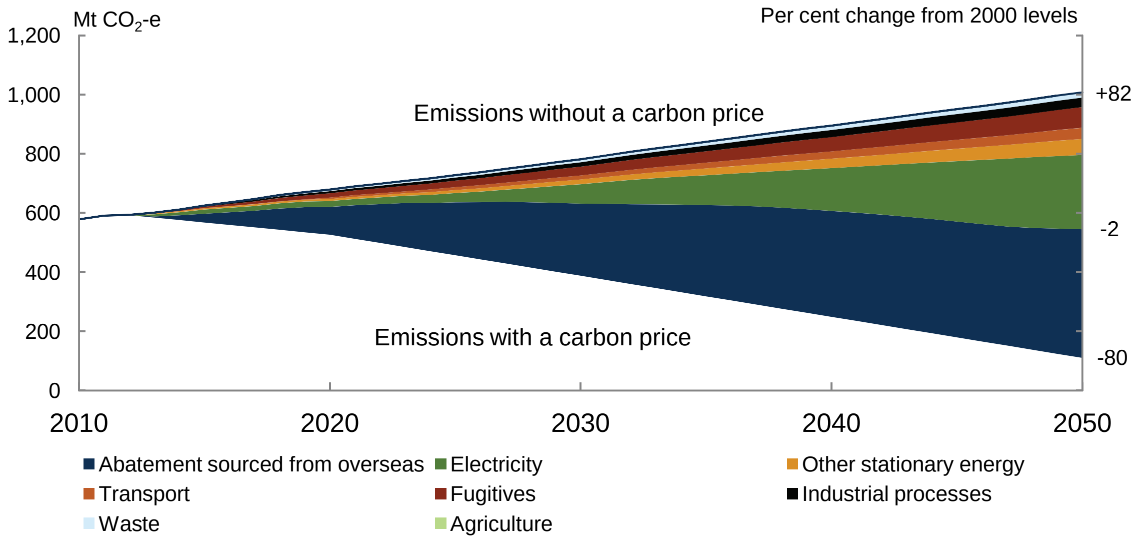
Across the scenarios, Australia's targets are met by reducing emissions within Australia and in other countries. While pricing carbon cuts emissions, it is much more expensive to meet the whole abatement task domestically. Sourcing emission reductions in other countries plays an important role, encouraging reduction in global emissions at the lowest economic cost.

The rate at which carbon prices reduce emissions varies, depending on which technologies become viable at different carbon prices. For example, the impact of a $1 increase in the carbon price will vary depending on the assumptions about the costs of low-emission technologies, such as carbon capture and storage technology or electric cars.

All sectors of the economy contribute to reducing emissions and can do so cost effectively. The greatest reductions occur in the electricity sector, as more renewable energy and gas are used to generate electricity, and coal fired generation declines.

Under carbon pricing, the structure of the economy shifts to lower emission activities, with carbon-intensive activities growing less rapidly and those activities offering low cost opportunities to reduce emissions growing faster. This restructuring makes most of the contribution to emission reductions.

Chart 3: Sources of emission reductions under the core policy scenario



Note: Abatement from the carbon farming initiative is included in emissions without carbon pricing.
Source: Treasury estimates from MMRF.

The economy transitions

The structure of the Australian economy is always changing. The jobs of the future will be in different industries than those of the past. This will be true with or without carbon pricing.

Taking advantage of economic opportunities in new areas and the cheapest abatement options will require a reallocation of resources across the economy. A market-based mechanism is best placed to achieve this transition, and at lower cost. Industries that provide low cost opportunities to reduce emissions will see the largest positive impacts from carbon pricing.

The shifts in jobs between industries caused by pricing carbon will be small compared to those caused by ongoing technological change and income growth. They will also be small compared to the usual churning of employment between firms and industries every year. For more than 95 per cent of the economy, pricing carbon produces changes in employment, up or down, of no more than 1 per cent, by 2020. Real wage growth continues, although at a slightly slower rate.

The modelling looks at the whole-of-economy effects of carbon pricing. While aggregate economic costs are small, they vary across regions and sectors, reflecting changes in Australia's comparative advantage in a low-emission world. Precise impacts vary depending on the emission intensity of a state, region or sector, and the opportunities to diversify into low-emission goods and production processes. Regions heavily reliant on emission-intensive sectors, such as some resource processing and emission-intensive manufacturing, may be the most strongly affected over the longer term.

The economic cost of domestic carbon pricing is estimated to be slightly higher than in the 2008 modelling. This reflects the reduced coverage of the modelled policy compared to previous assumptions, resulting in less domestic abatement, and the higher cost of purchasing overseas permits in the later years. Delayed and less coordinated global action also contributes to the increased cost.

Living standards continue to improve

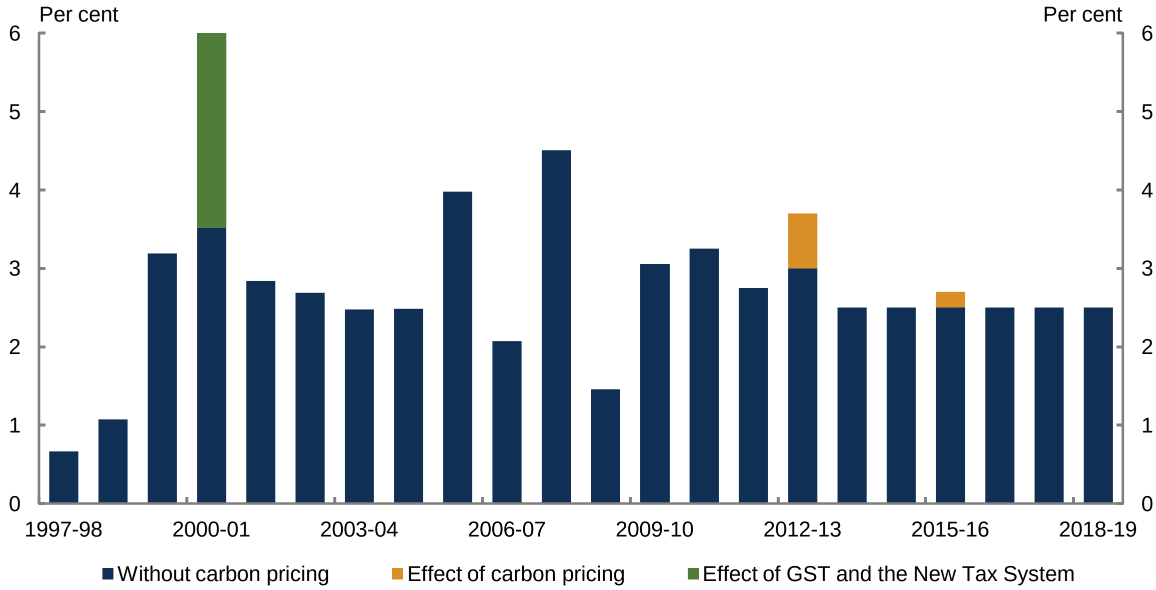
Living standards will continue to improve over time. Real GNI per person increases at an average annual rate of around 1.1 per cent in the core policy scenario compared to 1.2 per cent in the global action scenarios. By 2050, this results in income levels, with carbon pricing, that are around 1 ½ times current levels.

Carbon pricing will change the relative prices of goods and services and there will be an initial increase in the level of consumer prices. An initial impact will occur in 2012-13 with the introduction of the price, with a smaller step up in 2015-16, when the scheme moves to the international carbon price. For the core policy scenario, carbon pricing is estimated to raise the overall consumer price level by 0.7 per cent in 2012-13 and by a further 0.2 per cent in 2015-16, for a total of 0.9 per cent in 2015-16. Beyond 2015-16 there will be minimal implications for ongoing inflation.

Under the core policy scenario, average weekly expenditure will be higher by around $9.90 in 2012-13, of which electricity accounts for around $3.30 and gas around $1.50.

Real household income and living standards will continue to grow, despite higher prices for emission-intensive goods and services, particularly electricity and gas. As consumers respond to carbon pricing, many will find ways to reduce their relative consumption of emission-intensive goods, mitigating the effects.

Chart 4: CPI impact from carbon pricing compared with history



Source: Treasury estimates from PRISMOD.

Industries evolve

Australian output from emission-intensive, trade-exposed industries generally continues to grow but at a slightly slower rate. Output of iron and steel manufacturing, alumina and chemical production and refineries are all projected to continue to grow in the long term, but at a slightly slower rate of growth than in the global action scenarios.

The agriculture sector, which is excluded from the carbon price, continues to grow and has an incentive to reduce emissions through the Carbon Farming Initiative.

Allocation of some free permits to emission-intensive, trade-exposed industries will shield them from much of the effects of carbon pricing in the transition to a clean energy economy. This will slow the transition of resources out of these sectors and into other parts of the economy. In the long term, a gradual change in the structure of the economy is necessary to achieve Australia's emission targets at minimum cost.

Low-emission, trade-exposed industries benefit from carbon pricing. These industries include motor vehicle and parts production, textiles, clothing and footwear and food manufacturing.

The biggest transformations occur in the electricity sector

The carbon price drives significant changes in the mix of fuels and types of technology used to generate electricity in all the policy scenarios. A carbon price makes renewable generation more competitive relative to coal, leading to a transition away from conventional coal-fired generation towards renewable technology.

The electricity sector is the largest source of emission reductions. Instead of emissions growing by over 60 per cent by 2050 in the global action scenarios, emissions decline by around 60 per cent in the core policy scenario.

Emission reductions are a result of slower growth in electricity demand as well as substitution towards cleaner technologies. At higher carbon prices, the transition to cleaner electricity generation occurs faster.

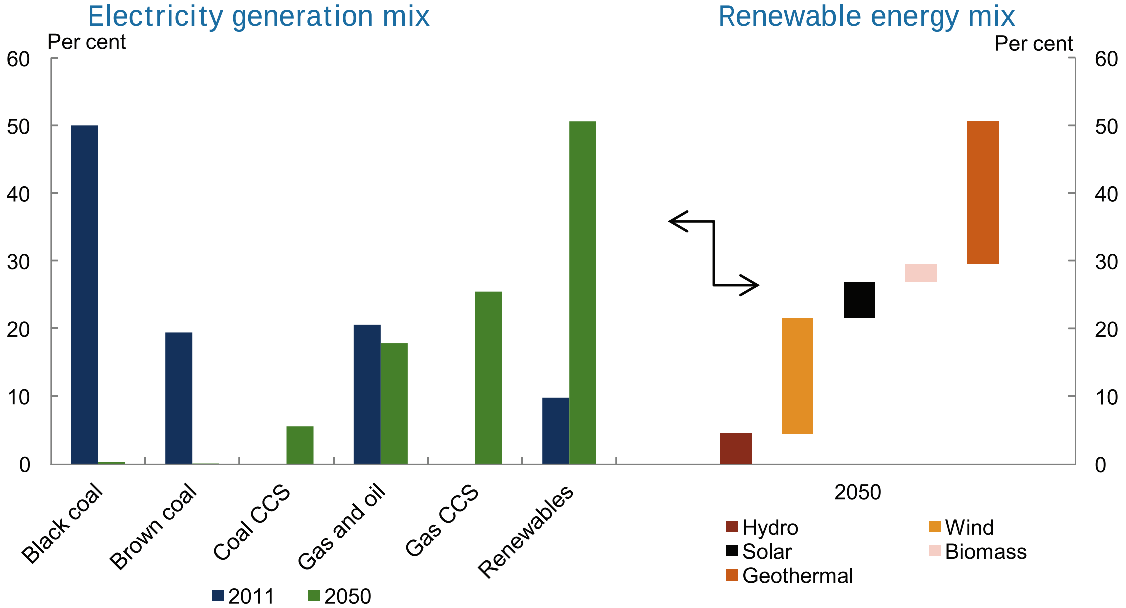
Electricity demand is an important source of abatement in the early years, comprising over 40 per cent of the cumulative abatement to 2020. By the mid 2030s carbon capture and storage is projected to be commercially viable and plays a significant role in further de-carbonising the electricity generation sector.

The modelling shows that carbon pricing will reduce the profitability of some coal generators, eventually leading to the retirement of some of the most emission-intensive power plants (though there is great uncertainty about the timing of retirements). However, carbon pricing will also make existing lower emission generators, such as gas generators, more profitable.

The modelling is robust to a range of assumptions. Sensitivity analysis shows that the emissions from electricity generation will fall significantly under a range of plausible technology and commodity price assumptions. Uncertainty about the future is a key reason why market-based mechanisms result in better outcomes.

The carbon price leads to an average increase in household electricity prices of 10 per cent over the first five years of the scheme. This is a modest increase in the context of the 40 per cent real increase in electricity prices over the past 5 years.

Chart 5: Electricity generation mix, core policy scenario



Source: Average of SKM MMA and ROAM.

Table 1: Headline Australian indicators

Macroeconomic modelling with an initial domestic carbon price of $20 in 2012-13

	Medium global ac tion scenario	Core policy scenario	Ambitious global action scenario	High price scenario
Current levels – at 2009-10				
Actual emissions, Mt CO_2-e	578	578	578	578
GNI per person, $'000/person	55.8	55.8	55.8	55.8
Medium term – at 2020				
Emission target, change from 2000 level, per cent	-	-5	-	-25
Emission target, tonnes CO_2-e per person	-	20.5	-	16.2
Domestic emissions, Mt CO_2-e	679	621	664	534
Carbon price, real, $/t CO_2-e	-	29	-	62
GNI per person, $'000/person	65.1	64.8	65.0	64.1
GNI, change from global action scenario, per cent	-	-0.5	-	-1.4
GDP, change from global action scenario, per cent	-	-0.3	-	-0.9
Emission-intensity of GDP, kg CO_2-e/$	0.39	0.36	0.38	0.31
Long term – at 2050				
Emission target, change from 2000 level, per cent	-	-80	-	-80
Emission target, tonnes CO_2-e per person	-	3.1	-	3.1
Domestic emissions, Mt CO_2-e	1008	545	951	323
Carbon price, real, $/t CO_2-e	-	131	-	275
GNI per person, $'000/person	91.2	86.9	90.6	84.2
GNI, change from global action scenario, per cent	-	-4.7	-	-7.1
GDP, change from global action scenario, per cent	-	-2.8	-	-4.7
Emission-intensity of GDP, kg CO_2-e/$	0.28	0.15	0.26	0.09
Overall impact, 2010 to 2050				
Australian real GNI per person, average annual growth, per cent	1.2	1.1	1.2	1.0
Australian real GDP per person, average annual growth, per cent	1.4	1.3	1.4	1.3
Gross world product, PPP, average annual growth, per cent	3.4		3.4	

Note: All dollars are 2010 prices, PPP - purchasing power parity, Mt CO_2-e - million tonnes of carbon dioxide equivalent.

Effects on household prices with an initial carbon price of $23 in 2012-13

	Weekly expenditure $ per week	Consumer prices Per cent
Electricity	3.30	10
Gas	1.50	9
Food	0.80	<0.5
Overall effect	9.90	0.7

Source: Treasury estimates from MMRF, GTEM and PRISMOD.

Chapter 1: Context for the modelling

Key points

The evidence that the globe is warming is unequivocal.

There is clear scientific advice that the climate is changing, that greenhouse gas emissions from human activity are a major cause and that we can avoid the worst impacts by reducing emissions.

The Treasury has undertaken a comprehensive modelling exercise using a suite of models comparable to that undertaken in the Government's *Australia's low pollution future: the economics of climate change mitigation* report released in October 2008. The impacts of carbon pricing have been assessed at the international, national, state, industry and household levels.

The analysis provides information on only one element necessary for evaluating climate change policy: the costs of taking action. To form policy judgements, this modelling analysis needs to be evaluated alongside the detailed analysis of the economic and social impacts of climate change itself and the benefits of reducing global emissions.

This report examines different scenarios in which Australia and the world take action to reduce emissions so greenhouse gas concentrations are stabilised at levels that avoid the worst impacts of climate change.

Two international action scenarios, assuming the world takes action to stabilise greenhouse gas concentration levels at around either 550 or 450 parts per million (ppm) by around 2100, provide a credible and realistic backdrop to examine the impact of a domestic carbon price in Australia.

The core and high price Australian policy scenarios assume Australian emissions will face different prices (A$20 and A$30) from 1 July 2012, which rise at a fixed rate each year, before the introduction of a flexible price cap-and-trade scheme on 1 July 2015. Australia's emission reduction targets of between 5 and 25 per cent below 2000 levels by 2020 and 80 per cent below 2000 levels by 2050 have been modelled.

This report adds to the large body of analysis that shows the economic cost of taking action to reduce emissions is modest, if action starts sooner rather than later. Delayed action only raises the eventual economic costs.

1.1 The climate change issue

Economic activity is the key driver of global greenhouse gas emissions. Modern industrial society depends heavily on fossil fuels for economic development. As the global economy expands and developing countries grow rapidly, global emissions continue to rise.

As global emissions rise, the stock of emissions in the atmosphere grows. 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, the most significant anthropogenic greenhouse gas, are estimated to be around 390 ppm, far exceeding the range estimated over the past 800,000 years (Garnaut, 2011a).

Changes in atmospheric concentrations of greenhouse gases change the global climate system's energy balance. Recent observations of changes in the climate system strengthen the conclusions of the IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report (2007a) and the Garnaut Review (2008) that contemporary climate change is indeed real, and is occurring at a rapid rate compared with geological time scales. Climate change is evident from recent observations confirming an increase in average air temperature at the Earth's surface, increase in ocean temperatures, widespread melting of snow and ice, and rising global average sea levels (Climate Commission, 2011).

Emissions of greenhouse gases induced by human activity are the primary factor triggering observed climate change since at least the mid 20th century. The IPCC Fourth Assessment Report attached 90 per cent certainty to that statement; research over the past few years has strengthened the confidence in this statement even more (Climate Commission, 2011).

Climate science projects that warming is likely to drive changes in wind patterns, rainfall, snow and ice cover, extreme weather events (for example, heat waves, floods and intense storms) and increasing acidification of the ocean (IPCC, 2007a).

For Australia, climate change could severely affect agriculture, infrastructure, biodiversity and ecosystems (Garnaut, 2008). Australia's hot and dry climate and economic structure make it 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; and Garnaut, 2011a). For example, more than $226 billion in commercial, industrial, road and rail, and residential assets is potentially exposed to inundation and erosion hazards at a sea level rise of 1.1 metres (DCCEE, 2011c).

If emissions are left unabated, the global atmospheric concentration of greenhouse gases could reach 1500 ppm, which would result in a 7 or more degree increase in global average temperatures from preindustrial levels. A greenhouse gas concentration of 450 ppm carbon dioxide equivalent (CO_2-e) generally is associated with a 50 per cent chance of limiting the increase in global average temperature to 2 degrees Celsius above preindustrial levels, while 550 ppm CO_2-e is associated with a 50 per cent chance of limiting the temperature increase to 3 degrees Celsius (IPCC, 2007a). With higher levels come increasing risk of greater temperature change and greater impacts on the climate system.

1.2 The policy context

The world is taking action on climate change. Governments in Australia and around the world have implemented a range of climate change mitigation policies (Productivity Commission, 2011). Many others are being considered and developed.

1.2.1 International policy context

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. Since its establishment, steady gains have been made towards the overall objective to stabilise atmospheric concentration of greenhouse gases at a level needed to prevent dangerous climate change.

These negotiations are ongoing and evolving. At Copenhagen in 2009, it was agreed any temperature increase needed to be held to below 2 degrees Celsius above preindustrial levels to prevent dangerous climate change. At Cancun in 2010, developed countries and, for the first time, developing countries pledged to reduce national emissions. Now 89 countries have pledged action, covering over 80 per cent of global emissions and over 90 per cent of the global economy (WRI CAIT, 2011; IMF, 2010; UNFCCC, 2011a and 2011b). These pledges suggest more countries have committed to action earlier than Treasury modelled in the CPRS scenarios in 2008.

To achieve these pledges, many of the world's key economies are introducing or planning emission trading schemes or carbon taxes. Australia's top five trading partners — China, Japan, the United States, the Republic of Korea and India — among others (New Zealand, the United Kingdom, Germany, Italy, France and the Netherlands) have implemented or are piloting emissions trading schemes or carbon taxes at the national, state or city level.

1.2.2 Australian policy context

Australian Government policy on climate change has progressed over many years. As part of considerations around the implementation of the Kyoto Protocol, the government of the day commissioned the Australian Greenhouse Office to do a series of discussion papers from 1999 onwards examining design aspects of a possible emission trading scheme. In 2003, the government considered an emissions trading scheme proposal and in 2007, set up the Prime Ministerial Task Group on Emissions Trading and adopted a policy to introduce an emission trading scheme no later than 2012.

In 2004, state and territory governments initiated the National Emission Trading Taskforce which released a series of discussion papers canvassing scheme design issues between 2005 and 2008.

The Rudd government commissioned The Garnaut Climate Change Review, Treasury modelling and presented the Carbon Pollution Reduction Scheme Green and White Papers through 2008.

The current Government established a number of processes to update and provide additional information to inform climate change mitigation policy. These include the Multi-Party Climate

Change Committee, the Business Roundtable on Climate Change and its working groups, the Non-Government Organisation Roundtable on Climate Change and its working groups, the independent Climate Commission, the Garnaut Climate Change Review update 2011, the Productivity Commission's *Carbon emission policies in key economies* research report; and updated Treasury economic modelling.

In February 2011, the Multi-Party Committee on Climate Change released a proposed architecture for a carbon price mechanism. It outlined the high level design features of the proposed carbon price mechanism, such as the start date, flexibility mechanisms to move between fixed-price and emission trading, sectoral coverage and international linking arrangements.

1.3 Purpose

The purpose of the report is to provide input into the policy-making process and help inform the Australian people of the economic implications of pricing carbon.

This report examines different scenarios in which Australia and the world take action to reduce emissions, so greenhouse gas concentrations are stabilised at levels that avoid the worst impacts of climate change. It updates and expands on the analysis undertaken for the Government's *Australia's low pollution future: the economics of climate change mitigation*, released in October 2008.

While there are many existing studies on the impact of pricing carbon, they usually consider only parts of the Australian economy or results at a high level of aggregation. This report provides a comprehensive and interconnected analysis of the international economy, Australian macroeconomy, industries, sectors and households under different carbon prices.

The analysis provides information on only one element necessary for evaluating climate change policy: the costs of taking action. To form policy judgements, this modelling analysis needs to be evaluated alongside the detailed analysis of the economic and social impacts of climate change itself and the benefits of reducing global emissions; analysis that has been provided elsewhere (Garnaut, 2008; Pearman, 2008; Stern, 2007; OECD, 2009; various CCSP studies, 2007). Benefits include the reduced risks of climate change impacts and the lower costs of adapting to the climate change that does occur.

1.4 The structure of this report

The rest of this report has the following structure:

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

Chapter 3 describes the global action scenarios. They project how the world could evolve, given global action to reduce the impacts of climate change. They provide a plausible back-drop, a starting point for the analysis of carbon pricing in Australia.

Chapter 4 explores the path of the Australian economy without a domestic carbon price. It includes the impact on Australia of the world moving to stabilise greenhouse gas concentrations.

Chapter 5 outlines the impact of different Australian carbon prices. It shows the implications for Australia in terms of the macroeconomic, sectoral and household response to different Australian carbon prices.

Reports commissioned from external consultants are available on the Treasury website at www.treasury.gov.au/carbonpricemodelling.

Chapter 2: Framework for analysis

Key points

The Treasury has used a suite of models to undertake a comprehensive modelling exercise comparable to that udertaken in 2008.

The impacts of carbon pricing are assessed at the global, national, state, industry and household levels.

The analysis provides information on one element necessary for evaluating climate change policy: the costs of taking action. To form policy judgements, this modelling analysis needs to be evaluated alongside the detailed analysis of the economic and social impacts of climate change itself and the benefits of reducing global emissions.

Modelling results need careful explanation and interpretation. Statistics and numbers can mean different things when reported in different contexts.

The modelling is robust to a range of assumptions. Sensitivity analysis across various components in the suite of models has been undertaken and shows aggregate economic costs are similar across a range of plausible assumptions.

2.1 Rationale for pricing carbon — using a market based mechanism

There is clear scientific advice that the climate is changing and that there is a real risk greenhouse gas emissions from human activity are a major cause. Scientific advice also indicates it is likely we can avoid the worst impacts by reducing emissions.

Countries have moved and will continue to move to reduce their emissions through a variety of policy mechanisms. The Productivity Commission (2011) found most countries they examined have adopted a large and diverse range of emission reduction policies.

The Productivity Commission also found, when firms and consumers make the decisions, rather than governments, the cost of reducing emissions is lower.

Explicitly pricing carbon ensures all companies and individuals either explicitly or implicitly factor into decisions the cost of greenhouse gas emissions. Companies and individuals do not need to make complex calculations about the emission intensity of particular goods, as the price of the goods will reflect that key information.

Over time, as prices reflect the emission content of goods, producers and consumers will have an incentive to find ways to reduce emissions. For instance, electricity producers will look to reduce the use of emission-intensive fossil fuels to generate electricity and consumers will be encouraged to use less electricity.

A stable market-based framework also will support investment by providing businesses with greater policy certainty over time.

2.2 Modelling framework

Climate change operates over very long timeframes, with significant time lags between greenhouse gas emissions and resulting impacts. Consequently, quantitative analysis of carbon pricing and climate change mitigation must take a long-term view. This report provides projections to 2050.[1] This difficult exercise requires assumptions for a wide range of economic, social and environmental variables which can change in unpredictable ways.

This report uses economic models to make long-term projections and analyse the effect of emission reductions on the Australian economy. Economic models mathematically represent how the economy operates and how various agents respond to changing signals.

Economic models are useful 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. While these models have their limitations, they integrate, in a comprehensive manner, economic and other data with economic theory about how the world responds to changing circumstances.

The models are used to estimate greenhouse gas mitigation costs to Australia by comparing two global action scenarios (where no new policies to reduce emissions are introduced in Australia) with policy scenarios where a domestic carbon price mechanism is introduced. The global action scenarios continue current Australian policies, extrapolate past economic trends and incorporate known information and assumptions about future developments, including international action to reduce emissions. The difference between each domestic policy scenario and the corresponding global action scenario represents the impact of the domestic policy.

2.2.1 Suite of models

No single existing model adequately captures all the global, national, state, industry and household dimensions or focuses on all relevant aspects of climate change policy in Australia. Most Australian studies of climate change mitigation policy focus on one of these dimensions — that is 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, Treasury's analysis uses a suite of models to create a holistic framework for climate change mitigation modelling across the five dimensions.

This section briefly describes the range of models used in this report (the appendices provide more detail).

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1 All results in this publication, unless otherwise indicated, are in Australian financial years, ending 30 June of the year quoted.

The modelling centres on two top-down computable general equilibrium (CGE) models developed in Australia: the Global Trade and Environment model (GTEM) and the Monash Multi-Regional Forecasting (MMRF) model. These whole-of-economy models capture interactions between different sectors of the economy and among producers and consumers.

GTEM, developed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and extended by Treasury, is a global model which provides insights into Australia's key international trading partners (Pant, 2007; and Australian Government, 2008). The version of GTEM used disaggregates the world into 13 geographic regions and 19 industrial sectors.

To examine whether emission trajectories from the international global action scenarios derived in GTEM meet specified emission targets around 2100, the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) is used to estimate the atmospheric concentrations of the trajectories (Raper et. al., 1996; Wigley and Raper, 1992; and Wigley and Raper, 2001). MAGICC is calibrated against more complex climate models and used in the IPCC's Fourth Assessment Report (Solomon et. al., 2007). GTEM covers emissions of 7 gases, including both low and high global warming potential gases from various sources and sinks. As the global action scenarios project emission paths only to 2050, projections of emissions beyond 2050 for the estimation of concentrations by MAGICC are based on emission trends before 2051 and draw on post 2050 emissions information from the Garnaut scenarios in previous Treasury modelling (Australian Government, 2008). World carbon price paths are set so the atmospheric concentrations of the emission paths from the model broadly match the environmental targets.[2]

MMRF, developed by the Centre of Policy Studies at Monash University, models the Australian economy (Adams et. al., 2011). It is rich in industry detail.

Several bottom-up sector-specific models for electricity generation and road transport sectors complement the CGE models. In addition, comprehensive analysis of emissions covered under the Carbon Farming Initiative (CFI) was undertaken and incorporated into the Australian macroeconomic modelling. Detailed analysis of these emission-intensive sectors enriches the understanding of the economy's likely response to climate change mitigation policy, particularly in the short-to-medium term.

Given the importance and inherent uncertainty about the evolution of the electricity generation sector, two detailed bottom-up models of the sector were used by ROAM Consulting and by SKM MMA part of the Sinclair Knight Merz Group. Using two models provides a natural hedge against the inherent uncertainty of economic modelling. These highly detailed models provide analysis of the Australian electricity generation sector, with projections for levels of generation, total capacity (installed), emissions (of carbon dioxide equivalent), energy use (fuel use), wholesale and retail electricity prices and the profit streams of generators (important for asset values and financing). Results are generally provided at the generator level or by the unit within each generator, giving insights into the transformation of the electricity generation sector.

2 There are scientific uncertainties in determining the exact sensitivity of the climate to increases in greenhouse gas concentrations. For example, for a doubling of carbon dioxide, the Intergovernmental Panel on Climate Change Fourth Assessment Report gives a best estimate of an increase in global temperature of 3 degrees Celsius. However, the range is likely between 2 and 4.5 degrees Celsius with the possibility of substantially higher values not excluded.

ROAM Consulting and SKM MMA models aim to represent actual market conditions as closely as possible. They have economic relationships between individual generating plants in the system; each power plant is divided into generating units defined by their individual technical and cost profiles. The models incorporate a range of fuel types, including brown and black coal, natural gas and renewables (including hydro, biomass, solar, wind and geothermal), technology such as carbon capture and storage, and differences between natural gas technologies (such as combined cycle gas turbines and the less efficient open cycle gas turbines).

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) models the Australian road transport sector. CSIRO uses a partial-equilibrium model of the Australian energy sector, the Energy Sector Model (ESM), with detailed transport sector representation (Graham and Reedman, 2011; and Graham et. al., 2008). The model has an economic decision-making framework, based around the cost of alternative fuels and technologies.

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

The potential for abatement under the CFI scheme for agriculture, land use change and legacy waste sectors was analysed by the Department of Climate Change and Energy Efficiency (DCCEE). The abatement estimates are based on a top-down approach using marginal abatement cost curves constructed to be consistent with previous bottom-up estimates published by DCCEE.

ABARES model the impact of the CFI on the Australian forestry sector[3]. Their framework is spatially explicit and involves analysing the opportunities for carbon sequestration provided by forestry on cleared agricultural land. The net present value of returns from forestry investments is compared with the projected agricultural land value to estimate the potential area of clear agricultural land that is competitive for forestry within each spatial grid cell.

Treasury's Price Revenue Incidence Simulation Model (PRISMOD.IO) models the impact of a carbon price on a range of prices. PRISMOD.IO is a large-scale highly disaggregated model of the Australian economy capturing the flows of goods between industries and final consumers. The 2011 version of PRISMOD.IO is based on data from the Australian Bureau of Statistics *Australian National Accounts, Input-Output Tables 2005-06* (ABS, 2009) and 2005-06 emissions data from the 2009 National Inventory Report (DCCEE, 2011a). PRISMOD.IO is linked with PRISMOD.DIST to obtain household price increases, including the consumer price index.

Treasury's Price Revenue Incidence Simulation Model and Distribution Model (PRISMOD.DIST) analyses the distributional implication for households. This static micro simulation model examines the distributional effects of government policies on spending by

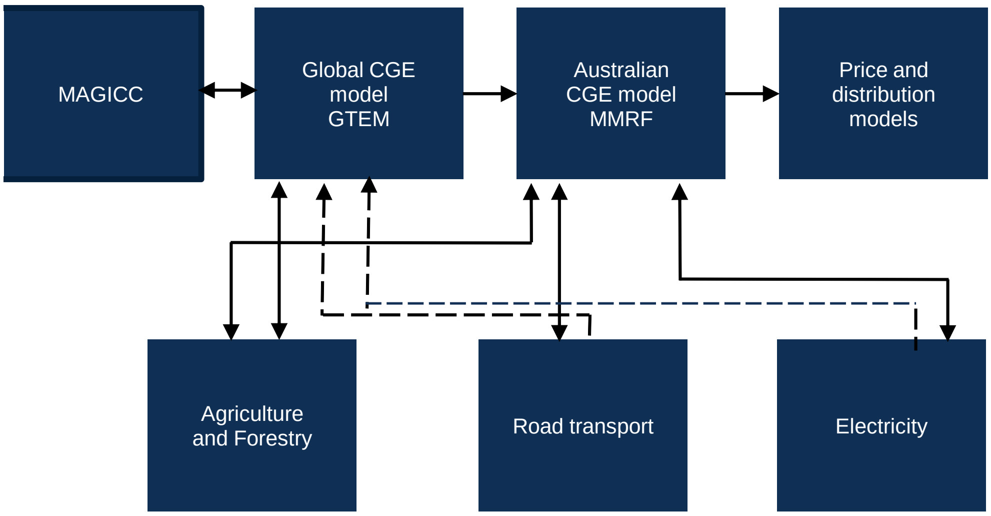
3 The Lawrence Berkeley National Laboratory used its Generalized Comprehensive Mitigation Assessment Process (GCOMAP) model for the forestry sector overseas in the 2008 modelling (Sathaye et. al., 2006 and 2008). As the international carbon prices were broadly similar, these detailed estimates were incorporated into the GTEM model as they were in 2008, with some adjustment for the timing of the carbon price. GCOMAP simulates how forest land users respond to changes in prices in forest land and products and carbon prices. GCOMAP calculations of net change in emission stocks associated with land use change and forestry are incorporated into GTEM.

different households. The 2011 version of the model is based on data from the *Household Expenditure Survey 2003-04* (ABS, 2006b).

2.2.2 Integrating the models

The results from each model are drawn together into an integrated set of projections that are broadly consistent at the macroeconomic level and sufficiently detailed in key sectors. They provide insights into the likely transformation of the Australian economy under carbon pricing.

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. GTEM does not take input from the agriculture model but does take input from the forestry sector.
Source: Treasury.

GTEM models the global economy to provide the international economic and emissions context for the Australian economy (MMRF), which in turn is informed by the bottom-up modelling of the electricity generation, road transport, agriculture and forestry sectors.

Linking economic models with different economic structures is not straightforward. Care is needed to obtain internally consistent results. For example, MMRF and GTEM have internally consistent, but different, assumptions about the supply responsiveness of various Australian industries. MMRF requires assumptions about world demand for Australian goods. This required careful linking to ensure the shift in the world demand curve is appropriatly inputted into the MMRF model. Similarly, the bottom-up electricity and transport supply-side models link iteratively with MMRF to ensure consistency.

2.3 Understanding the results

As with all modelling assessments, the modelling results require careful explanation. It is sensible to undertake alternative scenarios and sensitivity analysis to evaluate the robustness of the key messages obtained from the modelling analysis.

2.3.1 Scenario modelling

The analysis in this report estimates the cost of reducing emissions through carbon pricing by modelling various scenarios. Scenario modelling does not predict what *will* happen in the future. Rather it is an assessment of what *could* happen, given the structure of the models and input assumptions.

Scenarios are an analytical lens through which to view a problem; they do not factor in all elements of the 'real world'. In particular, the scenarios do not assess the impact of climate change on the economy. Scenarios guide understanding of policy impacts, relativities of different policy options and the extent that parts of the economy (technology, preferences and so on) need to shift from current trends to achieve particular outcomes, given the model's assumptions.

Input and policy assumptions are particularly important. Many variables affect the estimated cost of responding to carbon pricing. The future path of these variables is not known. However, 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 are intended to be plausible central estimates within a range of uncertainty, other analysts could well form different judgements.

The inherent difficulty in developing assumptions and undertaking simulations is compounded by the long timeframes required for this analysis. Generally, more caution is needed in interpreting results that are well into the future. As the timeframe expands, assumptions are more speculative. Just as modellers in 1972 could not have easily foreseen today's widespread internet use and China's economic transformation, modellers today are unlikely to accurately foresee all potentially relevant developments in the world of 2050.

2.3.2 Economic measures of cost

The modelling encompasses several measures of economic cost.

It focuses on gross national income (GNI)[4] as the high level measure of economic welfare impact rather than gross domestic product (GDP). GNI reflects changes in GDP, the terms of trade and international income transfers. Reducing greenhouse emissions in the least-cost way may involve transfers of income between economies, and influence nations' terms of trade. In that context, GNI is a better measure of welfare, as it excludes income accruing to overseas residents, thereby depicting the current and future consumption possibilities available to Australians. It measures what a nation can afford to buy.

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 primary factors such as land, labour and capital used in production. GDP is the sum of GVA across industries, plus taxes less subsidies on products. Gross output is the value of an industry's

4 GNI, aggregate primary income of Australians including income received from non-residents, was previously known as Gross National Product (GNP). The ABS has used the term GNI since 1998, to better reflect what the variable measures.

output and measures turnover or activity. The most appropriate measure of output will vary. GVA indicates an industry's contribution to economic activity, as it excludes the value of intermediate inputs from other industries. Gross output is the focus of this report as emissions are created during production.

All gross world product (GWP) and regional gross domestic product (GDP) statistics are in 2010 US dollars, using 2005 purchasing power parity weights.[5]

2.3.3 Presentation of results

Results need careful interpretation. Statistics and numbers can mean different things when reported in different contexts.

Research indicates the economic costs of reducing emissions are widely misunderstood and public attitudes towards action on climate change are significantly affected by how impacts and costs are communicated. A 2008 survey (conducted before previous Treasury modelling) found 25 per cent of Australian respondents believed that significantly reducing greenhouse gas emissions would result in incomes falling from current levels, despite economic modelling unanimously finding that emission reductions are consistent with continuing strong trend economic growth and increases in average incomes. Associated research finds clear communication that avoids this misunderstanding results in significantly higher support for policy action. Avoiding misunderstanding by making it clear that average incomes rise, but rise less than they would without policy action, also reduces opposition to policy action by around a third (Hatfield-Dodds and Morrison, 2010).

Other analysis finds people who are only weakly engaged on policy issues tend to withdraw their support when public debate becomes complex or highly contested, and these issues interact with communication and framing issues. This often hollows out expressed support, as evident in responses to the Australian debate around the release of the Stern Report in late 2006 (Morrison and Hatfield-Dodds, 2011).

This occurs around climate policy issues, despite the underlying science becoming more certain in its predictions (Leviston et. al., 2011; and Garnaut, 2011a). The recent Lowy Institute poll (Hanson, 2011), for example, finds both an increase in the share of people willing to pay an additional $20 per week or more for electricity as part of climate change action, and a significant reduction in people who are willing to pay $1 to $10 per week, between the years 2008 and 2011. The same survey question in June 2011 found more than 30 per cent of Australians believe that significantly reducing greenhouse gas emissions would result in incomes falling from current levels, in direct contradiction of economic modelling results, while around 60 per cent believe that incomes would continue to rise (Hatfield-Dodds, 2011).

Comparing results with a hypothetical future such as a reference scenario is a common and reasonable way to explain how a policy will influence the economy in isolation from other events.

However, such results must not be interpreted as suggesting policy will have an absolute impact relative to the *current* world. For example, if cutting interest rates would raise economic growth by 1 per cent relative to what otherwise would have been, this should not be interpreted as saying

5 See the discussion in Box 2.7 of Australian Government (2008).

the economy would necessarily rise 1 per cent from its current level, if interest rates were cut. The statement is only relative to how the economy would have evolved in the absence of a cut.

To help and enrich understanding of the economic implications of pricing carbon, this report presents a range of measures when reporting high level results.

Box 2.1: Alternative ways to report on modelling — a hypothetical example

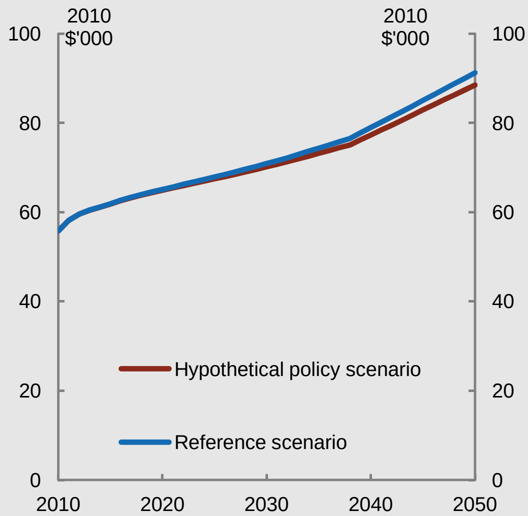
The same modelling results, reported differently, can convey different impressions to non-experts. For instance, the chart below (left) shows the impact on GNI per person in a reference scenario and in a hypothetical carbon price scenario. In the former, GNI per person grows from around $56,000 in 2010 to $91,000 by 2050 in today's dollars. The chart below (right) shows the percentage deviation from the reference scenario, and sometimes is reported as a 'loss' when it only indicates that GNI per person growth is slightly weaker than the reference scenario of ongoing income per person growth.

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

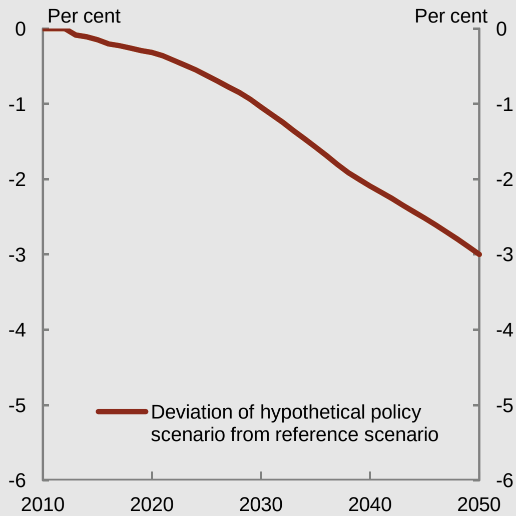
- GNI per person growth is 0.1 of a percentage point per year lower over 40 years in the policy scenario than in the reference scenario.
- GNI per person is around $2,700 ($2010) lower in 2050 in the policy scenario than in the reference scenario.
- GNI per person is 3.0 per cent lower in 2050 in the policy scenario than in the reference scenario.
- The cumulative GNI per person loss is around $40,000 ($2010) over 40 years in the policy scenario compared to the reference scenario.
- The cumulative GNI per person loss is 1.4 per cent of total GNI per person over 40 years in the policy scenario compared to the reference scenario.
- GNI per person is 1.5 times its 2010 level in 2046 in the hypothetical scenario (instead of in 2044 in the reference scenario), a delay of 2 years.

Chart 2.2: Real GNI per person scenarios

GNI per person in levels



GNI per person deviation



Note: All results in this publication, unless otherwise indicated, are in Australian financial years, ending 30 June of the year quoted.
Source: Treasury.

This report focuses on the costs of mitigation, not the net benefits of action, and the choice of discount rates is not important for interpreting the results.[6] The modelling shows the costs of mitigation as they happen in a relevant year. However, if the modelling results were to be used to judge the importance of future costs from today's perspective, alternative discount rates would alter that analysis.

Carbon prices can be reported in different units. Nominal carbon prices include the impact of inflation on prices. When a carbon price is reported in nominal terms, such as $20 in 2013, this is the actual nominal price of an emission in 2013 using the dollars available in 2013. Often, to adjust for inflation, carbon prices are in base year or 'real' prices: for example, a carbon price of $21 in 2014, in 2010 prices. This reflects the purchasing power of $21 in 2010 dollars. Carbon prices in this report are reported in both real and nominal terms, depending on the context, and are clearly labelled.

2.3.4 Model limitations and uncertainty

Economic models approximate the complex real world and consequently have limitations that affect the interpretation of results. Despite this, models examine complex issues rigorously and consistently across long timeframes.

The models are aggregated to different extents. Aggregation necessarily simplifies the real economy by accommodating data and computing power limitations. In industries where businesses are reasonably homogenous, with similar patterns of inputs and emission intensity, this simplification has little effect. But in industries where firms have different, sometimes dramatically different, patterns of inputs and emission intensity varies widely, this simplification reduces the accuracy of the modelling and results.

The models exclude the risks and impacts of climate change itself. Mitigation policy improves the efficiency of the economy by pricing the 'externality' involved — a form of market failure as those emitting do not bear all the costs of climate change associated with emissions. The effect of carbon pricing needs 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; Bollen et. al., 2009; Tol, 2009; Aldy et. al., 2010; and Garnaut, 2011b).

The CGE models generally are used to focus on the longer term economic adjustment costs of carbon pricing or other changes in the economy (such as high terms of trade). They capture short-term adjustment costs and transition paths less well. That is why they are supplemented with bottom-up models and other insights from partial analysis. MMRF assumed that capital, labour and emission intensity improvements take time to respond to changes in the economy, and these transition costs are captured in the analysis. GTEM assumes labour and capital adjust perfectly across industries, and it does not capture as many of the transition costs as would be experienced in the real world. Thus, GTEM more robustly explores the post-transition economy.

The models do not capture market failures caused by asymmetric information, strategic interaction between agents, public goods (goods for which the consumption by one individual does not preclude the consumption by others) and externalities.

6 Garnaut (2011b) discusses how discount rates can be useful for weighing up costs and benefits and how to choose the discount rate.

The models do allow for learning to make some technologies cheaper over time. For example, renewable technologies for electricity generation are subject to learning-by-doing, thus their capital costs fall with their output, which leads to a greater uptake of renewable technologies in the electricity generation sector. Economy-wide technological improvements are generally exogenous in the models. The sensitivity analysis, particularly in the electricity generation sector, explores alternative technology assumptions to check the robustness of key results.

The models do not capture transaction costs in reducing emissions, such as through regulating emission trading schemes. In the real world, implementing and monitoring emission markets has transaction costs, and identifying mitigation opportunities has search costs. Similarly, providing information could cheaply and easily reduce some transaction costs and such complementary measures are not explored in the modelling.

The models do not capture the potential co-benefits of climate change mitigation policy. Some co-benefits occur between mitigation and other environmental objectives, such as the simultaneous reduction in local and regional air pollution, together with carbon reduction from less coal burning.

The modelling reflects some forms of uncertainty by undertaking sensitivity analysis. It shows the modelling is robust to a range of assumptions and that aggregate economic costs are similar across a range of plausible assumptions.

The modelling also accounts for near-term electricity generation investments, which reflect the implications of current uncertainty about climate change mitigation policy. In the longer term, to the extent that uncertainty may reduce investment (Deloitte, 2011), the modelling may understate investment, possibly affecting the projected mitigation costs.

Chapter 3: Global climate change mitigation

Key points

International negotiations have resulted in 89 countries making pledges to undertake mitigation action. These countries cover over 80 per cent of global emissions and over 90 per cent of the global economy. These pledges have countries committing to action earlier than Treasury previously modelled in the Carbon Pollution Reduction Scheme (CPRS) scenarios in 2008.

The two global action scenarios incorporate world action to stabilise greenhouse gas concentration levels at around either 550 or 450 parts per million (ppm) by around 2100. They provide a credible and realistic backdrop to examine the introduction of a domestic carbon price.

World carbon prices are expected to range from A$29 to A$61 in 2015-16 (nominal), depending on the degree of international action.

The world continues to prosper while cutting emissions to reduce the risks of dangerous climate change. By 2050, global output is projected to be over 3½ times higher than today even with ambitious cuts in global emissions.

Pricing carbon will drive structural change in the global economy, moving resources and employment towards less emission-intensive industries.

Early global action is cheaper than delayed action. For economies with high levels of carbon pollution per unit of output every year of deferring action on climate change will lead to higher long term costs.

The global modelling is robust to a range of assumptions. Sensitivity analysis shows that the aggregate economic costs are similar across a range of plausible assumptions.

3.1 Description of global action scenarios

Without concerted climate change mitigation policy, increases in global prosperity will be tied to rising global emissions, which are projected to be over double what they are today by 2050.[1] Current scientific advice is that the implications of such a rise in global emissions would result in catastrophic changes to the world's environment.

Since the 2008 Treasury modelling, international negotiations have resulted in 89 countries making pledges to undertake mitigation action. These countries cover over 80 per cent of global emissions and over 90 per cent of the global economy. These pledges suggest international mitigation effort has been brought forward, compared to what Treasury modelled in the CPRS scenarios in 2008.

The global action scenarios project how the world could evolve, given global action to reduce the impacts of dangerous climate change. They incorporate world action to stabilise greenhouse gas concentration levels at around either 550 or 450 parts per million (ppm) respectively by around 2100. They provide a credible and realistic backdrop to examine the introduction of a domestic carbon price.

With and without global action to reduce emissions, global output is expected to continue to grow strongly, if the likely costs from climate change itself are not included. Strong growth is driven by the continued catch-up of lower income economies towards the GDP per person levels enjoyed by high income countries.

Gross world product (GWP) in the medium global action scenario is projected to rise from $75 trillion in 2010 to $290 trillion in 2050. The projected average annual growth rate in GWP is 3.4 per cent, slightly slower than the 3.9 per cent experienced over the past 50 years. Average annual growth in GWP is expected to be around 4 per cent to 2030, before slowing due to projected changes in demographics.

This strong global outlook contains within it a shift in the source of global growth towards fast growing Asian economies. The Chinese and Indian economies joint share of global output is projected to increase sharply from less than 10 per cent in 1990 to 25 per cent of global output by the end of this decade and to around a third by 2030. China's GDP is projected to overtake that of the US in 2018 and India is projected to overtake the US after 2039.

The productivity catch-up occurring in these and other countries will result in an increase in the income of billions of people. By 2050, China's GDP per person is expected be over six times the current level and India's GDP per person over nine times the current level.

This analysis does not include the economic impacts of rising global emissions. To form policy judgements, this modelling analysis needs to be evaluated alongside the detailed analysis of the economic and social impacts of climate change itself and the benefits of reducing global emissions.

1 All years in this publication, unless otherwise indicated, are Australian financial years, ending 30 June of the year quoted.

Box 3.1: Climate change projections: stabilisation at 450 and 550 ppm

Climate change could severely affect Australian agriculture, infrastructure, biodiversity and ecosystems (Garnaut, 2008). Australia's hot and dry climate and economic structure make Australia particularly vulnerable to climate change (Pearman, 2008; Garnaut, 2008; and Garnaut, 2011). For example, more than $226 billion in commercial, industrial, road and rail, and residential assets is potentially exposed to inundation and erosion hazards at a sea level rise of 1.1 metres in the high end scenario for 2100 (DCCEE, 2011).

The global average surface temperature has risen around 0.8 degrees Celsius since 1850. It will rise further in the coming decades as a result of emissions that have already occurred, based on current scientific studies. Without further mitigation, atmospheric concentration is projected to rise to around 1500 ppm by around 2100. This has a 50 per cent chance of a temperature increase of 7 degrees above pre-industrial levels, leading to catastrophic consequences for the world.

Avoiding these consequences will require atmospheric concentrations being stabilised at a substantially lower level, requiring significant cuts in global greenhouse gas emissions. Lower stabilisation levels require global emissions to peak within the coming decade and fall well below current levels by 2050 (IPCC, 2007a).

Stabilisation at 450 ppm CO_2-e leaves a 50 per cent chance of limiting global average warming to around 2 degrees Celsius above pre-industrial levels. This temperature threshold is frequently referred to in the scientific literature as representing the limit beyond which 'dangerous' climate change may occur (for example, Hansen et al., 2007).

Stabilisation at 550 ppm CO_2-e leaves a 50 per cent chance of limiting global average warming to around 3 degrees Celsius above pre-industrial levels — 20 to 30 per cent of all species are projected to face a 50 per cent likelihood of extinction under this scenario (IPCC, 2007b), involving total realignment of ecosystems across Australia. Coastal communities, agriculture and infrastructure would all face significant risks, including 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).

3.1.1 International action

At the December 2010 United Nations Climate Conference in Cancun, developed and developing countries pledged side-by-side to reduce or limit their national emissions under the United Nations Framework Convention on Climate Change. Now 89 countries have pledged action. These countries cover over 80 per cent of global emissions and over 90 per cent of the global economy (World Resource Institute, 2011; IMF, 2010). There was broad international agreement to limit the global temperature increase to less than 2 degrees Celsius.

Given this international backdrop, two global action scenarios have been modelled that allow for gradual but effective mitigation. Low-end 2020 pledges made under the United Nations Framework Convention on Climate Change serve as the basis for the medium global action scenario's allocations to 2020. The high-end pledges, with more stringent reductions for some regions at 2020, are the basis for the ambitious action scenario.

Table 3.1: Summary of international global action scenario assumptions

Medium global action scenario	Ambitious global action scenario
Stabilises concentrations of greenhouse gases at 550 ppm CO_2-e by around 2100.	Stabilises concentrations of greenhouse gases at 450 ppm CO_2-e just beyond 2100.
Incorporates the low end pledges under the Cancun Agreements until 2020[(a)].	Incorporates the high end pledges under the Cancun Agreement to 2015-16. After 2016, major advanced economies increase their effort above the pledge levels.
Multistage action: developed countries and China lead the mitigation effort initially; all countries act by 2031.	Multistage action: developed countries and China lead the mitigation effort initially; all countries act by 2026.
Mechanism: from 2013 to 2015 uncoordinated global action, no trade in permits, differentiated carbon prices. From 2016 onwards, countries trade, either bilaterally or through a central market.	
Coverage: all sectors are covered from the start, except agriculture, which is covered from 2031.	
Technology: nuclear is only considered a technology option in countries that have current nuclear generation[(b)].	

(a) Where a whole region does not have a pledge (such as OPEC), the 2020 allocation is set equal to baseline emissions. Where a region includes a number of countries with 2020 pledges, regional allocations have been estimated, weighted by individual countries' share of total regional emissions in 2005 (CAIT, 2005), with those countries in the region without pledges getting allocations equal to baseline emissions.
(b) Sensitivity analysis explores the effect of a worldwide freeze on nuclear generation capacity.

After 2020, allocations are based on a multistage allocation rule similar to the CPRS scenarios in the previous Treasury modelling, adjusted to reflect existing 2020 pledges. Under the multistage approach, regions make equal percentage reductions from baseline, with a five or ten year lag for some developing regions.

In the medium action scenario, developed regions, China, OPEC and South Africa enter the multistage approach from 2021. India, Indonesia and Other South and East Asia enter in 2026. The Rest of World region enters in 2031. In the ambitious action scenario, the lag between different regions is compressed, with all regions except Rest of World entering in 2021 and Rest of World entering in 2026.

The transition from a region's pledge level at 2020 to the multistage allocation level in 2040 is linear. Thus, the stringency of the allocations between 2020 and 2040 depends on the region's pledged 2020 target, when it enters the multistage allocation rule as well as baseline emissions.

Table 3.2: Regional emission allocations[2]

	2020		2050	
	Medium global action	Ambitious global action	Medium global action	Ambitious global action
	per cent change from 2001		per cent change from 2001	
United States	-15	-28	-76	-88
European Union (25)	-14	-41	-80	-90
China	224	188	31	-34
Former Soviet Union	36	6	-58	-79
Japan	-35	-41	-84	-92
India	107	107	108	-21
Canada	-13	-22	-71	-85
Indonesia	-20	-20	-28	-73
South Africa	1	1	-36	-68
Other South and East Asia	-21	-21	-55	-83
OPEC	63	63	-29	-64
Rest of world	25	24	-7	-57
World average	39	24	-32	-67

Source: Treasury estimates from GTEM. Note: all years in this publication, unless otherwise indicated, are Australian financial years, ending 30 June of the year quoted.

2 For explanation of GTEM regions see Appendix B.

Regions are assumed to meet their targets from domestic sources only during the uncoordinated transition from 2013 to 2015. Global coordinated action emerges from 2016. This results in regions being able to source abatement from each other, minimising their mitigation costs.

A country will source abatement from others if this provides a cheaper option than reducing emissions found domestically. Similarly, a country will supply abatement to others to earn income if it is relatively cheaper to reduce emissions. An equilibrium global permit price emerges to clear the global permit market.

Table 3.3: Regional shares of global mitigation, population and GWP in 2050

Per cent of global total

			Mitigation	
	Population	GDP	Medium global action	Ambitious global action
United States	4	12	9	9
European Union (25)	5	10	5	5
China	14	20	35	34
Former Soviet Union	3	3	7	7
Japan	1	2	1	1
India	18	16	13	14
Canada	0	1	1	1
Indonesia	3	3	2	3
South Africa	1	1	1	1
Other South and East Asia	6	5	3	3
OPEC	4	4	6	6
Rest of world	39	22	15	16

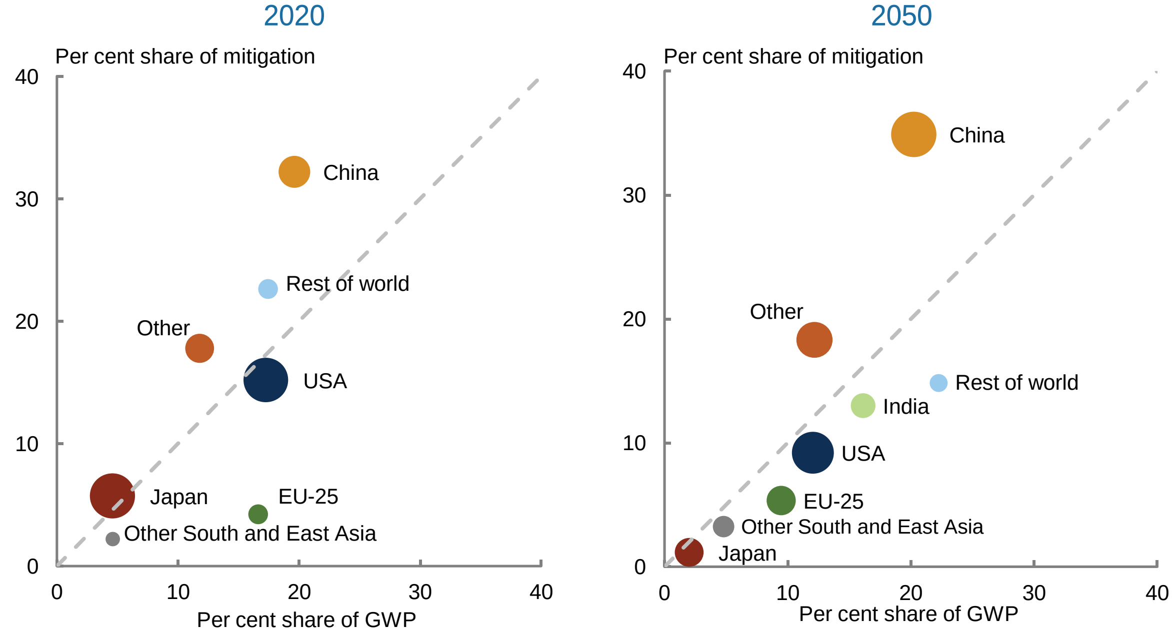
Note: GWP shares are calculated using 2005 purchasing power parity (PPP) weights. GWP shares differ slightly between the action scenarios, for simplicity the average GDP share is shown.
Source: Treasury estimates from GTEM.

Each region's mitigation effort reflects the allocation methodology assumed, which dictates equal percentage emission reductions from the baseline. The higher a country's baseline emissions, the larger their share of the mitigation effort. China is projected to have strong GDP growth in the baseline, accompanied by increasing emissions, leading to a large share of the global mitigation effort in both global action scenarios. These respective shares of mitigation effort simply reflect projected global economic significance.

Although China accounts for 34-35 per cent of the global mitigation effort in 2050, its emissions actually continue to grow in both global action scenarios to around 2030, while developed countries' emissions peak by 2015.

Chart 3.1: Regional contribution to mitigation action

Medium global action scenario



Note: Position of country circles indicates both share of mitigation and share of GWP, with the 45 degree line showing equal proportion over both categories. Circle size indicates the relative mitigation per person for each region. 'Other' includes Former Soviet Union, Canada, Indonesia, South Africa and OPEC. India does not appear on the LHS chart because its emissions mitigation is zero compared to the baseline.
Source: Treasury estimates from GTEM.

The regions above the 45 degree line are those countries with strong emission growth projected in the baseline. Each region's share of GWP relative to their share of mitigation reflects the stylised allocation approach used.

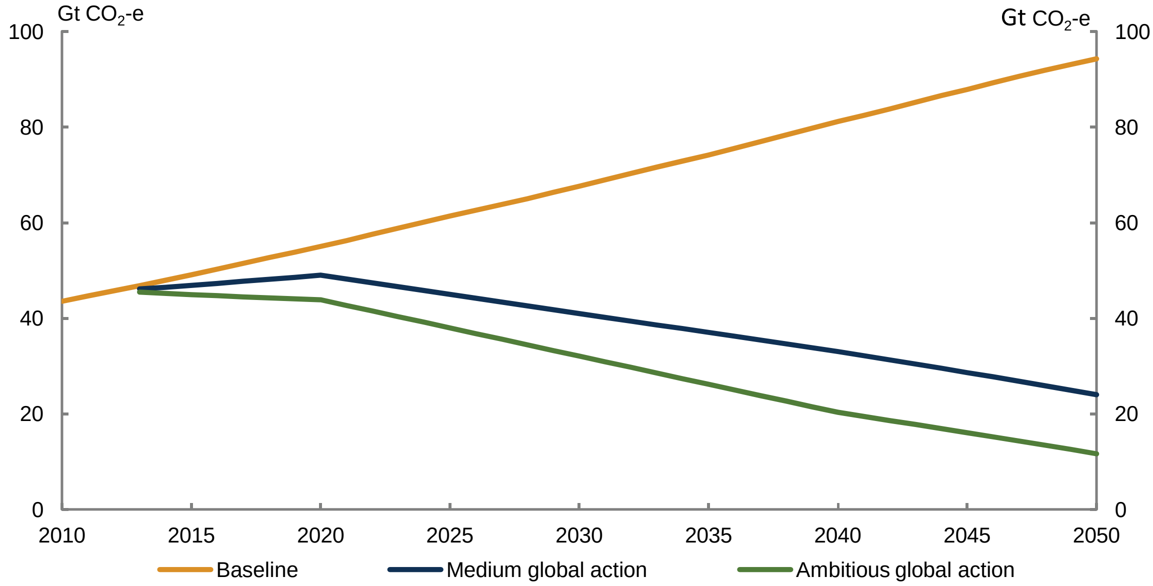
3.1.2 Global emission reductions

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 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 GTEM.[3] The carbon price grows from a specified starting level at the real interest rate, assumed to be 4 per cent on average per year, which represents the rate of increase in comparable financial assets. Other recent climate modelling exercises use similar growth rate assumptions.[4] The starting carbon price for each scenario is set so that the global emissions give the desired path for the concentrations of the modelled greenhouse gases using the MAGICC model.[5]

3 For further discussion of the Hotelling rule see Appendix B.
4 For example, see CCSP, 2007, p 89.
5 See Chapter 2 for further information.

Chart 3.2: Global emission allocations



Note: The baseline is a scenario in which no further mitigation occurs. For more information on the baseline see Appendix B.
Source: Treasury estimates from GTEM.

Table 3.4: Global emission allocations (Gt CO_2-e)

	Baseline	Medium global action	Ambitious global action
Global allocations, per cent change from 2001			
2020	56	39	24
2050	167	-32	-67
Allocations per capita, per cent change from 2001			
2020		12	1
2050		-55	-78
Global allocations, per cent change from no action			
2020		-11	-20
2050		-75	-88
Year in which global emission allocations peak		2020	2012
Greenhouse gas stabilisation goal, ppm CO_2-e	Over 1500 ppm	550	450
Mean temperature change at stabilisation	7°C or more	3°C	2°C
Global emissions in 2050, Gt CO_2-e	94	34	18

Source: Treasury estimates from GTEM and MAGICC.

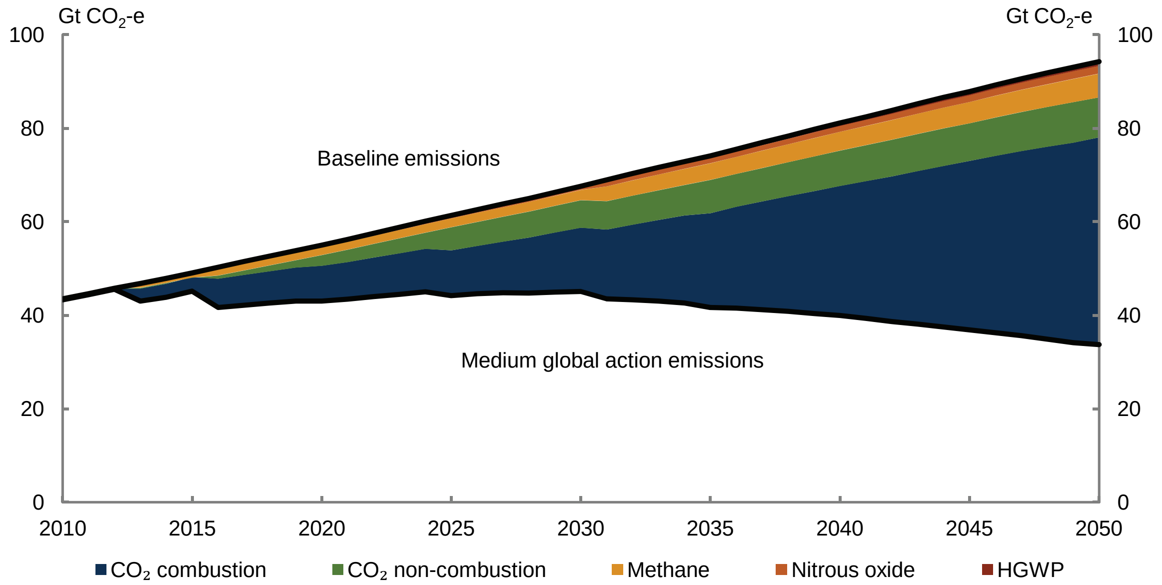
Global allocation levels are slightly higher in the initial years than in the previous Treasury modelling, reflecting the uncoordinated global action. In later years the allocation levels are lower.

Reducing emissions from fossil fuel combustion account for most of the mitigation effort to 2050. Global mitigation can be achieved at lowest cost if policy is designed to cover a broad range of emissions. Targeting only CO_2 in mitigation efforts would increase the costs of achieving the same environmental goal substantially (OECD, 2009).

Forestry sinks across most regions provide substantial emission sequestration, wholly offsetting non-combustion CO_2 emissions from all sources by around 2020. Non-combustion CO_2 emissions — including fugitive emissions, waste and emissions associated with land-use change and forestry — 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 carbon prices than CO_2 emissions; consequently, these sources contribute less to global mitigation. In addition, emissions from agriculture are not included in international policy mechanisms until after 2030. As a share of total global emissions, methane increases from 14 per cent now to 16 per cent in 2050;[6] nitrous oxide increases from 6 per cent to 11 per cent. Global emissions of the other gases (SF_6, HFCs and PFCs) are largely eliminated through changes to industrial processes, and are expected to comprise around 1 per cent of total emissions in 2050.

Chart 3.3: Global mitigation by gas
Medium global action scenario



Note: HGWP refers to high global warming potential gases, including SF_6, HFCs and PFCs.
Source: Treasury estimates from GTEM.

3.1.3 Global carbon price

In the near term, the modelling assumes countries will meet their Accord targets through existing measures, where possible. For example, the modelling assumes countries and regions with emissions trading schemes already in place continue with their schemes. However, several regions are assumed to take additional individual action from 2013 to meet their 2020 pledges.

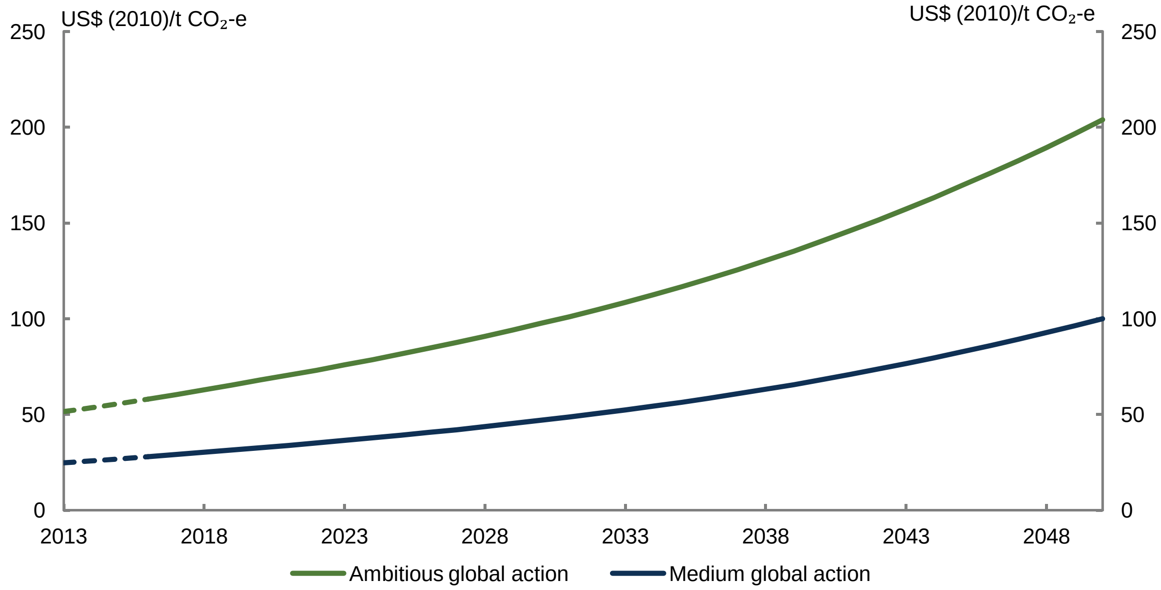
Global prices in the early years of the international scenarios (2013 to 2015) reflect uncoordinated global action with countries acting largely in isolation to reduce emissions. Countries and regions face individual carbon prices.

The modelling assumes an eventual shift to a lower cost coordinated international policy framework, recognising that this is ultimately in all countries' best interests. By 2016, a more coordinated international policy regime allows countries to trade either bilaterally or through a common central market. As a result, a harmonised world carbon price emerges in 2016.

6 These shares are 1 per cent higher than found in the CPRS-5 scenario, reflecting later inclusion of agriculture (agriculture is included from 2031 in current scenarios, while in the CPRS scenarios it was included from 2015).

Once a common price emerges, the global action scenarios choose the required starting carbon price to achieve the desired greenhouse gas concentration stabilisation level. The global carbon prices for the 450 ppm scenario are more than double those of the medium global action scenario in 2016, US$58 and US$28[7] respectively.

Chart 3.4: Global carbon prices



Note: Dotted lines indicate an implied harmonised world carbon price before 2016.
Source: Treasury estimates from GTEM.

World carbon prices are projected to be higher than the previous Treasury modelling for the ambitious global action scenario, but broadly unchanged for the medium action scenario. Delayed and less coordinated international action on climate change pushes up world prices to achieve the same environmental outcome. The global financial crisis delayed emissions growth in developed countries and higher projected energy prices push down world carbon prices. However, emissions growth in developing countries is projected to be stronger, pushing up world carbon price estimates.

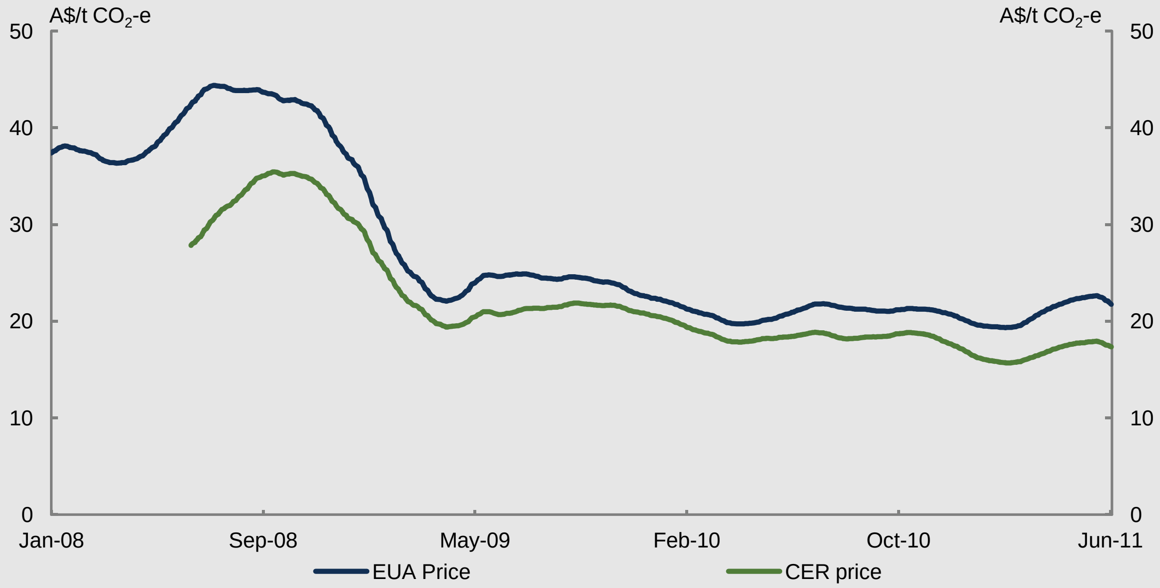
7 All international carbon prices are in 2009-10 dollars unless otherwise stated.

Box 3.2: Comparing international carbon prices

The global carbon price varies across markets. The most significant carbon units traded today are European Union Allowance permits (EUAs) and Certified Emission Reductions (CERs). EUAs can be purchased or sold by companies covered by the EU Emissions Trading Scheme to meet their targets. CERs are emission reductions achieved by Clean Development Mechanism (CDM) projects. CERs may be directly used to comply with targets under the Kyoto Protocol or sold through the EU Emissions Trading Scheme.

The spot and futures prices of EUAs and CERs change reflecting expectations about the demand and supply of permits. The spot prices for EUAs have traded between A$16 and A$23 over the past 3 months and the futures prices for December 2014 have traded between A$19 and A$28 over the same period (IntercontinentalExchange, 2011). This is broadly comparable to the implied world carbon prices of around A$24 in 2012-13 (nominal) suggested in the medium global action scenario. Deutsche Bank has also forecast the EUA price to be around A$25/t CO_2-e at the end of 2011 (Thomson Reuters, 2011).

Chart 3.5: International carbon prices



Note: Prices are a 3 month moving average.
Source: IntercontinentalExchange and Reserve Bank of Australia.

3.2 Global results

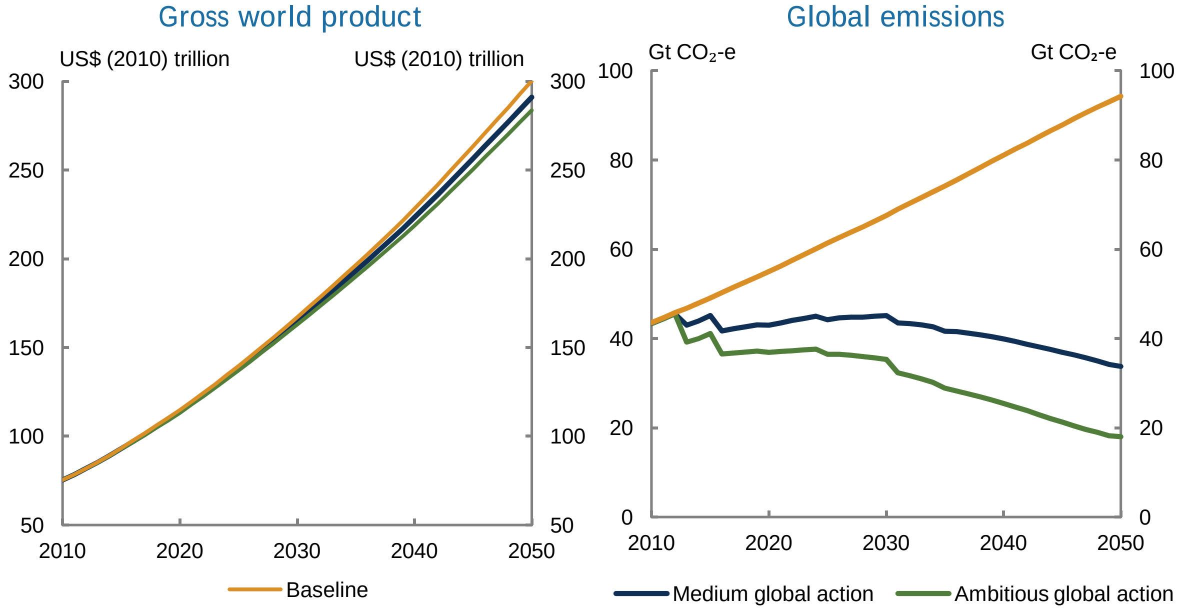
Pricing carbon decouples the link between global economic and emissions growth. All global action scenarios modelled show robust global economic growth, while emissions are dramatically reduced.

Under both global action scenarios the world economy will continue to prosper, with average annual growth in GWP is around 0.1 of a percentage point slower over the period to 2050. GWP is expected to be more than 3½ times higher than current levels by 2050. This level of GWP is 16 to 29 months behind what it would have been without taking mitigation action.

The broad sectoral trends in the global economy continue as the world acts on climate change. The services sector continues to comprise a growing share of the global economy, and agriculture and energy-intensive industries continue to comprise declining shares. However, reducing emissions requires a shift away from the production of emission-intensive goods towards low-emission goods, combined with a general decline in the emission intensity of production across all sectors.

This analysis does not assess the economic impacts of climate change itself. As a consequence the results presented will understate the net benefit of action. The environmental and economic risks averted by taking action to avoid damaging climate change are substantial.

Chart 3.6: Global emissions and gross world product



Note: GWP is calculated using 2005 PPP weights. The shifts reflect timing of different mitigation actions and coverage of agriculture. The shift at 2013 reflects the increase in uncoordinated world action; the shift at 2016 reflects the emerging coordinated world action; and the shift in 2031 reflects the expansion of global mitigation policy to agriculture emissions.
Source: Treasury estimates from GTEM.

Total global mitigation costs vary depending on the nature, horizon and stringency of the global stabilisation target, and the policies used to reach it. The global environmental objective is a key to determining carbon prices and aggregate global costs. Lower stabilisation levels, which reduce the risks of dangerous climate change, generally increase mitigation costs.

The reduction in emissions steepens over time and additional resource costs reduce as the structure of the economy shifts and new technologies are adopted. The global cost of being on the ambitious 450 ppm stabilisation path is around 110 per cent greater than being on the medium global action 550 ppm path by 2020. However, the cost difference narrows to around 80 per cent by 2050.

Table 3.5: Global headline indicators

	Baseline	Medium global action	Ambitious global action
Current levels - at 2010			
Actual emissions, Gt CO_2-e	44	43	43
GWP per capita, US$'000/person	10.9	10.9	10.9
Medium term - at 2020			
Emission allocation, Gt CO_2-e		49	44
GWP, change from Baseline, per cent		-0.6	-1.3
GWP, per capita, US$'000 /person	15.0	14.9	14.8
Emission-intensity of gross output, kg CO_2-e/US$	0.5	0.4	0.3
World emission price, real, US$/t$CO_2$-e		33	68
Long term - at 2050			
Emission allocation, Gt CO_2-e		24	12
GWP, change from Baseline, per cent		-3.0	-5.5
GWP per capita, US$'000/person	32.3	31.3	30.5
Emission-intensity of gross output, kg CO_2-e/US$	0.3	0.1	0.1
World emission price, real, US$/t$CO_2$-e		100	204
GWP per person real annual average growth rate			
2010 to 2050, per cent	2.7	2.7	2.6
GWP real annual average growth rate			
2010 to 2050, per cent	3.5	3.4	3.4

Note: Dollar values are in US$ 2010. GWP is calculated using 2005 PPP weights.
Source: Treasury estimates from GTEM.

Box 3.3: Comparison with other international modelling studies

The modelling results presented in this report are compared with other relevant international modelling studies. Comparing results across different models is not straightforward, as there are differences in model structures, input assumptions — including macroeconomic assumptions and model parameter values, details of aggregation and the ways in which a policy is modelled.

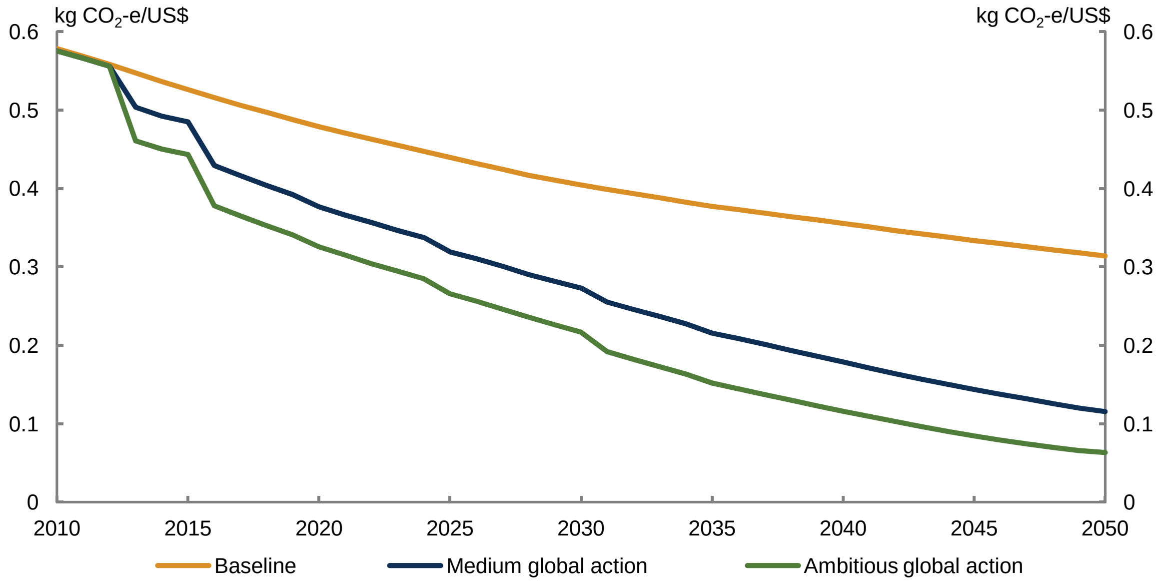
These differences need to be considered in interpreting the results across studies. However, most scenarios show that the costs of mitigation, when approached through a broad market-based mechanism, are modest.

Table 3.6: Comparison of modelling reports

Source	GDP Costs at 2030	GDP Costs at 2050	Mitigation at 2050
	Per cent change from baseline		Gt CO_2-e
Global, weighted with PPP			
OECD 2009			
Scenario A (550ppm Overshoot)		-3.9	
Scenario C (50% reduction from 2005)		-6.9	
ALPF GTEM 550ppm (CPRS -5, Garnaut -10)	-1.4	-2.8	67-68
ALPF GTEM 450ppm (Garnaut -25)	-2.1	-4.3	81
ALPF G-Cubed 550ppm (CPRS -5)	-3.1	-3.3	38
G-Cubed (Copenhagen)#	-3.2		
OECD 2008			
All 2008	-0.8	-0.9	38
450ppm	-0.5	-2.5	46
UK - CCC			
PAGE (3% low trajectory)		-0.9 to -1.5	44
PAGE (4% trajectory)		-1.0 to -1.7	48
GLOCAF (3% low trajectory)		-2.4	51
GLOCAF (4% trajectory)		-3.3	55
Results from current Treasury modelling			
GTEM medium global action	-1.2	-3.0	61
GTEM ambitious global action	-2.5	-5.5	76
Global, weighted with market exchange rates			
CCSP 530	-0.6 to -3	-1.9 to -5.4	31-56
IPCC 4AR 535-590	-0.2 to -2.5	Slightly positive to -4	
Stern 550 (Chapters 8 & 10)		-1	50
den Elzen et al 550	-0.4	-1.1	
Domestic			
UK - DEFRA			
MARKAL 60% ##		-0.8	60% by 2050
MARKAL 70% ##		-1.1	70% by 2050
MARKAL 80% ##		-1.6	80% by 2050
US - EPA			
American Power Act ###		-0.9 to -1.1	
NZ - CCP Modelling			
Infometrics (Run 8) ####	-0.6		4.3% by 2025
NZIER (Run 8) ####	-0.7		5.5% by 2025

Decline at 2020.
Reduction on 2000 emission level.
Reduction in household consumption relative to no action.
Decline at 2025.
Note: All GWP costs are percentage point deviations from each study's respective baseline.
Source: Treasury estimates from GTEM and G Cubed; CCC, 2008; CCSP, 2007; DEFRA, 2007; den Elzen et al, 2007; EPA, 2010; IPCC, 2007; McKibbin et al, 2010; NZIER & Infometrics, 2009; OECD, 2008; OECD, 2009; Stern, 2007.

Chart 3.7: Global emission intensity of gross world product



Source: Treasury estimates from GTEM.

The emission intensity of GWP falls in response to carbon pricing, allowing strong growth to continue as emissions fall. The emission intensity of GWP declines from 0.58 kg of CO_2-e per US$ in 2010 to less than 0.12 kg of CO_2-e per US$ in 2050 under both global action scenarios. The decline in emission intensity increases as the carbon price grows.

Costs of delaying global action

In the medium global action scenario, regions have differentiated carbon prices between 2013 and 2015 with emission reductions on the pathways to meet their pledged 2020 targets. From 2016, global actions are coordinated with a uniform global carbon price emerging across all regions to meet the 550 ppm concentration stabilisation target.

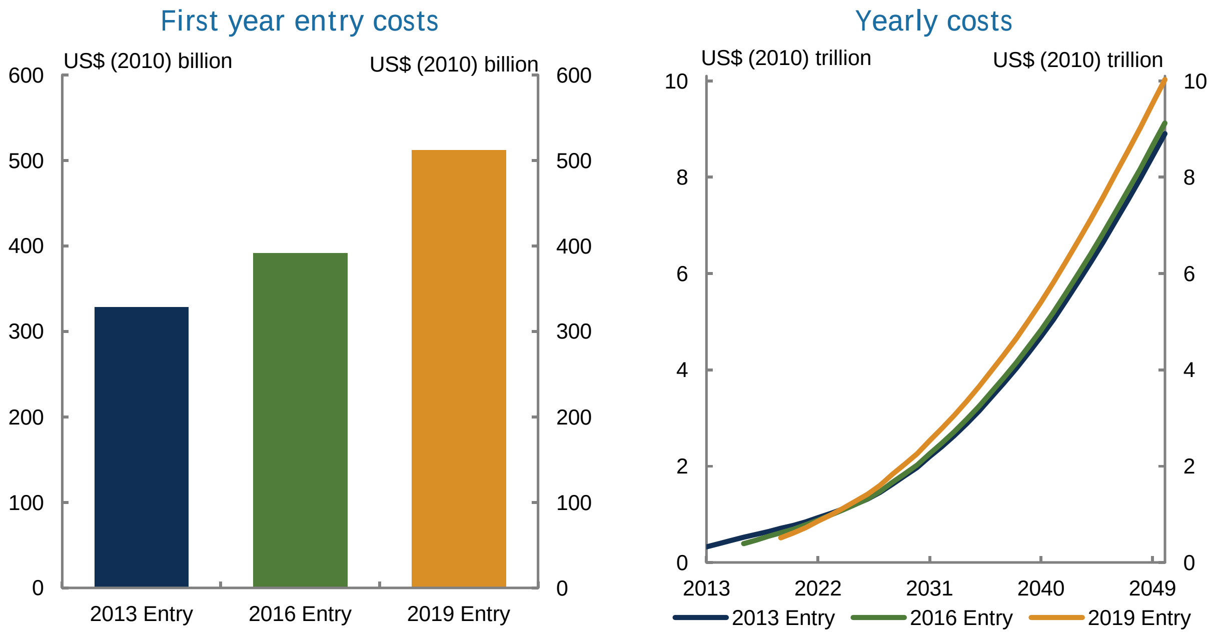
If the world were to act in a more coordinated way from 2013 there is a direct economic benefit. Moving coordinated action forward 3 years would reduce mitigation costs by 2 per cent in 2050.

Conversely, delaying global mitigation action increases climate change risks, locks in more emission-intensive industry and infrastructure, and defers cost reductions in low-emission technology. This will increase the cost of achieving a given environmental goal. The costs of global delay have gone up since the previous Treasury modelling.

Sensitivity analysis examines the effect of delaying global mitigation action by 3 and 6 years, but still stabilising global greenhouse gas concentration levels at around 550 ppm. Delay brings initial benefits when emissions are not priced. However, GWP levels end up lower than they would have been under early action. And, the more delay there is, the higher the eventual economic cost of achieving the same environmental outcome.

Delaying global action by 3 years adds around 20 per cent to the first year entry mitigation cost; a further three years adds a further 30 per cent to the first year mitigation cost.

Chart 3.8: Costs of delayed global action



Source: Treasury estimates from GTEM.

A delayed shift to less emission-intensive technologies and infrastructure will have higher economic cost in the long term.

Sensitivity analysis estimated the costs to late movers. Depending on countries' emission reduction targets and the ability to source permits from other countries, a 3-year delay of mitigation action results in higher mitigation costs of 2 to 10 per cent in 2050.[8] The range of costs reflects alternative emission targets of each country, but no matter what the target assumed, delayed action leads to higher eventual mitigation costs.

3.2.1 Regional mitigation costs

Mitigation costs vary between regions and countries depending on the emission intensity of the economy and its ability to respond with mitigation. Some regions' gross national income (GNI) may improve relative to no action if they are able to sell abatement to other countries. Income from selling abatement depends on the allocation of emissions rights across countries, abatement opportunities and the ability to adopt clean energy technologies.

8 The costs were estimated based on aggregated GDP for all late movers modelled as a group.

Table 3.7: Regional GDP and GNI per person costs

Per cent change from baseline

GNI per person	2020		2050	
	Medium global action	Ambitious global action	Medium global action	Ambitious global action
United States	0.0	0.0	-0.1	0.5
European Union (25)	-0.1	-0.6	-0.9	-1.6
China	-1.2	-2.2	-5.0	-9.5
Former Soviet Union	-2.4	-6.5	-9.2	-11.8
Japan	-0.1	-0.3	-0.9	-2.0
India	-0.1	0.6	-2.9	-6.3
Canada	-1.0	-1.8	-3.0	-5.3
Indonesia	-2.4	-4.5	-3.4	-8.0
South Africa	-2.0	-2.9	-5.1	-7.0
Other South and East Asia	-0.1	0.1	0.5	1.8
OPEC	-0.9	-1.3	-10.9	-18.4
Rest of world	-0.7	-1.4	-1.4	-4.4
World	-0.6	-1.3	-3.0	-5.5
GDP per person	2020		2050	
	Medium global action	Ambitious global action	Medium global action	Ambitious global action
United States	-0.1	-0.1	-0.3	-0.5
European Union (25)	0.0	-0.1	-0.4	-1.2
China	-1.4	-2.9	-3.9	-6.8
Former Soviet Union	-3.0	-6.7	-11.5	-16.8
Japan	0.1	0.2	0.1	-0.5
India	-1.1	-2.1	-4.0	-6.5
Canada	-0.3	-0.6	-1.9	-3.7
Indonesia	-1.8	-3.4	-4.6	-8.9
South Africa	-1.6	-2.8	-5.4	-8.1
Other South and East Asia	-0.1	-0.4	-2.0	-3.8
OPEC	-1.3	-3.0	-7.9	-16.5
Rest of world	-0.3	-0.6	-2.1	-4.5
World	-0.6	-1.3	-3.0	-5.5

Source: Treasury estimates from GTEM.

Pricing carbon tends to reduce GDP relative to no action more in developing economies, compared with developed economies, as developing economies tend to have a higher emission intensity of economic output. Agriculture, natural resource extraction and manufacturing are all relatively emission intensive and account for a higher share of activity in developing economies. A given amount 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 the European Union experience the smallest GDP reductions as their economies are relatively low-emission intensive with a large services sector share of the economy.

How emission intensity of output falls in response to carbon 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.

Although developing economies have larger declines in GDP (relative to the baseline) than developed economies, they benefit from income transfers through selling abatement, partially offsetting the negative GDP effects in these regions. Selling abatement helps countries and regions such as India and other South and East Asia.

Income transfers between regions occur because of changes in the terms of trade, the sale of abatement and changes in foreign interest payments. Net income transfers positively affect GNI in regions with low mitigation costs as they can sell abatement. The sale of large amounts of abatement tends to cause the exchange rate to appreciate, positively affecting net foreign interest payments and further boosting net income transfers.

Most developed economies source abatement from overseas, raising their GNI mitigation costs relative to their GDP costs. However, allowing abatement to be sourced from the least-cost location results in lower economic costs for both developed and developing economies.

Table 3.8: Net transfer of abatement

	2020		2050	
	Medium global action	Ambitious global action	Medium global action	Ambitious global action
	Mt CO_2-e		Mt CO_2-e	
United States	-203	-300	-110	899
European Union (25)	-95	-927	-625	-261
China	498	849	-814	-1774
Former Soviet Union	149	-137	560	659
Japan	-345	-361	-306	-213
India	556	804	249	-621
Canada	-118	-108	-90	-76
Indonesia	-131	-97	190	40
South Africa	-84	-29	-3	38
Other South and East Asia	219	403	1324	1521
OPEC	359	651	-1501	-304
Rest of world	-805	-748	1127	91

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

Table 3.9: Regional emissions

	2020		2050	
	Medium global action	Ambitious global action	Medium global action	Ambitious global action
	per cent change from 2001		per cent change from 2001	
United States	-23	-36	-64	-94
European Union (25)	-24	-32	-59	-79
China	171	122	103	41
Former Soviet Union	13	-8	-58	-88
Japan	-18	-25	-56	-72
India	47	24	181	62
Canada	-8	-20	-46	-66
Indonesia	-17	-24	-18	-61
South Africa	9	-9	-8	-58
Other South and East Asia	-43	-55	-105	-152
OPEC	41	24	92	-25
Rest of world	22	15	14	-34
World average	22	5	-4	-49

Source: Treasury estimates from GTEM.

Box 3.4: The global carbon market

Access to international mitigation through a market based mechanisms such as international emission trading and the Clean Development Mechanism (CDM) can reduce overall costs of meeting any given target by allowing mitigation to occur where it is cheapest.

The global carbon market has seen robust growth in recent years, increasing in size from US$11 billion in 2005 to US$144 billion in 2009 (World Bank, 2011). The market contracted slightly to US$142 billion in 2010, primarily due to a lack of post Kyoto regulatory clarity. The EU Emissions Trading Scheme (ETS) dominates the global market, making up 84 per cent of the total market in 2010.

Future of the Clean Development Mechanism

The CDM established under the Kyoto Protocol, enables Annex I Parties (developed) to purchase certified emission reductions (CERs) from non-Annex I Parties (developing) and use those offsets against Annex I mitigation commitments for the first commitment period of the Kyoto Protocol (as inscribed in Appendix B of the Protocol).

The first commitment period expires at the end of December 2012. Whether a second commitment period will occur is unclear. However, it is likely that the CDM will continue in some form beyond 2012 as the EU has declared that CERs will be eligible to be used in its ETS up until 2020.

3.2.2 Sectoral analysis

The broad sectoral trends in the global economy continue as the world acts on climate change. The services sector continues to comprise a growing share of the global economy, and agriculture and energy-intensive industries continue to comprise a declining share. However, reducing emissions requires 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.

Sectoral output

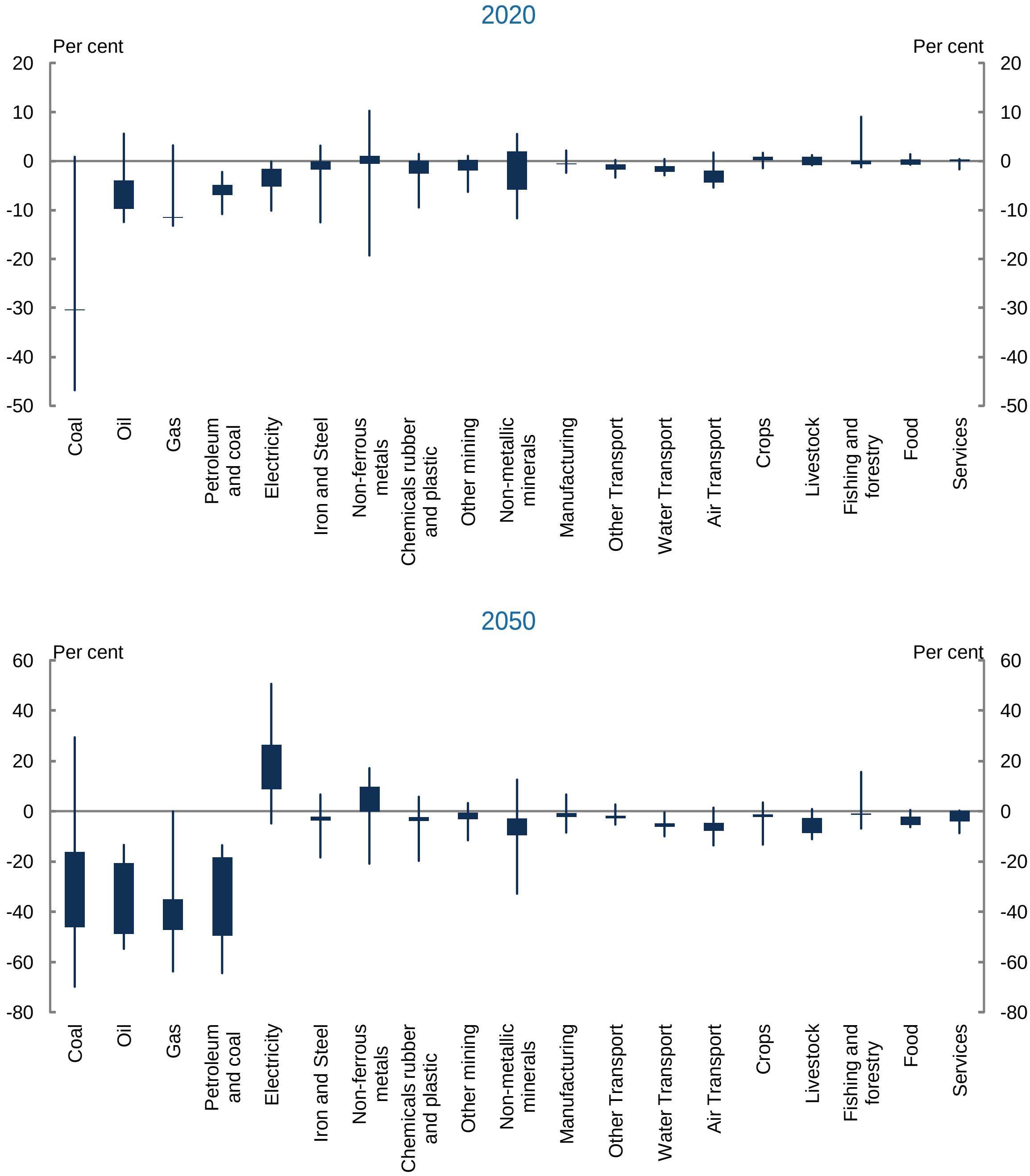
Global demand for most commodities and services remains strong with action on climate change. While the growth in output of some sectors slows, most emission reductions come from changes in production processes and adoption of new technology.

The effect on output varies across sectors and regions. In some cases acting on climate change causes output growth in the medium global action scenario to increase, reflecting improvements in comparative advantage following carbon pricing. Services are generally less affected than other sectors of the economy, with total global output in the medium global action scenario slowing such that the level is around 1½ per cent lower in 2050 compared to the baseline. Global manufacturing output growth slows slightly compared to the baseline, with India and the former Soviet Union region experiencing the largest declines, reflecting their higher emission intensity.

The growth in the fossil fuel mining sector slows considerably as a result of substitution towards cleaner fuel sources. In 2020, coal mining output is around 30 per cent lower than it would otherwise be, while global oil and gas mining output is 4 to 12 per cent lower than baseline. Electricity generation is less affected, as it switches from fossil fuels to nuclear and renewables.

Over time, development and deployment of technologies significantly affects sectoral growth. For example, the availability of carbon capture and storage technologies reduces the impact of carbon pricing on coal mining. Oil and gas mining, however, continue to slow throughout the projection period to 2050, compared to the baseline. The output of electricity generation rises significantly to be higher in 2050, as continued switching to cleaner technology options enables electricity to become cost competitive against direct use of fossil fuels. This results in considerable substitution towards electricity consumption by energy consumers.

Chart 3.9: Sectoral Output



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

Sectoral emissions

Mitigation occurs across the economy. In all economies, most emissions 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, reduce emissions from fossil fuels. As the electricity sector reduces its emissions, other sectors, such as transport and industrial processes, plug in to the electricity grid.

Similar adjustment processes are expected for developing economies, where non-energy emissions from agriculture and land use change and forestry play a larger role. While proven low-emission options in agriculture are fewer, they include fertiliser application methods, animal management practices and animal diets. As the agriculture sector is assumed to be excluded from any emission reduction obligations until 2031, these factors are less important. Stopping deforestation is the most important factor for land use change and forestry.

Table 3.10: Global emissions by sector

Change from baseline

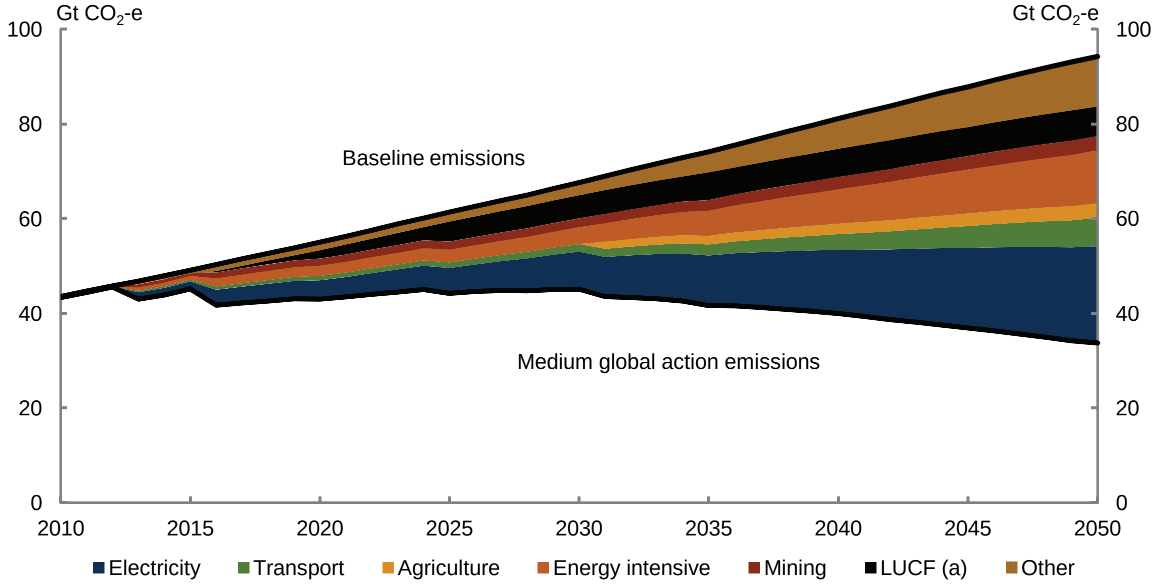
	Baseline Gt CO_2-e	Medium global action Per cent	Ambitious global action Per cent
2020			
Electricity	16	-25	-42
Transport	8	-11	-17
Agriculture	7	0	0
Energy-intensive	11	-20	-32
Mining	3	-47	-62
Land-use change and forestry(a)	1	-125	-135
Other	9	-20	-30
Total	55	-22	-33
2050			
Electricity	29	-70	-83
Transport	14	-44	-71
Agriculture	11	-30	-43
Energy-intensive	20	-55	-70
Mining	4	-71	-80
Land-use change and forestry(a)	1	-1145	-1312
Other	16	-66	-82
Total	94	-64	-81

(a) Land use change and forestry per cent changes are large due to small baseline values. Net emissions range from -0.4 to -0.5 Gt CO_2-e in 2020 and -5.7 to -6.6 Gt CO_2-e in 2050.

Source: Treasury estimates from GTEM.

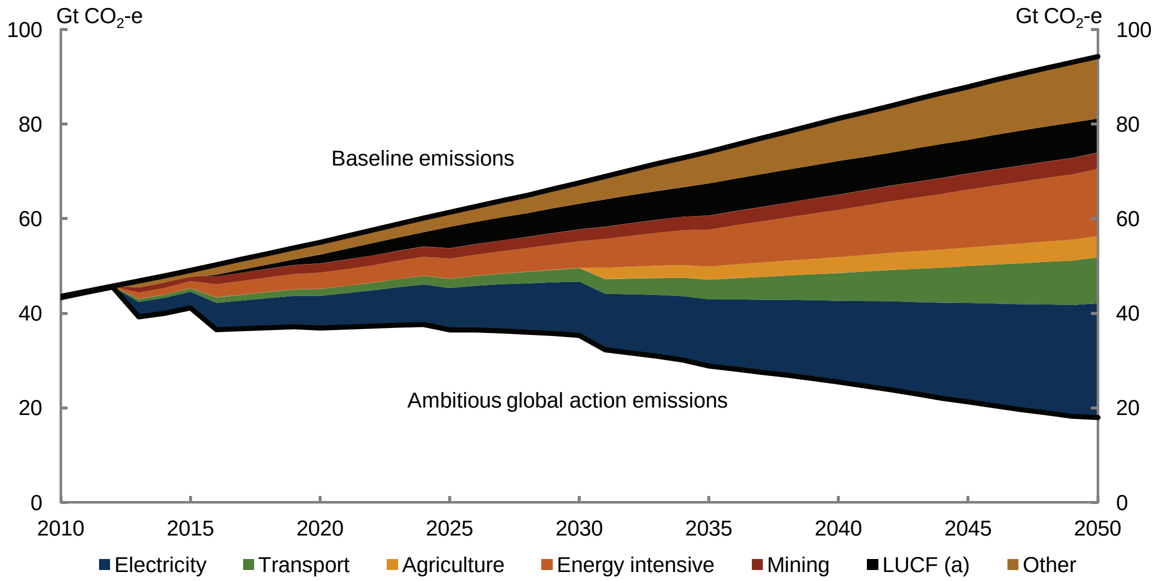
Electricity generation provides the largest source of mitigation until 2050. Electricity emissions initially decline relative to a world without action, resulting from both declining electricity generation and substitution towards cleaner technologies.

Chart 3.10: Global emission mitigation by sector
Medium global action



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

Chart 3.11: Global emission mitigation by sector
Ambitious global action

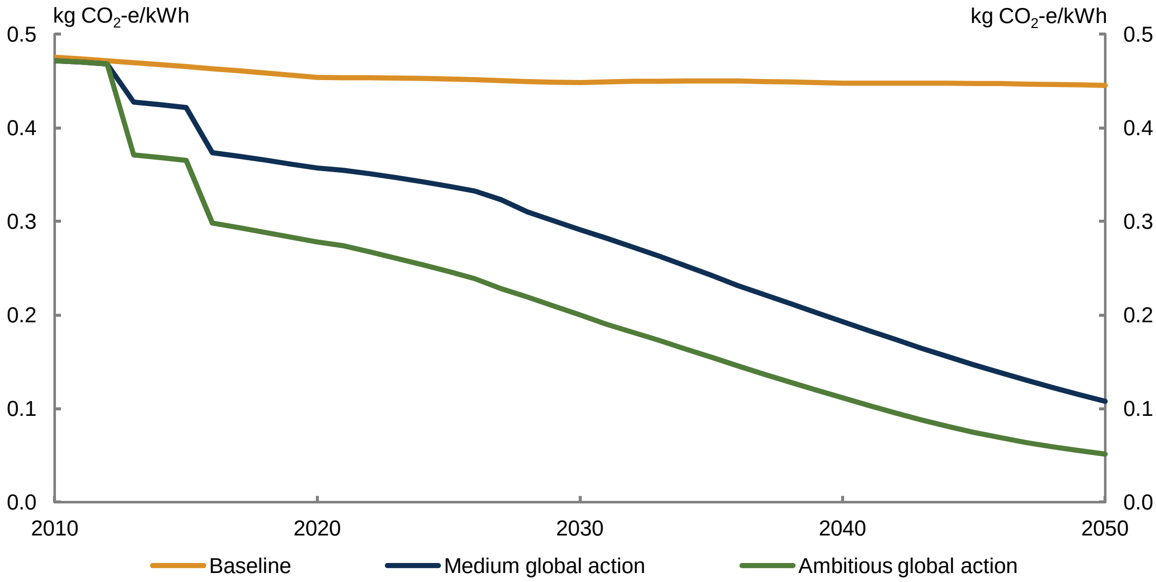


(a) Land use change and forestry.
Source: Treasury estimates from GTEM.

Electricity

The electricity generation sector is a major source of global emissions (around 30 per cent in 2010), and it provides the largest source of abatement. Initially, pricing carbon leads to a decrease in the demand for electricity. However, as electricity decarbonises, the substitution is back towards electricity as a source of energy, so that by 2050, electricity demand is higher than in the baseline — 23 per cent higher in the medium global action scenario and 48 per cent higher in the ambitious global action scenario.

Chart 3.12: Global emission intensity of electricity generation



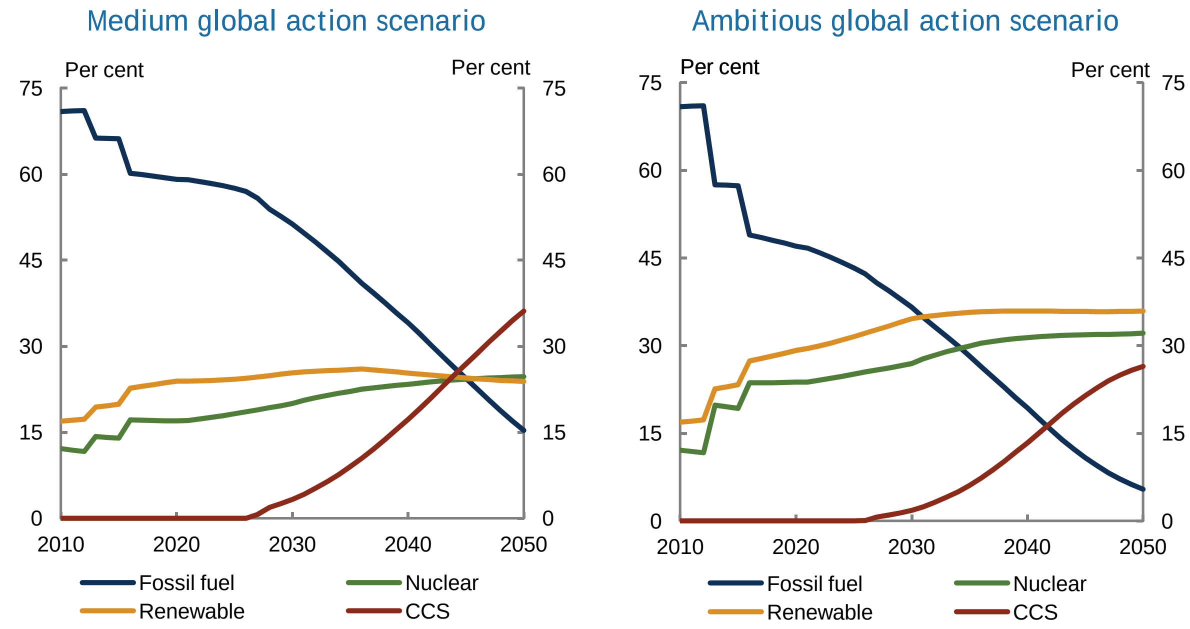
Source: Treasury estimates from GTEM.

Carbon pricing adds to the cost of fossil fuel fired electricity, making renewable and nuclear technologies more competitive. Shares in low emission technologies rise over time. New technologies, such as carbon capture and storage (CCS) become a large share of electricity generation once they are commercially viable.

In all scenarios, fossil fuels' share falls consistently, with the fall more pronounced under the ambitious action scenario due to higher carbon prices. The reduction in fossil fuel initially is taken up by renewables, particularly wind and nuclear power, which are established zero emission technologies.

Renewable technologies are projected to make up 24 per cent of the global electricity sector in 2050 (in the medium global action scenario) compared to only 13 per cent in the baseline. Traditional fossil fuel generation (not including CCS) declines from around 59 per cent in 2020 to around 15 per cent in 2050.

Chart 3.13: Global electricity sector technology shares

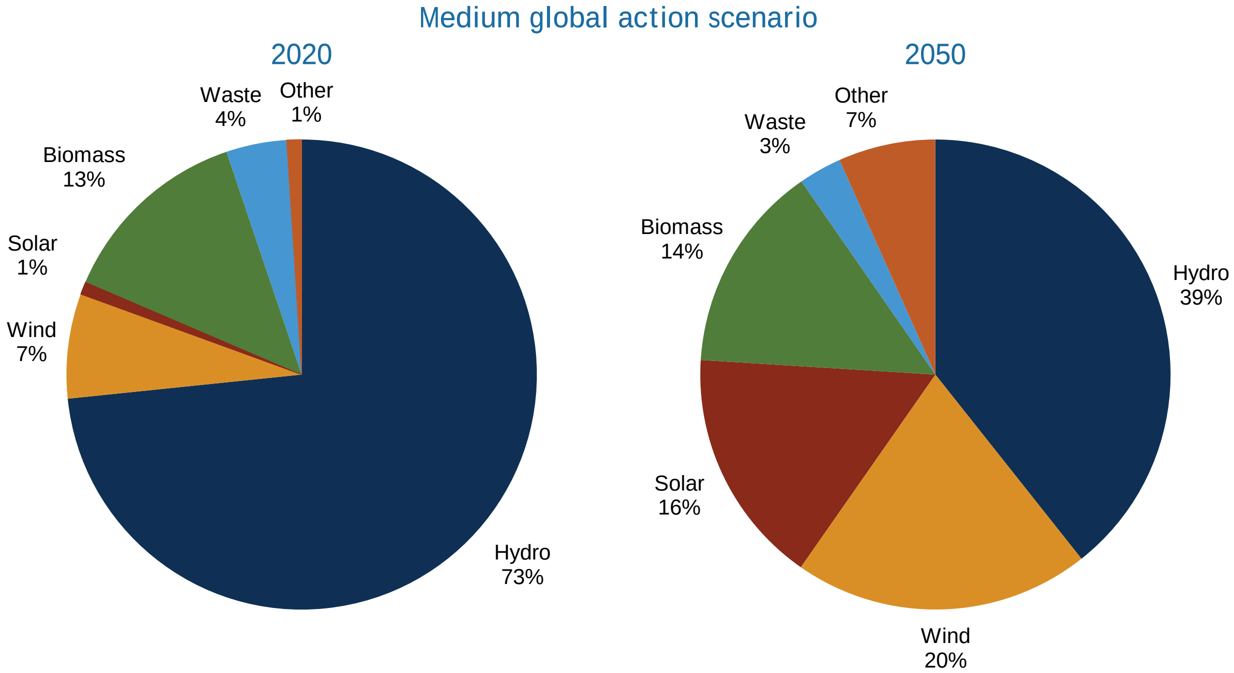


Source: Treasury estimates from GTEM.

CCS provides a potential to reduce emissions from coal and gas generated electricity by up to 90 per cent. This would provide a significant benefit to mitigation efforts. At present, around 30 per cent of emissions come from electricity generation and around 65 per cent of electricity generation comes from coal and gas.

Sensitivity analysis explores the effects of CCS proving commercially unviable. If CCS proves to be unviable global economic costs increase by more than 3 per cent compared to the medium global action scenario in 2050.

Chart 3.14: Renewable electricity generation shares



Source: Treasury estimates from GTEM.

Prediction of commercial viability of clean technologies in the future is difficult. Given recent developments in the nuclear industry in Japan, future expansion in the capacity of nuclear electricity generation has become less certain. Similarly, there is uncertainty over the pace of cost reduction of clean technologies.

Assuming no new nuclear capacity is installed beyond 2020, the modelling shows the global economic cost of achieving the same environmental target is 18 per cent higher than in the medium global action scenario by 2050, as more expensive technologies need to be substituted in order to achieve the targeted emission reductions.

If it was possible to achieve a faster cost reduction in clean technologies through the doubling of the learning-by-doing parameter values, global economic costs could be reduced by 14½ per cent in 2050, compared to the medium global action scenario.[9]

Transport

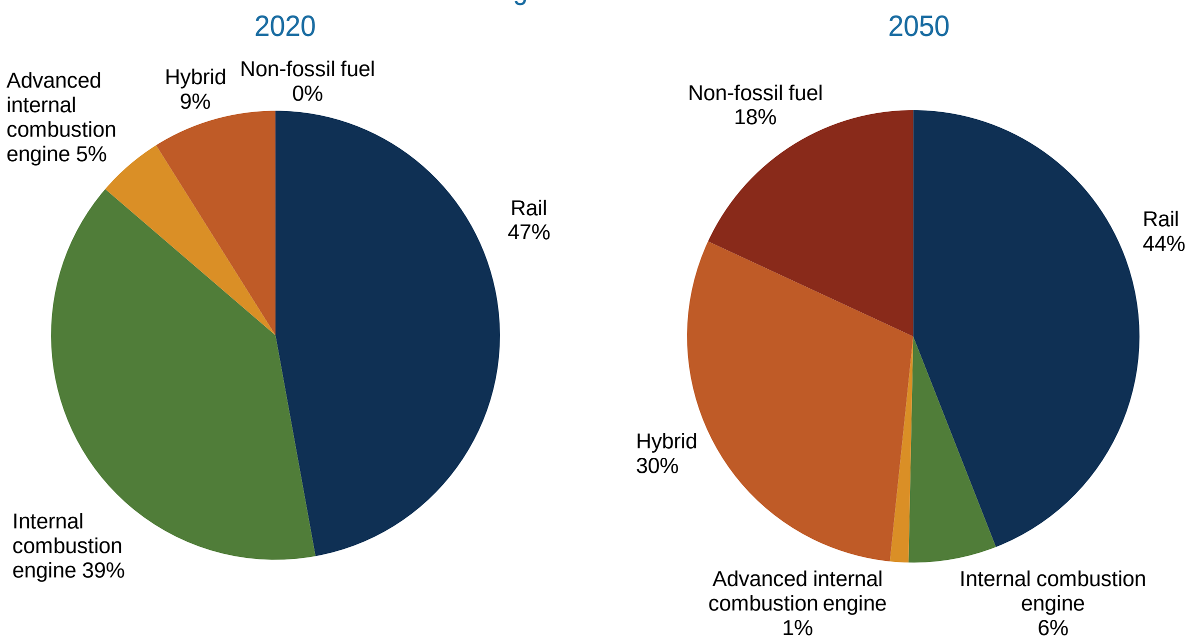
Global transport emissions grow to 2050, as demand strengthens and emission intensity improves only moderately with the uptake of energy-efficient vehicles and hybrids.

Strongest growth in transport emissions occurs where income grows faster, 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 fossil fuels remain the primary source of transport fuel to 2050.

Chart 3.15: Global transport technology shares

Medium global action scenario



Source: Treasury estimates from GTEM.

9 Learning-by-doing is implemented by assuming efficiency improvement in labour and capital as the global cumulated output grows.

Projections of future commodity prices are inherently uncertain and these have significant bearing on modelling outcomes. To estimate the impacts of commodity prices on the mitigation costs, low and high global oil price path sensitivities have been modelled.

The results show that a 35 per cent lower long-term oil price path raises the global economic cost by more than 3 per cent in 2050. Lower oil prices induce higher emissions, and hence a stronger mitigation effort is needed to achieve the same environmental target.

A higher global oil price path will have different impacts, depending on the extent of the price increase. The results show that increasing the oil price path by approximately 15 per cent reduces the global cost by ½ per cent in 2050; while an increase of approximately 35 per cent increases the global economic cost by 1½ per cent in 2050. To a certain point, higher oil prices curb consumption, which lowers the mitigation effort required to achieve the same environmental target. However, due to the inelastic nature of oil demand, after a threshold is reached, higher oil prices do not induce lower emissions. This makes reaching the same environmental goal harder and requires a greater mitigation effort.

Land use change and forestry

The carbon 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 130-150 Gt CO_2-e from 2013 to 2050.[10] Other South and East Asia and the United States contribute the largest forest sinks across the range of scenarios to 2050.

Other

Agriculture is assumed not to be covered by global mitigation policies until 2031 and emissions continue to grow strongly. 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.

In energy-intensive sectors, mitigation occurs through uptake of low-emission technologies and fuel substitution away from fossil fuels. Global demand for these sectors is largely unchanged with action on climate change.

In both the resource processing and other emission-intensive manufacturing sectors, emissions decline 20 to 38 per cent relative to a world without action in 2020. In 2050, emissions decline by around 46 to 72 per cent in both scenarios.

10 A sink is defined as detracting from, or storing emissions.

Chapter 4: Australia without carbon pricing

Key points

This chapter outlines the path of our economy before accounting for domestic carbon pricing, taking into account other forces at work on the economy.

The Australian economy will continue to grow, generating jobs and income. Nonetheless, the Australian economy is expected to undergo substantial structural change over the next 40 years, driven by demographic pressures, a sustained high terms of trade, and changes in consumer preferences and technology.

Real gross national income (GNI) per person is expected to grow at an annual rate of 1.2 per cent to 2050. While aggregate growth is projected to be strong, growth across sectors and industries will vary.

Over the next decade, the services sector grows the strongest in absolute terms, while mining and related sectors grow the most in percentage terms, owing to the high terms of trade.

The manufacturing sector grows at a slower rate than the rest of the economy — around ½ per cent annually to 2020 — as Australia's economy continues the long-term shift towards services.

The medium global action scenario shows that, in the absence of a carbon price, Australia's emissions are expected to grow to 679 Mt CO_2-e by 2020 (22 per cent above 2000 levels), and to 1,008 Mt CO_2-e (82 per cent above 2000 levels) by 2050.

Electricity sector emissions are projected to grow by over 60 per cent by 2050, driven by a doubling in energy demand. Growth in electricity demand is largely satisfied by increased renewables over the next ten years, but new coal-fired power plants make up the majority of new baseload capacity thereafter.

Even in the absence of a carbon price, household electricity prices are projected to grow significantly over the next ten years, partly driven by higher gas prices and increased costs of new generation capacity, and partly by rising network charges.

Transport emissions continue to grow, but at a slower rate primarily due to higher and rising oil prices.

The Australian economy continues to prosper without a carbon price while other countries take action. However, Australia's prosperity also depends on the actions of other countries that are likely to take measures to penalise countries that do not assist in global mitigation efforts.

The analysis in this report has been updated from the 2008 modelling to incorporate new policies such as the enhanced Renewable Energy Target, updated population projections and international mitigation action.

4.1 Introduction

The global action scenarios tell a story of an Australian economy that will continue to grow, generating jobs and income growth. It is also a story of ongoing and substantial structural transformation driven by demographic change, the high terms of trade, uneven productivity growth across industries, and continued trend changes in consumer preferences. While aggregate growth is projected to be strong, growth across sectors and industries varies, with the strongest percentage growth in mining and related sectors over the coming decade.

If Australia does not act on climate change, growth boosts Australia's real gross national income (GNI) per person by over 63 per cent from 2009-10 to 2050[1], excluding the likely costs from climate change itself.[2] GNI growth per person moderates to an average of 1.2 per cent per year reflecting a falling terms of trade, and slowing labour force growth.

By 2050, Australia's population is projected to increase by 62 per cent to be 36.3 million. Australia's ageing population drives slower economic growth while creating increased demand for health and aged care services. Ageing of the population is projected to slow annual real GDP growth per person by 0.3 percentage points.

International action on climate change has a small negative impact on the Australian economy, through reduced demand for our exports relative to a baseline where global emissions continue to grow strongly, particularly energy exports such as coal and gas. If the world acts to achieve a 550 ppm stabilisation goal, Australia's GNI growth is expected to be reduced by less than 0.03 of a percentage point per year over the period to 2050, or equivalently the level of Australian GNI in 2050 is reduced by around 1.2 per cent relative to a baseline where global emissions continue to grow strongly.

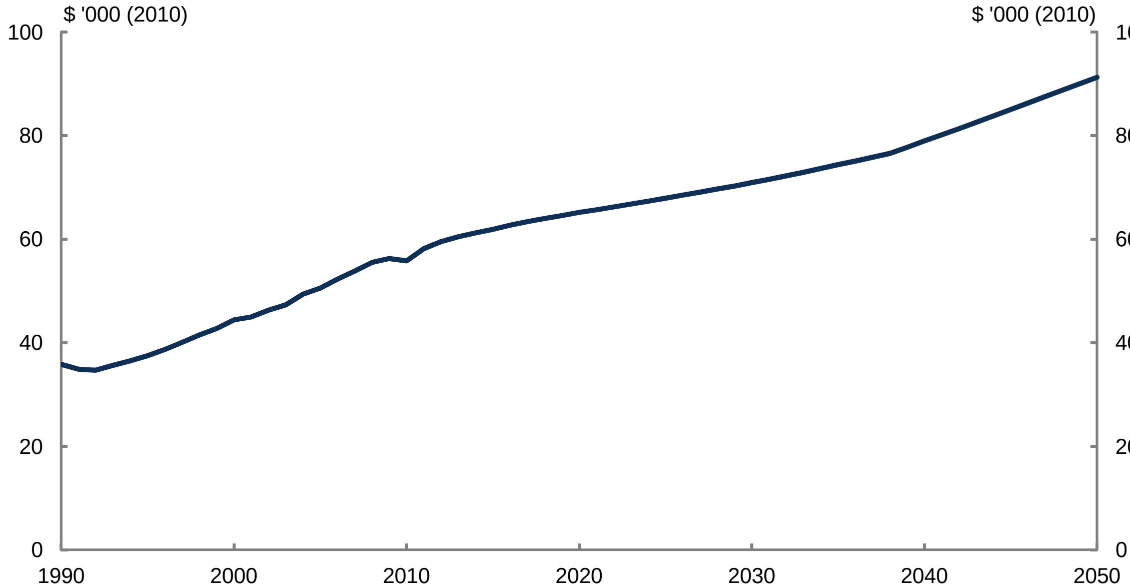
In the medium global action scenario with a 550 ppm target, Australians will be significantly wealthier in 2020 and 2050 than today. Real GNI per person is projected to increase from today's levels of $56,000 to around $65,000 per person in 2020 and around $91,000 per person in 2050 (in 2010 dollars).

While the ageing population slows economic growth, movements in the terms of trade drive national income growth. Improvements in the terms of trade have provided more than half of Australia's GNI growth since the mining boom started in 2004.

1 All years in this publication are Australian financial years, ending 30 June of the year quoted.

2 Current scientific advice is that rising global emissions would eventually result in catastrophic changes to the world's environment. The analysis presented here does not include the economic impacts of a rise in global emissions. As such the modelling provides information on only one element necessary for evaluating climate change policy: the costs of taking action. To form policy judgements, this modelling analysis needs to be combined with a detailed analysis of the economic and social impacts of climate change itself and the benefits of reducing global emissions, analysis that has been provided elsewhere.

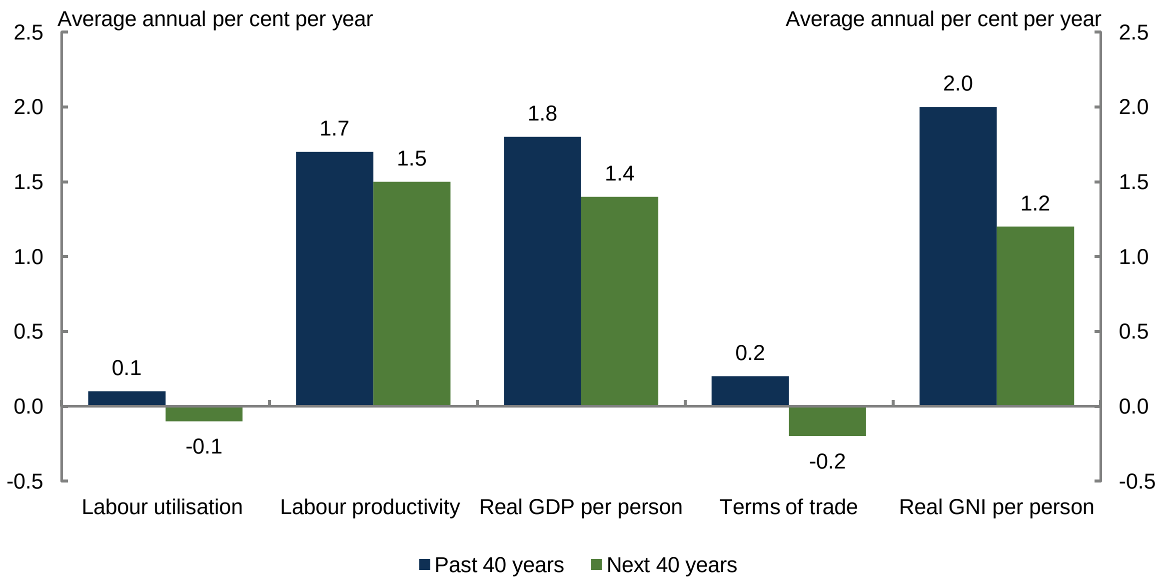
Chart 4.1: Australian real GNI per person
Medium global action scenario



Note: All years in this publication are Australian financial years, ending 30 June of the year quoted.
Source: ABS and Treasury estimates from MMRF.

Terms of trade projections have changed significantly since the previous modelling, now peaking in 2010-11, almost 30 per cent higher than the previous projection. While they gradually unwind, they remain historically high for a considerable time, in contrast to previous modelling, reflecting higher non-rural commodity prices due to stronger demand for Australia's resources and more persistent supply constraints.

Chart 4.2: Real GNI growth by source, 1970 to 2010 and 2010 to 2050
Medium global action scenario



Note: Labour utilisation includes contributions from share of population aged 15 and over, participation rate, unemployment rate and average hours worked. Terms of trade include the contribution from net income transfers.
Source: ABS, Treasury and Treasury estimates from MMRF.

Growth in different industries is important for emissions as some activities are more emission intensive than others. In recent years, energy and emission-intensive industries have influenced

Australia's living standards more than their share of production would suggest. This reflects their export share and high world prices.

These global action scenarios assume other countries that constrain their own carbon emissions do not restrict trade with Australia. In these scenarios, Australia would benefit initially from not pricing carbon. Increases in the cost of producing emission-intensive goods in other countries that take action on climate change would raise demand for Australian emission-intensive goods. However, these scenarios are unlikely to eventuate as other countries are likely to take measures to penalise high-income countries like Australia that are seen to free ride on the emission reduction efforts of others.

A sensitivity analysis was undertaken to examine the effect of other countries imposing a border tax adjustment (BTA) on Australia. Each of Australia's trading partners who act on climate change was assumed to apply a border tax on Australian exports to reflect their carbon content, and a subsidy on their own exports to Australia. A BTA on Australian trade leads to a slight improvement in gross world product compared with the medium global action scenario, as it partially brings Australia into the global mitigation effort. For Australia, such a border tax adjustment would reduce GNI per person, by around 0.3 per cent in 2020, compared to the medium global action scenario.

Box 4.1: Australia's terms of trade and exchange rate

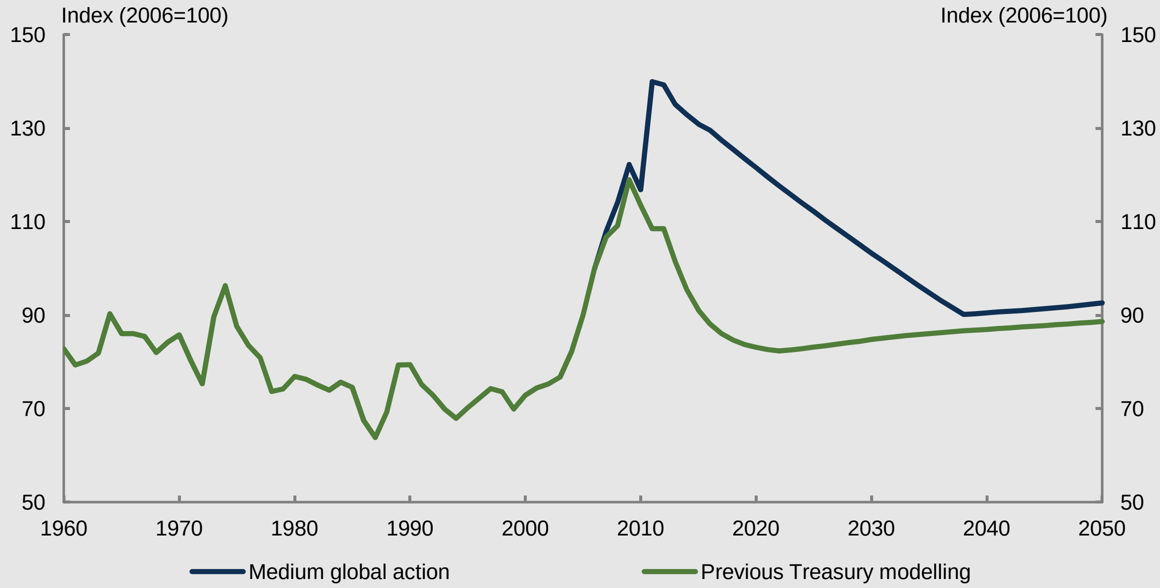
Australia has experienced a sustained increase in the terms of trade throughout the past decade as world demand for non-rural commodities, supported by Asia's rapid industrialisation and urbanisation, has outstripped supply. As a result, Australia's commodity prices and terms of trade rose sharply through the 2000s, except during the global financial crisis (GFC).

Supply has responded slowly to these high prices, despite increasing investment, reflecting long lead times for new resource projects. These supply constraints, coupled with recent weather disruptions, underlie forecasts of a further rise in Australia's terms of trade in 2010-11. As a result, the terms of trade are almost 30 per cent higher in 2010-11 than in the previous modelling. This results in the projected level of Australia's GNI per person in the global action scenarios being around 4½ per cent higher in 2020 than in the 2008 climate change mitigation modelling (Australian Government, 2008).

As world commodity producers increase supply in response to current high prices and rates of return, commodity prices are expected to gradually fall. Hence, Australia's terms of trade are projected to decline by slightly more than 20 per cent over a 15 year period after peaking in 2010-11, and continue falling until 2038. This projected fall in the terms of trade is now more gradual than assumed in the previous modelling due to persistent supply constraints and stronger global demand. After 2038, Australia's terms of trade improve gradually as export prices rise and import prices remain modest, reflecting likely patterns of global productivity growth.

Australia's exchange rate increased from an average of around 60 US cents in the period between the Asian financial crisis and 2004, to an average of 80 US cents during the first stage of the mining boom. The exchange rate has risen further after the GFC, reflecting high commodity prices, and consistent with the 2011-12 Budget, is assumed to be 107 US cents in 2011-12. Over the projection period, the exchange rate moves to maintain Australia's external balance, responding to movements in the terms of trade, trade volumes and income flows.

Chart 4.3: Terms of trade

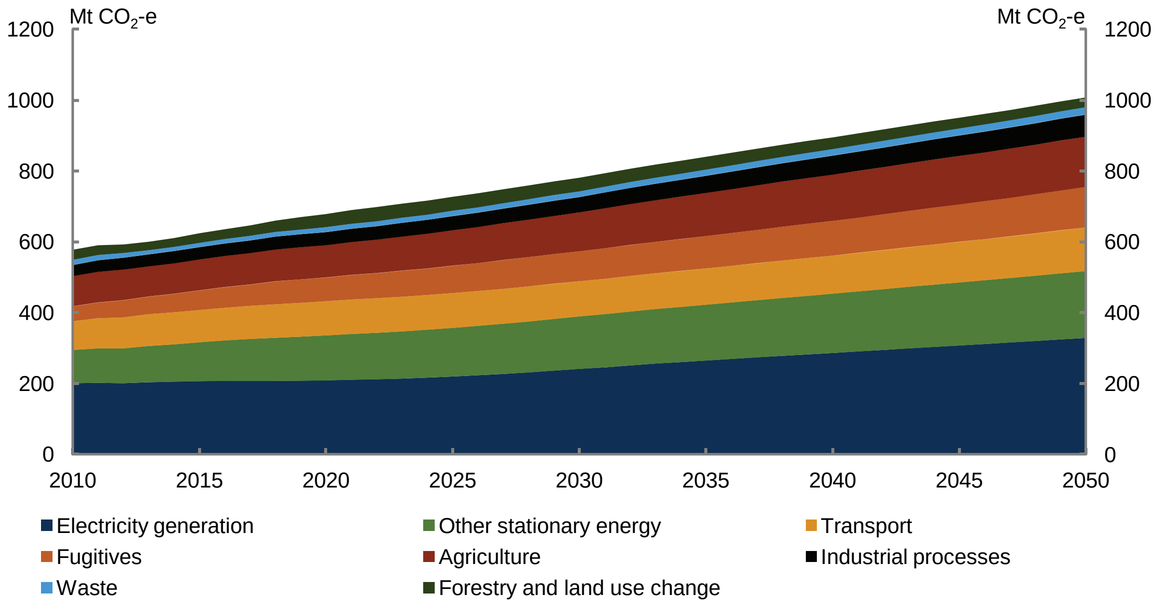


Source: ABS and Treasury estimates from MMRF.

4.2 Emissions

Without a carbon price, Australia's emissions are expected to reach 679 Mt CO_2-e in 2020 (22 per cent above 2000 levels) in the medium global action scenario and 664 Mt CO_2-e in 2020 (20 per cent above 2000 levels) in the ambitious global action scenario. Emissions are projected to continue to increase, reaching 1,008 Mt CO_2-e (82 per cent above 2000 levels) by 2050 in the medium global action scenario and 951 Mt CO_2-e in 2050 (71 per cent above 2000 levels) in the ambitious global action scenario.

Chart 4.4: Australia's emissions
Medium global action scenario



Source: Treasury estimates from MMRF.

Australia's abatement task is significant. To meet the unconditional 5 per cent reduction target by 2020, 159 Mt CO_2-e of abatement is required by 2020. This excludes abatement from the Carbon Farming Initiative (CFI) of 7 Mt CO_2-e in 2020. Without a domestic carbon price, CFI abatement is exported or used in voluntary markets and therefore cannot be counted towards Australia's abatement task.

Australia's emissions mainly flow from energy production, which is dominated by the use of black and brown coal. Stationary energy is the largest source of emissions, at around half of total emissions, of which more than two thirds come from electricity generation. Stationary energy sector emissions grew by almost 50 per cent (97 Mt CO_2-e) from 1990 to 2010 and are projected in the medium global action scenario to grow to 518 Mt CO_2-e by 2050.

The strongest emissions growth in this sector is from electricity generation, which is projected to increase by around 130 Mt CO_2-e by 2050. Demand for electricity continues to rise as the population grows, and reliance on black and brown coal continues.

Table 4.1: Emissions by source
Medium global action scenario

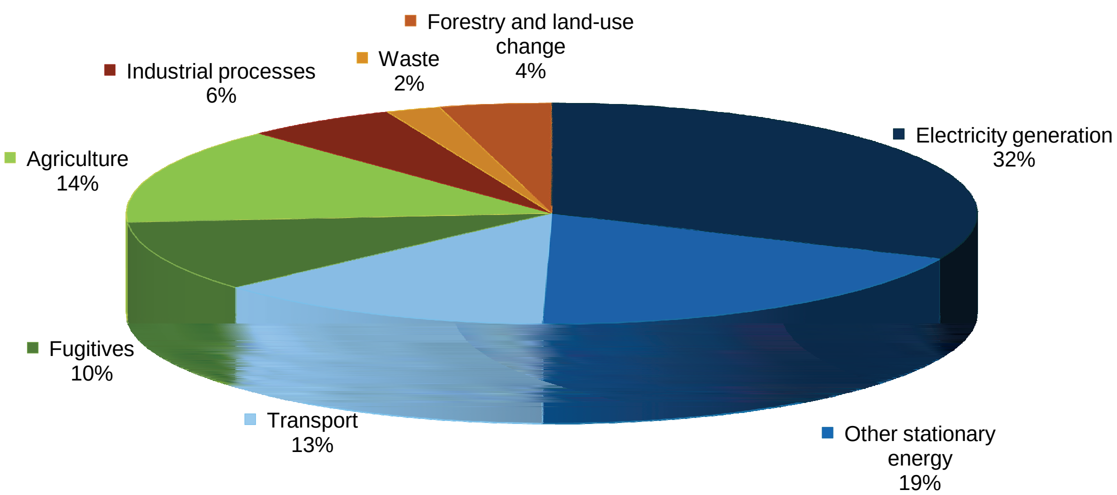
	2010		2020		2050		Growth rate (per cent)	
	Mt CO_2-e	Per cent	Mt CO_2-e	Per cent	Mt CO_2-e	Per cent	2010-2020	2020-2050
Energy	418	72	499	74	755	75	1.8	1.4
Electricity generation	201	35	209	31	329	33	0.4	1.5
Other stationary energy	94	16	127	19	189	19	3.1	1.3
Transport	81	14	97	14	123	12	1.7	0.8
Fugitives	42	7	67	10	114	11	4.8	1.8
Agriculture	86	15	91	13	142	14	0.7	1.5
Industrial processes	31	5	37	5	62	6	1.6	1.8
Land use change	49	8	45	7	37	4	-0.9	-0.6
Forestry	-20	-4	-7	-1	-10	-1	5.2	-1.5
Waste	15	3	14	2	21	2	-0.8	1.5
All sectors	578	100	679	100	1008	100	1.6	1.3

Note: All years in this publication are Australian financial years, ending 30 June of the year quoted.
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. Output growth reflects ongoing productivity growth and strong world demand for Australian agricultural goods. By 2050, emissions from agriculture are projected to be just over 140 Mt CO_2-e.

Fugitive emissions include liberated gas previously trapped within coal seams, emissions released in producing and processing oil and gas, and gas leakage through transmission and distribution. Emissions from the fugitives sector grow strongly and more than double to 114 Mt CO_2-e by 2050. Continued world demand for Australia's fossil fuels, coal and gas, drives this growth although it is partly offset by rising gas prices and global mitigation efforts.

Chart 4.5: Share of cumulative emissions — 2009-10 to 2050
Medium global action scenario



Source: Treasury estimates from MMRF.

The emission intensity of energy-intensive industries is expected to fall slightly to 2050, largely reflecting continual improvements in energy efficiency. As the economy shifts towards the services sectors, the aggregate emission intensity of output is also expected to fall.

Australia's emissions per person are one of the highest in the OECD and amongst the highest in the world. However, they are broadly comparable to similar resource rich economies, such as Canada. In 2009-10, Australia's emissions per person were 26 t CO_2-e and are expected to increase slightly to 2050, without domestic carbon pricing.

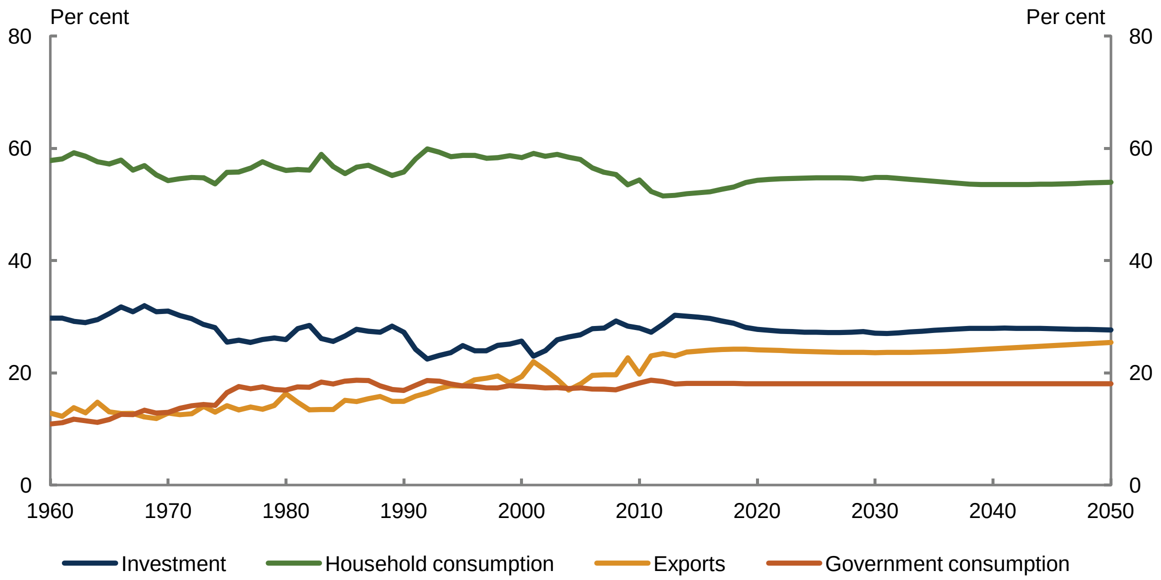
4.3 The macroeconomy

4.3.1 Consumption and investment

Under the medium global action scenario, household consumption remains roughly constant as a share of nominal GDP. Household consumption expenditure increases by more than 160 per cent from 2009-10 to 2050. As Australian per person income rises, household preferences continue to shift to demand more services. Total government consumption (including federal, state and local) is assumed to be broadly constant as a share of nominal GDP.

Chart 4.6: Consumption, investment and export shares of nominal GDP

Medium global action scenario



Note: MMRF estimates after 2010 are spliced onto historical ABS data.
Source: ABS and Treasury estimates from MMRF.

Investment's share of nominal GDP increases in the near term as investment, particularly in mining and related construction, responds to strong global demand for Australia's mineral resources. The massive forward pipeline of mining investment reflects record profitability and the prospect of continued strong demand for commodities. Some $430 billion in resources investment is either underway or planned as at April 2011, up from around $380 billion in October 2010 (ABARES, 2011b). Mining investment in 2009-10 has trebled from its 2004 level and is expected to remain at high levels.

Investment's share of GDP gradually falls in the second half of the 2010s, as the terms of trade decline, increased global supply pushes mining commodity prices down, and current projects are completed. Thereafter, investment's share of GDP remains broadly flat.

4.3.2 Exports

With rising incomes in developing economies and the world's economic geography shifting from West to East, Asia's rising middle class will spend a larger share of its income on more energy-intensive goods, higher value food products and services. Increasing consumer purchasing power and changing spending patterns will strengthen demand for Australia's exports, beyond mining, and substantially change Australia's pattern of trade.

China is already Australia's largest export market, and China and India are projected to be the first and second largest export markets by 2050 — positions held until recently by Japan and the European Union.

Export shares shift between sectors by 2050, with services exports becoming as important as mining and related manufacturing. Australia's exports continue to diversify to 2050.

Australia's exports are more emission intensive than total Australian production. This emission intensity remains high until 2020, then falls gradually as productivity, including in energy use and other emission-intensive inputs, continues to improve. There is a compositional shift to relatively low-emission exports, such as tourism and education services, as demand from the emerging Asian middle class increases.

Box 4.2: Energy price assumptions

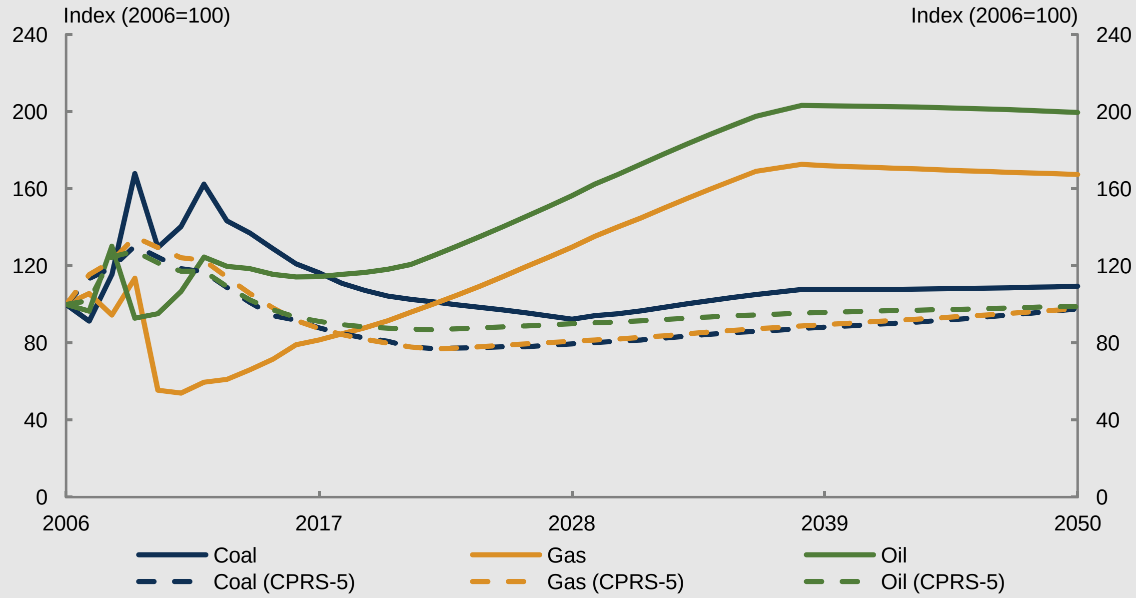
World real prices for oil and coal in the global action scenarios are higher than in previous modelling (CPRS-5) and are expected to remain strong. World gas prices have fallen recently but are expected to grow strongly over the next 25 years.

Coal prices have risen dramatically in recent years. Rapidly increasing demand, particularly from China and India, and a sluggish supply response have driven these rises. Current contractual arrangements indicate prices will continue to remain at elevated levels into 2011-12. Real coal prices then fall through to 2028 in the global action scenarios, as increased supply comes on line and demand growth moderates in response to global mitigation action. Coal prices are expected to stabilise around the level implied by the long-term marginal cost of extraction, which itself is influenced by mitigation action.

Oil prices have risen in recent years and are expected to remain at elevated levels. A range of factors contribute to the rise including: growing demand from developing economies; a fall in spare production capacity; allowances for carbon pricing; and political uncertainty affecting major producers. Prices will continue to be buoyed in the longer term by strong economic demand and rising costs of production. These factors will be partly offset by increases in supply of natural gas liquids and 'unconventional' oil from oil sands and oil shale. However, many unconventional sources have higher greenhouse emission factors, which raise their marginal cost of extraction in a carbon constrained world.

Global gas prices have fallen recently due to weak demand and substantially increased supply capacity. They are expected to recover in the short term as demand picks up, particularly in a carbon constrained world. In the longer term, gas prices will be less affected by long-term contracts and move more in line with prices in spot markets. This narrows the price gap between oil and gas in the projections.

Chart 4.7: Energy commodity prices



Note: The current projections reflect the medium global action scenario and are based on 2010 Australian dollars.
Source: Treasury estimates from MMRF.

4.4 Trends at the sectoral level

Australia's economy is expected to continue its long-term trend towards services and relative decline of manufacturing. Sustained higher terms of trade, driven by Asia's urbanisation and industrialisation, will heavily influence this trend. Stronger demand for Australia's energy and mineral resources remain supportive of commodity prices and continued strength in mining returns draws capital and labour from the rest of the economy. Sustained elevation of the real exchange rate shifts domestic demand towards imports and reduces the competitiveness of exports and import-competing activities, accelerating the decline of manufacturing.

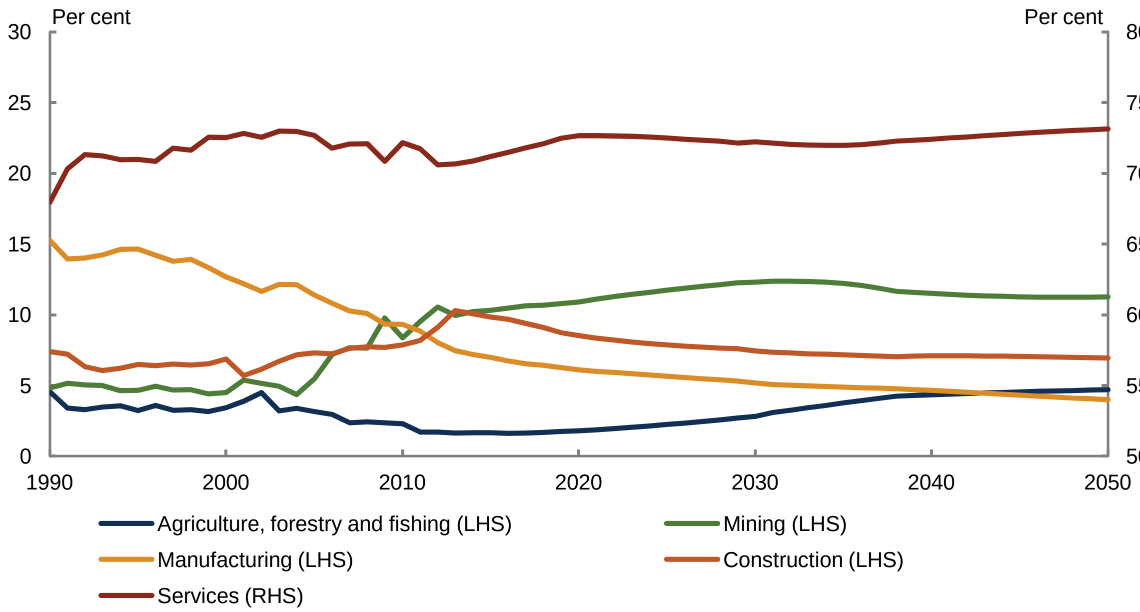
Other supply and demand side factors drive sectoral trends.

On the supply side, near-term rates of productivity growth are based on historical patterns for each industry. For instance, productivity growth in the communications industry is projected to be almost twice the economy-wide average, while productivity growth in other services sectors, such as public administration, is expected to be below average. Over time, industry productivity growth rates converge, reflecting uncertainty about the persistence of historical differences over long timeframes.

On the demand side, consumers continue to adopt new technologies, reshaping the economy. For example, ongoing improvements in information and communication technology, including the National Broadband Network, will considerably change how Australia does business, improve services in education and health, and offer potential to improve productivity.

Australia's services sector, which is currently around two thirds of the economy, expands to meet growing domestic demand and demand from the increasingly rich middle classes in Asia. The services sector, which includes education, tourism, business services, utilities, transport, and retail and wholesale trade, accounts for most of production and employment, and continues to grow slightly faster than the rest of the economy. Under the medium global action scenario, services sector output increases by about 38 per cent between now and 2020, and employment increases more than 16 per cent.

Chart 4.8: Nominal value added shares
Medium global action scenario



Note: Shares are of total gross value added. MMRF estimates after 2010 are spliced onto historical ABS data.
Source: ABS and Treasury estimates from MMRF.

Mining comprises a small share of employment, but has been making an increasing contribution to output recently because of the high prices for mining commodities, particularly coal and iron ore. Investment generated by the current elevated level of commodity prices leads to continuing strong output growth to 2020, as new supply comes on line. As the terms of trade fall from current high levels, growth moderates from 2020 to 2050. Mining output is expected to increase by around 75 per cent by 2020, with employment increasing around 16 per cent.

Higher commodity prices draw capital and labour to the mining sector, where the rate of return is higher. Very strong commodity prices have put upward pressure on the exchange rate, reducing the competitiveness of other trade-exposed industries not benefiting from higher commodity prices, such as manufacturing. Over time, prices fall as more supply comes on line, and the exchange rate falls, assisting those other industries.

Agriculture has higher average productivity growth relative to mining and manufacturing, although the fixed amount of agricultural land limits expansion in production. This supply-side constraint coupled with strong world demand result in increased world agricultural prices over time, raising agriculture's share of total value added. Agricultural output increases by 11 per cent by 2020, with employment increasing by 9 per cent.

Manufacturing is one sector from which resources are drawn towards the higher rates of return in the mining sector. The high real exchange rate and competition from relatively inexpensive Asian manufactures put more pressure on manufacturing.

Despite this, manufacturing output continues to grow over the next decade, albeit at a slow rate. Manufacturing subsectors related to mining and construction perform more strongly than others. Some parts of the manufacturing sector experience absolute falls in output. Continued productivity growth and weak demand growth lead to manufacturing employment falling by 16 per cent by 2020. As the terms of trade decline and the exchange rate falls, pressure on manufacturing eases.

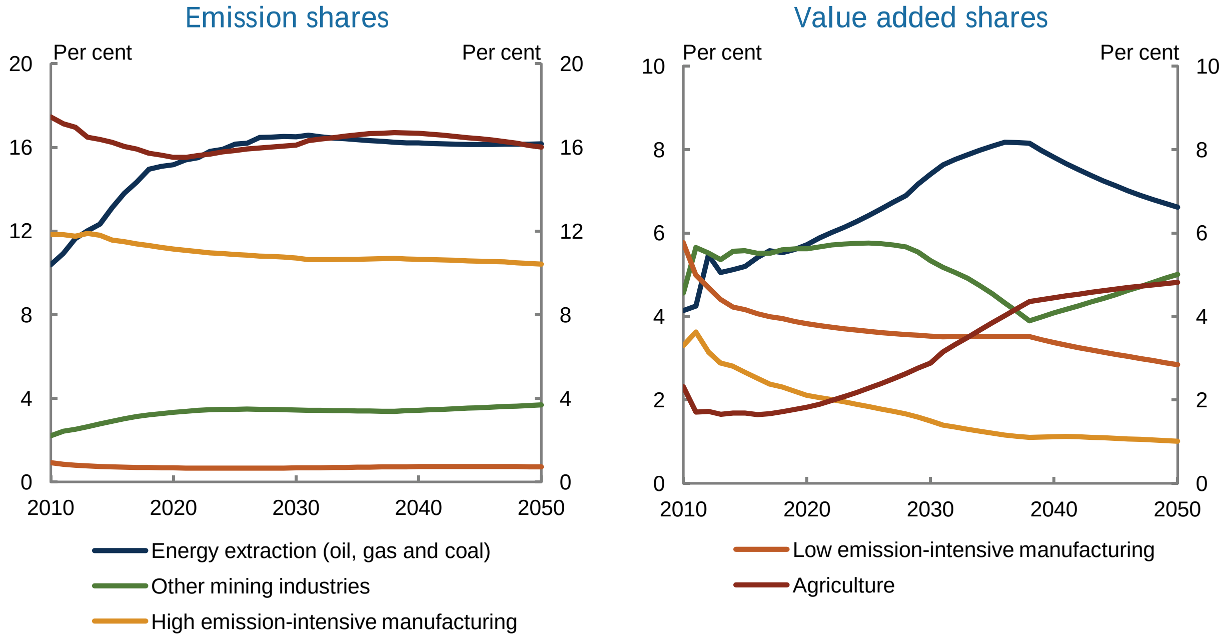
Construction output grows strongly, by 52 per cent by 2020 and with employment increasing by 24 per cent, as the mining boom draws heavily on it. Engineering construction, led by large projects in the LNG, iron ore and coal sectors, continues to increase strongly. In line with mining activity, construction growth moderates over 2020 to 2050, relative to the 2010s, as supply outstrips demand and falling commodity prices flow through to economic activities.

4.4.1 Goods processing industries

The goods processing sectors include energy extraction (oil, gas and coal), other mining, high emission-intensive manufacturing, low emission-intensive manufacturing and agriculture. They produce around 43 per cent of emissions and around 20 per cent of value added output. Under the medium global action scenario, their share of output falls over the next decade, continuing the long-term trend towards a more services-oriented Australian economy. Their share of total emissions is expected to continue to increase up to the middle of the 2030s. In particular, the energy extraction sector grows strongly in the next decade and its share of emissions increases in step with output, due to expansion of both coal mining and gas, particularly for export as LNG.

Chart 4.9: Goods processing industries

Medium global action scenario



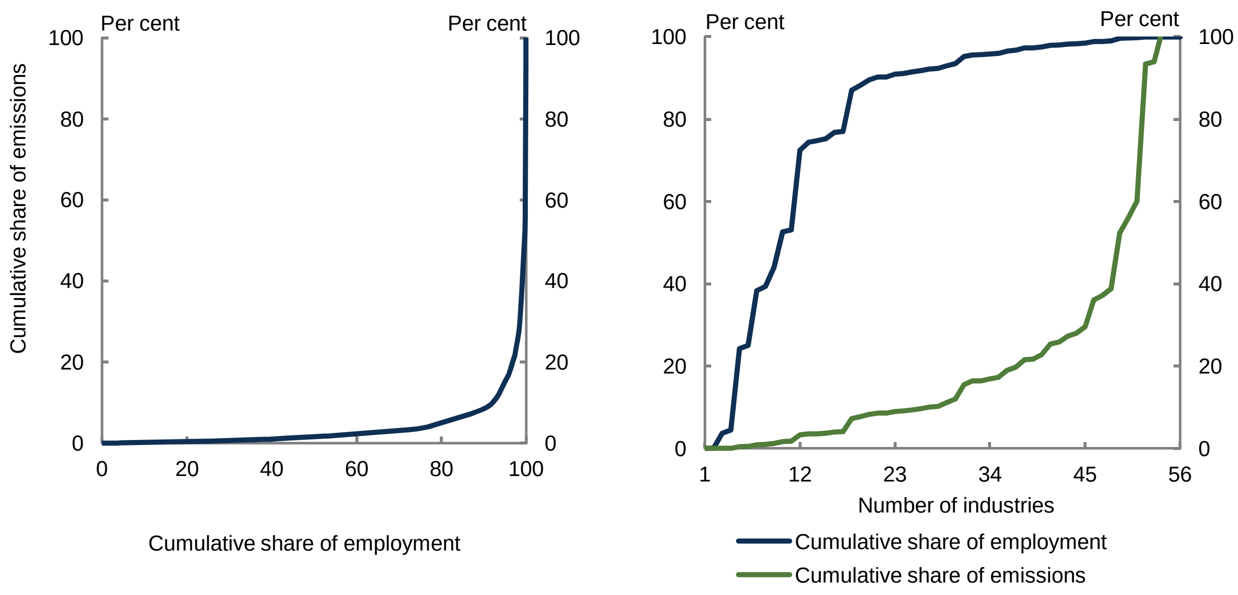
Source: Treasury estimates from MMRF.

It is important to note that the distribution of emissions does not match the distribution of jobs in the economy. Emissions are concentrated in relatively few industries. Indeed, industries that employ more than 90 per cent of the workforce account for less than 10 per cent of emissions. The charts below show employment shares plotted against emission shares in two different ways, with industries ordered in terms of increasing emission intensity.

This means that the majority of the economy will be largely unaffected by structural changes that flow from carbon pricing.

Chart 4.10: Cumulative shares of emissions and employment, by industry — 2009-10

Medium global action scenario



Source: Treasury estimates from MMRF.

4.4.2 Electricity generation sector

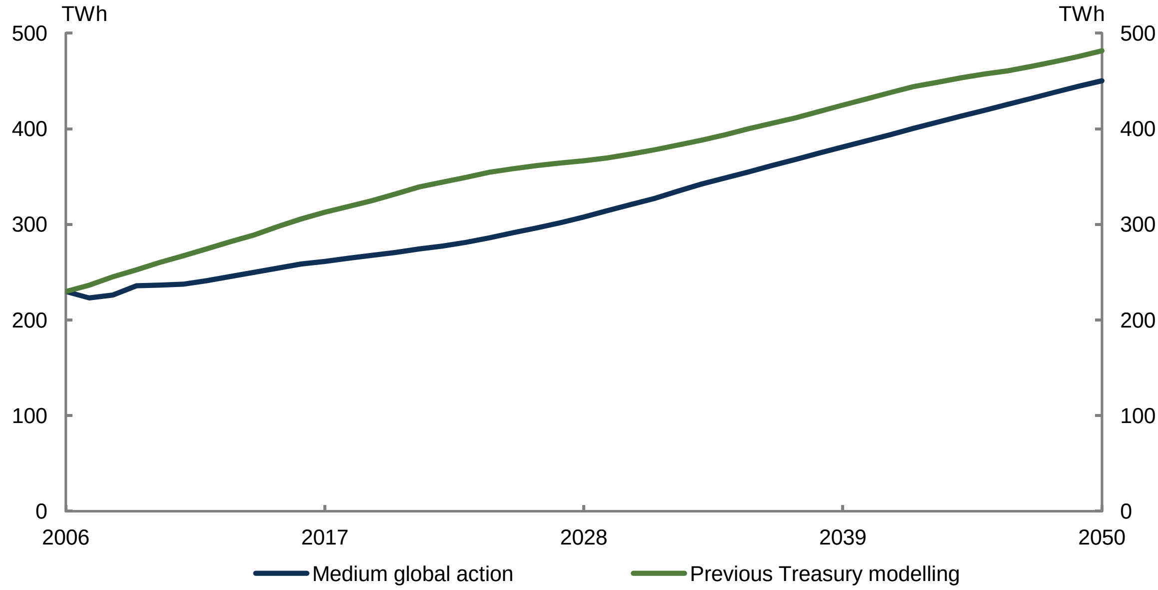
Electricity generation accounts for around a third of Australia's current emissions. In 2010-11, around 70 per cent Australia's electricity generation comes from coal, and a further 20 per cent from gas fired power plants. Coal fired power plants account for almost 90 per cent of electricity sector emissions, and around 30 per cent of Australia's total emissions.

Given the importance of the electricity sector, Treasury engaged two consultants to provide electricity sector modelling (SKM MMA, part of the Sinclair Knight Merz Group) and ROAM Consulting). The two sets of results in this section outline different electricity sector projections. Both sets of results are plausible outcomes within the reasonable bounds of uncertainty.

Electricity demand

In the global action scenarios, energy demand is projected to almost double by 2050, driven by population and economic growth.

Chart 4.11: Electricity generation (sent out)



Source: Treasury estimates from MMRF, SKM MMA and ROAM.

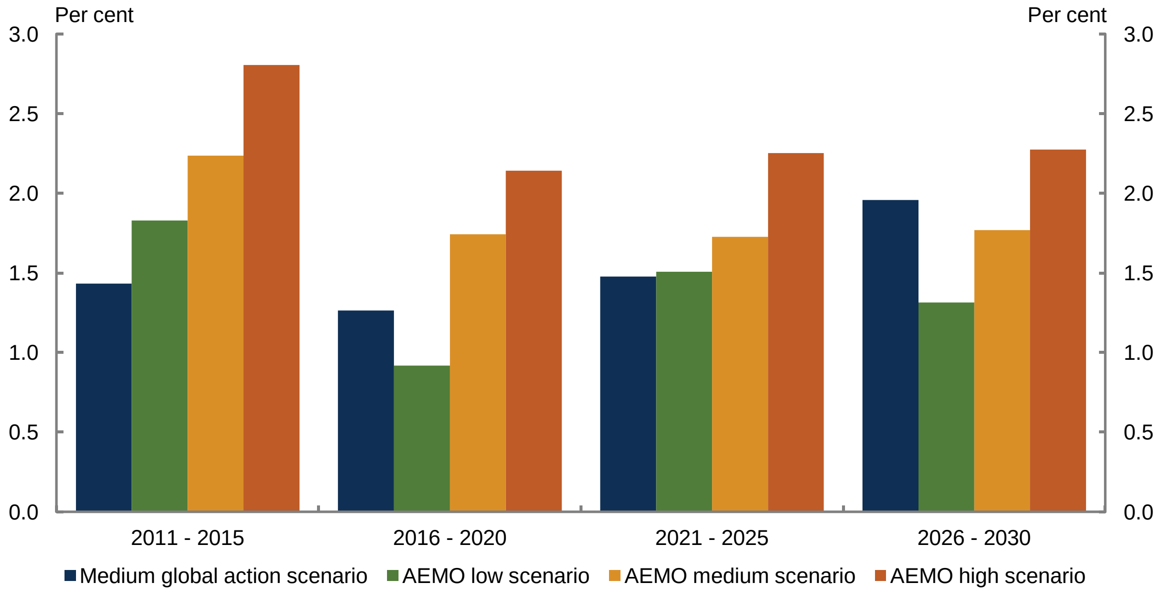
Differences in the electricity demand profiles between the ambitious global action scenarios and the medium global action scenarios are only marginal as a result of offsetting global demand factors. In the ambitious global action scenario, global output growth is slightly slower, and so demand for some Australian exports slows. Offsetting this, mitigation action taken by the rest of the world creates additional demand for electricity-intensive Australian products and output in these industries grows slightly faster.

Short-term projections for electricity demand in the global action scenarios are lower than in previous Treasury climate change mitigation modelling, reflecting different demand growth outcomes and stronger improvements in energy efficiency. Beyond 2020, growth in electricity demand is stronger, largely reflecting stronger population growth.

Demand growth differs among the states due to the electricity intensity of their industry structure. In particular, stronger economic growth in Western Australia and Queensland results in faster growth in electricity demand than the national average. In contrast, demand growth in Tasmania and South Australia is modest.

Growth in electricity generation is at the lower end of the range previously published by the Australia Energy Market Operator (KPMG Econtech, 2010). Key differences relate to different views about improvements in energy efficiency and higher electricity prices.

Chart 4.12: Average annual growth in generation
Comparison with AEMO projections



Source: Treasury estimates from MMRF; and AEMO.

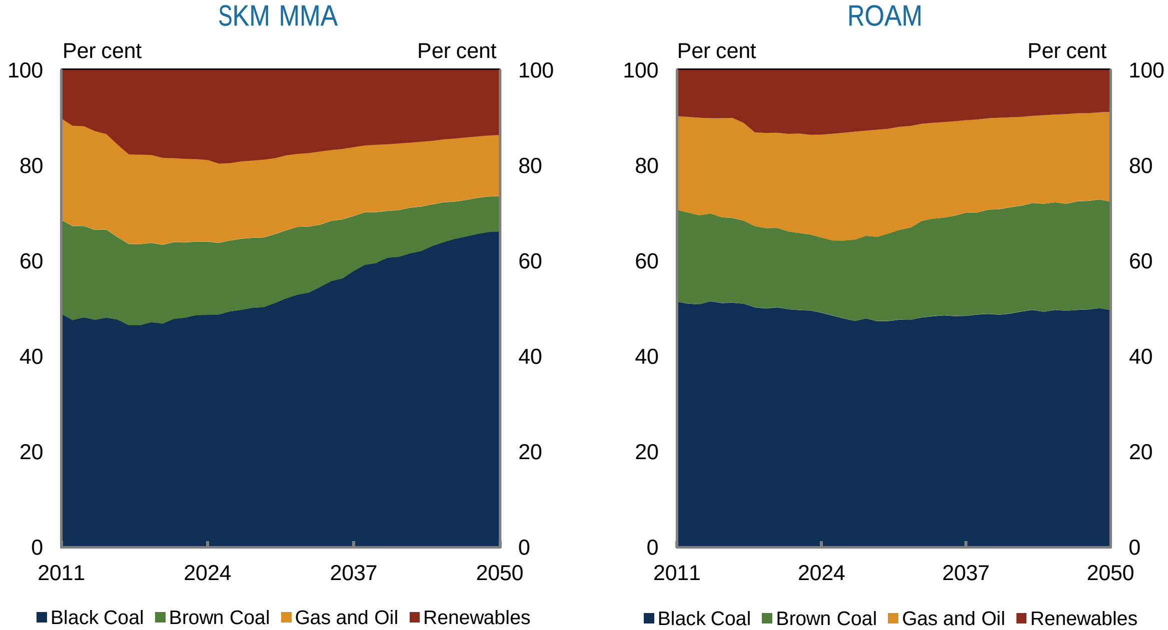
Transformation of the electricity generation sector

Growth in electricity demand to 2020 is mostly satisfied by an increase in renewable generation, driven by the large-scale renewable energy target (LRET). Without a carbon price, total renewable generation reaches around 15 to 20 per cent of total generation by 2020. This includes renewable generation driven by the small-scale renewable energy scheme (SRES).

The Government's 20 per cent renewable target is not met in ROAM modelling. This is because, without a carbon price, the higher relative cost of renewable generation drives electricity retailers to pay the penalty price of the LRET. This limits investment in additional renewable generation.

After 2020, growth in generation from new coal-fired power plants largely satisfies growth in demand. Notwithstanding the introduction of emission standards for new generators, stronger improvements in the technological efficiency of brown coal assumed in the ROAM modelling results in brown coal forming a growing share of the generation fleet after 2030.

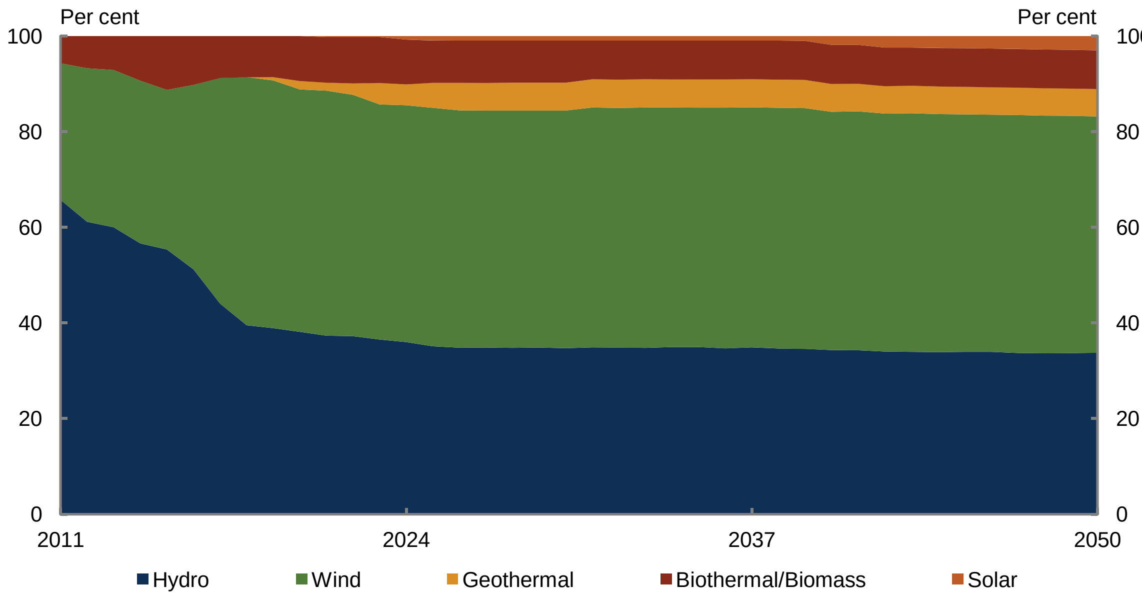
Chart 4.13: Generation fuel mix
Medium global action scenario



Source: SKM MMA; and ROAM.

Hydroelectric generation grows only marginally, as most of Australia's hydroelectric potential is already exploited. Other renewables, particularly wind, increase their share of generation initially in response to incentives created under the LRET scheme. However, without new policies, renewables comprise a declining share from the late 2020s owing to the cost advantage of fossil fuel technology.

Chart 4.14: Renewable technology generation
Medium global action scenario



Source: SKM MMA; and ROAM.

Gas-fired generation capacity grows by around 10 percentage points to around 35 per cent by 2050. Part of this increase reflects the role of peaking gas generation as a back-up for wind baseload generation. However, the use of gas for baseload generation is partly constrained by rising east coast gas prices, which reduces its competitiveness.

New investment

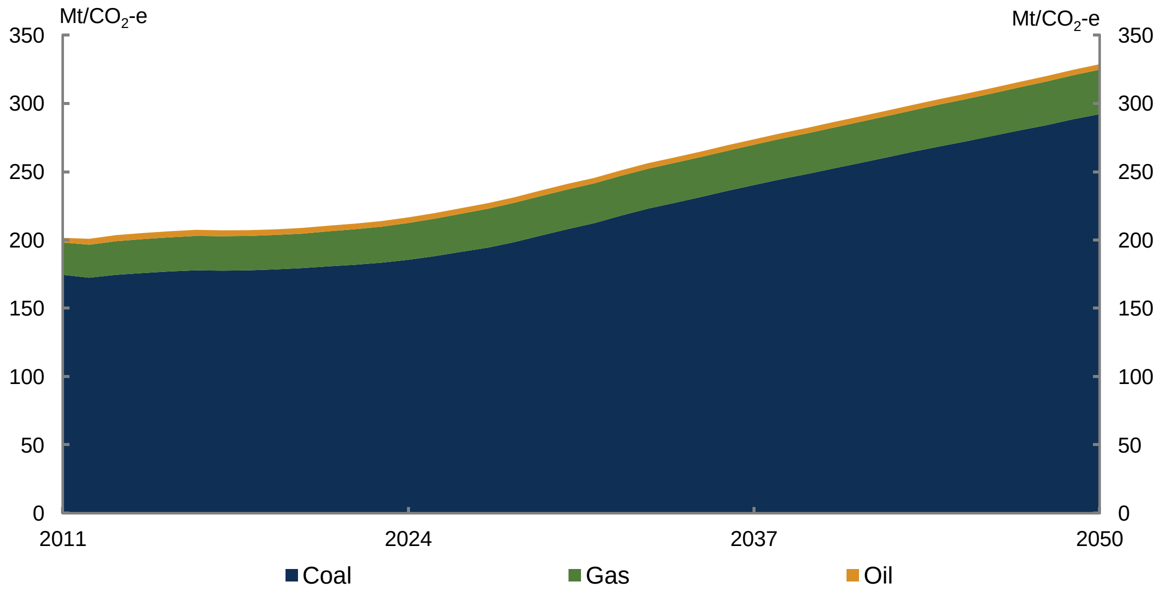
Around $20 billion of investment in new generation capacity is projected over the next ten years, growing to $100 billion to 2050. This includes between $13 billion and $29 billion in renewables, $23 billion in gas and $55 billion in coal generation.

Electricity generation emissions

Annual electricity emissions rise by over 60 per cent by 2050. The emission intensity of electricity generation improves by nearly 14 per cent by 2050 due to technical efficiency improvements, investment in renewable technology to meet the LRET and the Cleaner Future for Power Stations commitment.

Chart 4.15: Emissions by energy source

Medium global action scenario



Source: Treasury estimates from MMRF, SKM MMA and ROAM.

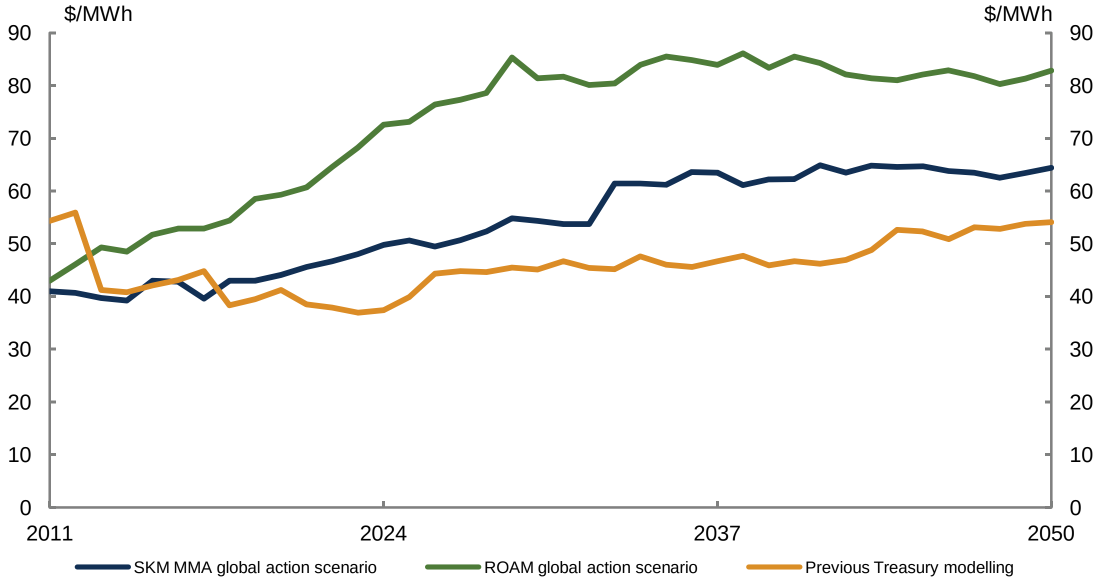
Wholesale electricity prices

Wholesale electricity prices are projected to be higher, even without a carbon price. Prices grow relatively strongly to 2030, mainly driven by rising gas prices and higher capital costs for new electricity generation plants that enter the market to meet growing demand. Wholesale prices are also higher than previously modelled.

While both SKM MMA and ROAM project rising wholesale prices, the extent of these increases differs. This is largely driven by different views of the costs for new electricity generation plant. ROAM generally assumes higher costs for new coal-fired capacity than SKM MMA, and this flows through to higher wholesale prices.

Climate change policy uncertainty is also likely to have a negative impact on the economy. However, quantifying these effects is itself subject to uncertainty. The modelling includes some of the short-term effects of policy uncertainty, to the extent that these have impacted on near-term investment plans. However, over time, continued uncertainty is likely to place far greater upward pressure on electricity prices than is incorporated into the modelled global action scenarios. For example, previous studies have estimated that continued uncertainty could raise wholesale electricity prices by between $1 and $7 per MWh by 2020.[3] The longer that uncertainty prevails, the higher the costs of uncertainty.

Chart 4.16: Wholesale electricity prices



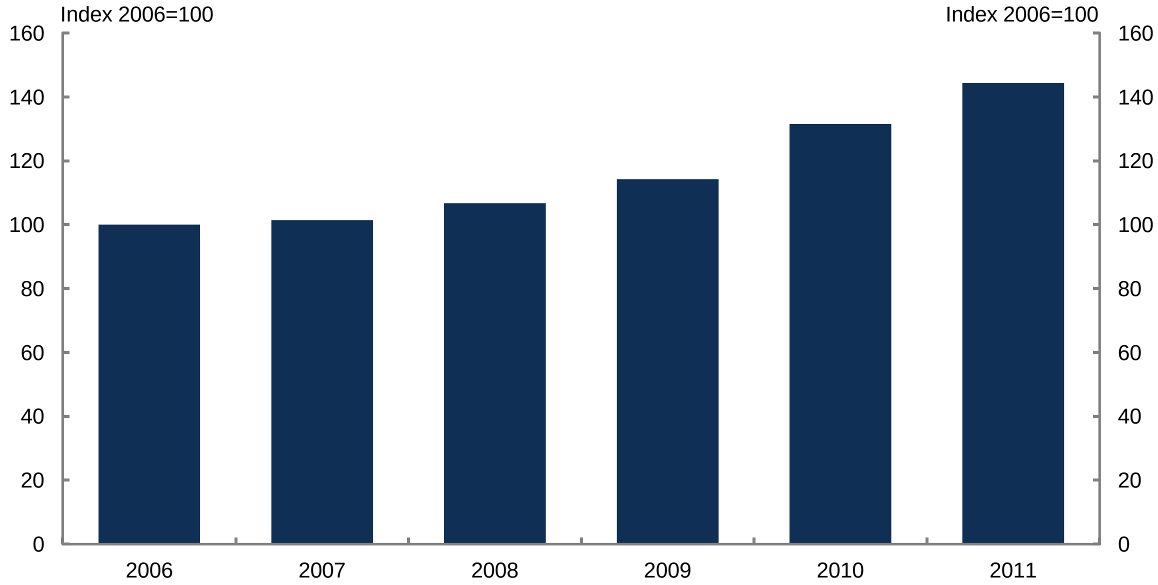
Note: Prices in 2010 dollars.
Source: SKM MMA, ROAM and previous Treasury modelling. Average of medium and ambitious global action scenarios.

Household electricity prices

Over the past five years, real household electricity prices have risen by over 40 per cent.

3 See for example Deloitte, 2011 and Nelson et al, 2011.

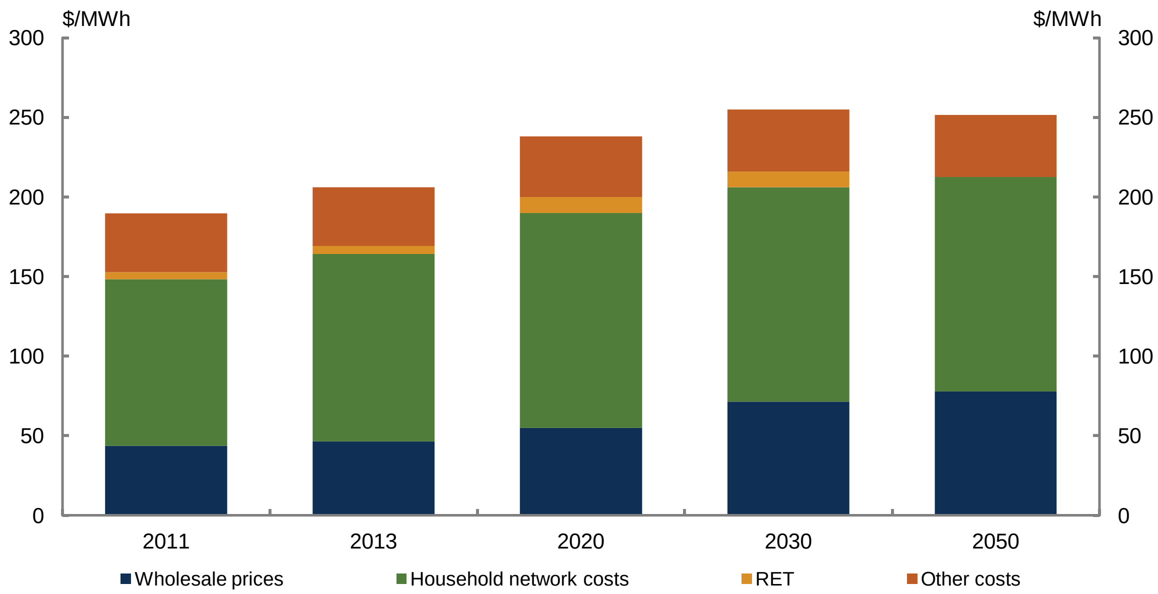
Chart 4.17: Growth in real household electricity prices



Note: Data is four quarters to June except 2011 which is three quarters to end-March.
Source: ABS, 2011a.

Household electricity prices are projected to increase by a further 16 per cent over the next five years, partly from higher wholesale prices but also from rising network charges. The costs from the Renewable Energy Target will remain a small proportion of overall electricity costs but are expected to grow as the target increases.

Chart 4.18: Household electricity prices
Medium global action scenario



Note: Prices in 2010 dollars.
Source: Average of SKM MMA and ROAM.

4.4.3 Transport

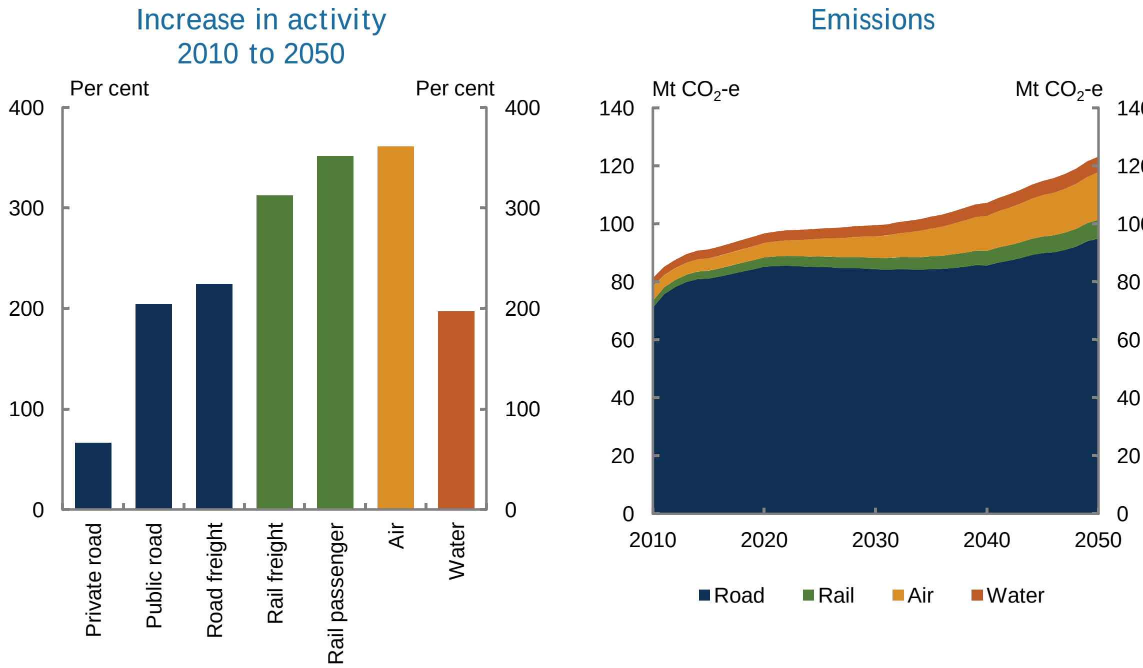
Transport is important to a large country like Australia. In 2010, transport accounted for around 14 per cent of all emissions. The transport sector comprises road, rail freight, rail passenger, air and water transport.

Activity in air, rail freight and rail passenger transport is projected to increase more than four-fold to 2050, driven by growing incomes and economic activity. Rising oil prices are also expected to drive some substitution from road to rail.

Road transport activity will continue to grow as the economy expands. From 2010 to 2050, vehicle travel is expected to treble. Private transport activity grows broadly in line with population growth. Road freight transport grows faster than aggregate economic activity, reflecting the importance of road freight to the mining sector.

Chart 4.19: Transport activity and emissions

Medium global action scenario



Source: Treasury estimates from MMRF and CSIRO.

Road transport[4]

Road transport is the largest transport sector, accounting for over 85 per cent of total transport emissions.[5]

Even without a carbon price, substantial changes are projected in the road transport sector. High and rising oil prices combined with government transport policies are expected to move motorists and businesses into more fuel efficient vehicles and alternative transport fuels. This drives fuel efficiency and lowers emission intensity of the transport sector over time, which in turn reduces growth in emissions.

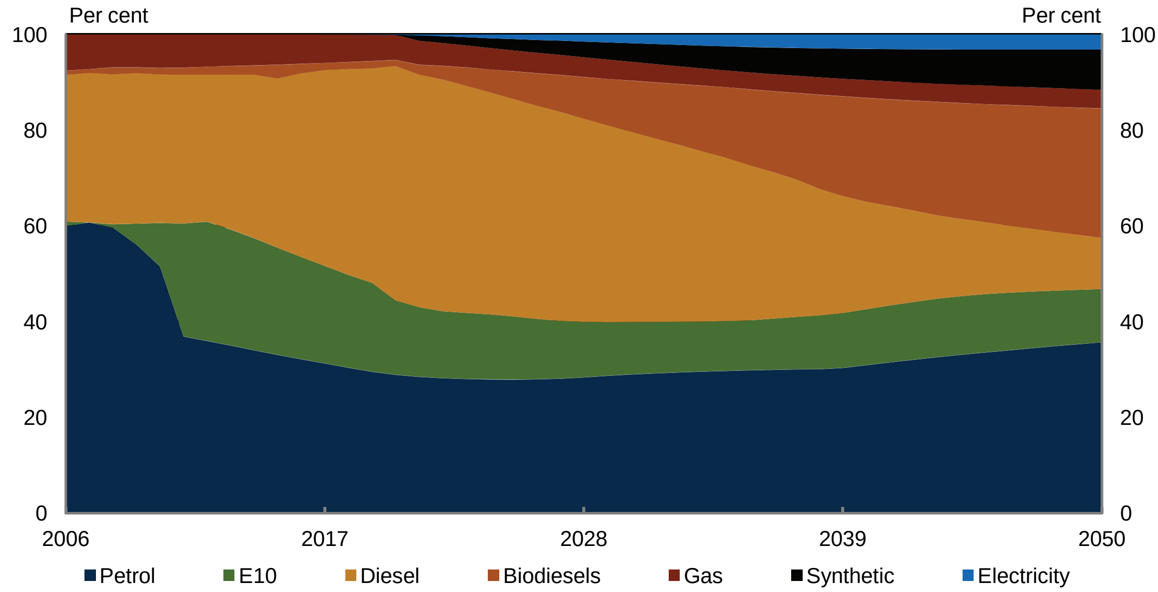
4 The medium global action and ambitious global action scenarios are very similar. For simplicity, results are presented for the medium global action scenario.

5 Only direct emissions from fuel use are attributed to the transport sector. Emissions from the production of fuels are included in the direct emissions of other sectors (for example, the refinery or electricity generation sectors).

Conventional fuels remain the major transport fuels although alternative fuels grow as a share of fuel used. Over the next decade, diesel becomes the dominant fuel used. Diesel consumption rises as diesel engine technology becomes more cost competitive relative to petrol. There is a shift back to petrol from 2030 onwards due to the increased economic viability of petrol-hybrid vehicles and faster improvements in fuel efficiency. From 2020, biodiesel blends begin to displace conventional diesel, and synthetic diesels are also used over time, although in much smaller quantities than biofuels.[6]

Chart 4.20: Road transport fuel mix

Medium global action scenario



Note: Bio-diesels are B20, pure biodiesel and biomass-to-liquid. Synthetic diesels are coal-to-liquid and gas-to-liquid.
Source: CSIRO.

The early reduction in conventional petrol use is a result of E10 adoption, driven by the NSW Biofuels Act.

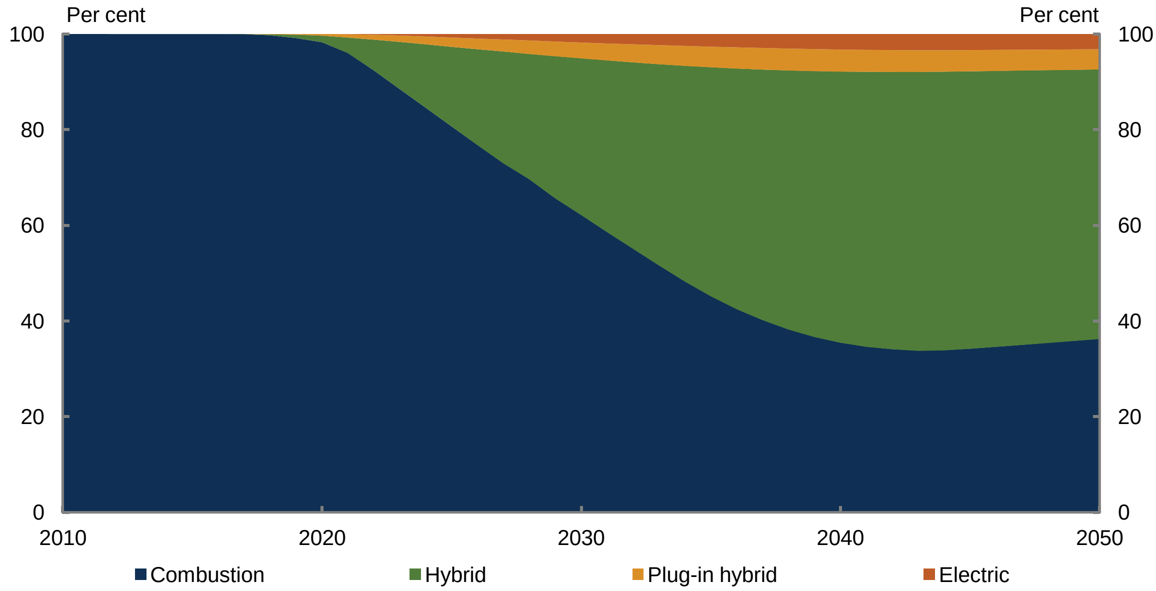
Limited technological change in the existing vehicle fleet occurs in the near term. This reflects the rate of turnover of vehicles in the fleet, which creates a lag between the availability and uptake of new transport technologies.

From 2020, hybrid vehicle uptake is rapid, becoming the dominant transport choice from 2035. In 2050, hybrid vehicles account for over half of road travel. There is also some limited uptake of electric and plug-in hybrid vehicles (3 per cent and 4 per cent respectively) by 2050.

The fuel efficiency benefits of smaller passenger and light commercial vehicles mean that these vehicles form a greater share of their respective markets over time.

6 CO_2 emissions from the combustion of biofuels are not counted in the National Greenhouse Gas Accounts as these emissions are equivalent to the carbon sequestered through growth of feed stocks.

Chart 4.21: Road transport technology mix
Medium global action scenario



Source: CSIRO.

4.4.4 Land sector and legacy waste

Aggregate emissions from the land sector (agriculture, land use change, forestry) and legacy waste are expected to grow over the projection period, primarily driven by strong growth in agricultural output.

Emissions from agriculture are projected to grow by around 65 per cent between 2012-13 and 2050 in the global action scenarios. Output of livestock and cropping, and hence emissions, is driven by export demand.

Sequestration from forestry plantations is expected to decline in the medium global action scenario as the current stock of trees mature and harvesting starts.

Emissions from legacy waste decrease over time as this waste decomposes.

Land use change emissions are driven by deforestation. Baseline land clearing rates are generally assumed to continue at the same level as occurred on average between 2001 and 2006 for all states.[7] The exceptions are Queensland and New South Wales, where land clearing reforms reduce deforestation.

7 Abstracting from the impacts of the Carbon Farming Initiative.

Table 4.2: Emissions from land and legacy waste
($MtCO_2$-e per year)

	Medium global action			Ambitious global action		
	2013	2020	2050	2013	2020	2050
Agriculture	86	91	142	85	90	143
Forestry	-20	-7	-10	-21	-16	-44
Land use change	44	45	37	42	42	30
Legacy waste	9	4	1	9	4	0
Total	119	133	170	115	120	129

Source: Treasury estimates from MMRF, ABARES and DCCEE.

Carbon Farming Initiative

The Carbon Farming Initiative (CFI) helps to lower domestic emissions. However, without a domestic carbon pricing mechanism, this does not contribute to meeting Australia's abatement challenge. Without a domestic carbon pricing mechanism in place, credits created under the CFI would be either sold to foreign purchasers or used in the domestic voluntary market (for example, by firms seeking to be carbon neutral). If CFI credits are exported, then the purchasing country is entitled to count the abatement, not Australia. If CFI credits are used and cancelled in the voluntary market, the Government has committed that this abatement would be in addition to meeting our targets.

In both the global action and policy scenarios, abatement in the land and legacy waste sectors is largely driven by the CFI. The CFI provides an incentive for abatement from livestock, crops, savannah fire management, legacy waste, avoided deforestation and managed regrowth, and carbon plantations that satisfy the CFI criteria. Amongst other things, the CFI requires that abatement be additional and permanent.

The CFI enables the sectors listed to generate abatement credits which can be sold internationally. The modelling assumes that CFI credits are sold at the prevailing world carbon price and this price determines the level of abatement in the global action scenarios. As a result, there is greater abatement from the CFI in the ambitious global action scenario than in the medium global action scenario.

Aside from indirect impacts (abatement driven by rising electricity and fuel prices), no additional abatement is modelled in the domestic policy scenarios from these sectors as they are assumed to be excluded from the carbon pricing mechanism.

Agricultural abatement

Although agricultural sector emissions grow substantially, the level of abatement remains modest to 2050, even with the higher carbon prices of the ambitious global action scenario. It is assumed that non-price barriers to the uptake of abatement opportunities reduce abatement, such as technology and information constraints. Additionally, the cost of an additional unit of abatement from agriculture rises with increases in abatement, as cheaper forms of abatement are exhausted. Hence, the carbon prices in the ambitious global action scenario, which are around double those in the medium global action scenario, result in an increase in abatement of just over 25 per cent.

Forestry and land use change abatement

Reforestation activities covered by the CFI are projected to cumulatively sequester around over 860 Mt CO_2-e by 2050 in the ambitious global action scenario, significantly higher than the 72 Mt CO_2-e in the medium global action scenario.

The variation in area of reforestation between the medium and ambitious global action scenario is driven by a 'tipping point' carbon price at which specific areas of land become economically viable. The decision to invest in plantings takes into account the value of other possible uses of the land and that the CFI requires land to be 'locked up' for 100 years as part of the permanence requirement.

Given the world carbon prices projected in the medium global action scenario carbon prices, only a very limited area of planting is economically viable. The higher carbon prices in the ambitious global action scenario drive a much larger plantation area and, consequently, sequestration increases significantly. With the higher carbon price, 80,000 hectares of additional plantations are added each year on average over the first ten years, and to 2050 the area of plantations increases by 130,000 hectares per year on average.

The forestry abatement estimates are lower than the previous modelling estimates as they now incorporate a broader range of factors such as water interception and pricing, estimation of Kyoto compliant land, environmental restrictions and the risk of reversal buffer under the CFI policy.

Avoided deforestation and managed regrowth provide a significant share of the abatement from the CFI. Abatement from these land use change activities is constrained by permanence requirements and strong growth in agricultural commodity prices which results in rising opportunity costs of avoided deforestation.

Legacy waste

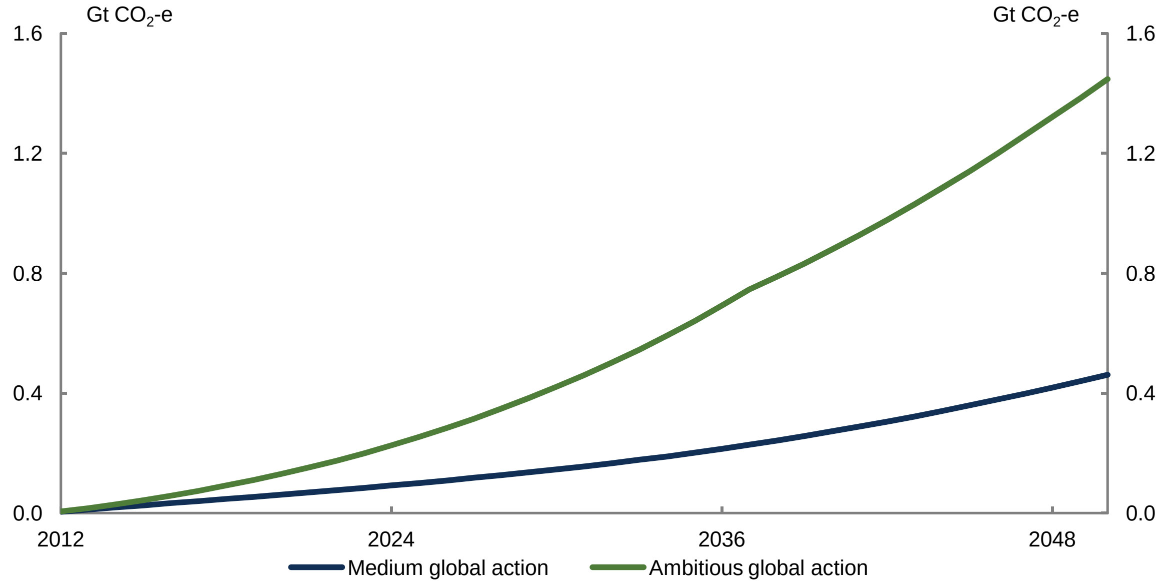
Despite the high uptake of abatement opportunities in the legacy waste sector, abatement falls over time as the stock of legacy waste declines. Proportionally, uptake is in fact high in the legacy waste sector. In the medium global action scenario, nearly half of baseline legacy waste emissions are captured by 2050, and this rises to two thirds in the ambitious global action scenario.

Table 4.3: Abatement from the CFI

	Medium global action				Ambitious global action			
	2013	2020	2050	Cumulative	2013	2020	2050	Cumulative
Agriculture								
Abatement (Mt CO_2-e/year)	2	2	4	100	2	2	5	127
Legacy waste								
Abatement (Mt CO_2-e/year)	2	1	1	36	2	2	1	53
Land use change								
Abatement (Mt CO_2-e/year)	4	4	11	252	6	6	18	403
Forestry								
Sequestration (Mt CO_2-e/year)	<1	<1	6	72	1	9	41	865
Total abatement (Mt CO_2-e/year)	7	7	22	461	11	20	65	1448
Forestry								
Cumulative additional area ('000 Hectares)	1	9	345		78	625	4900	
Per cent of current agricultural land	<0.1	<0.1	0.1		<0.1	0.2	1.3	

Source: ABARES; and DCCEE.

Chart 4.22: Cumulative abatement from the CFI



Source: ABARES; and DCCEE.

4.5 State analysis

Differences in economic growth across the states and territories are largely due to industrial structures and population growth rates. These reflect the impact of the mining boom with resources continuing to shift to more resource intensive states.

South Australia and Tasmania experience slower average growth in gross state product (GSP), largely reflecting slower population growth. Queensland, Western Australia and the Northern Territory have rising shares of the national population, while New South Wales, South Australia, Tasmania and the Australian Capital Territory have falling national shares. The population share for Victoria remains relatively stable.

Table 4.4: Gross state product

Annual average growth rates — medium global action scenario

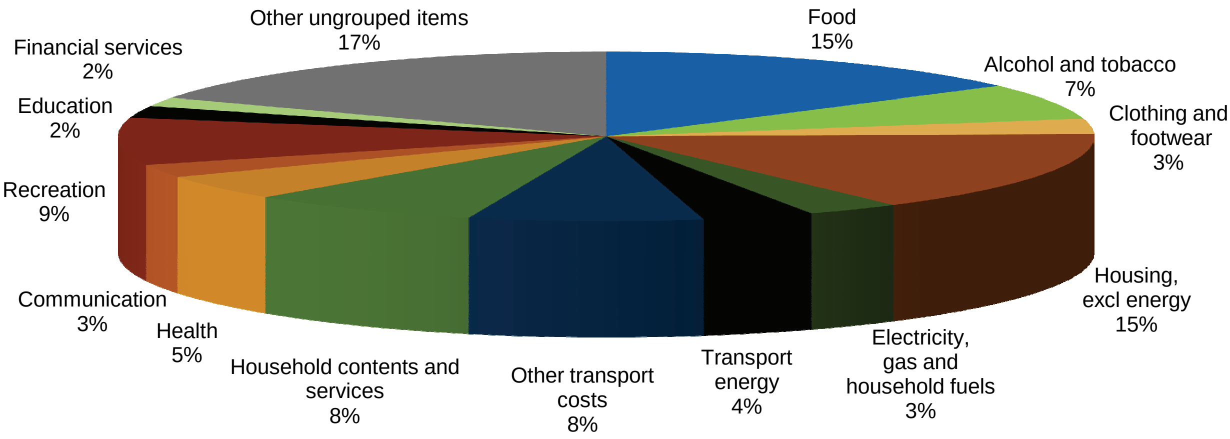
Decade	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
2010s	2.5	2.7	3.6	2.1	4.3	2.0	3.8	2.3
2020s	2.5	2.5	2.9	1.6	3.0	1.9	2.8	2.4
2030s	2.7	2.5	2.8	1.9	2.6	2.1	2.8	2.6
2040s	2.4	2.3	2.6	1.8	2.4	1.9	2.9	2.4

Source: Treasury estimates from MMRF

4.6 Households

Overall, households spend most of their budget on housing, food and recreation. Direct energy consumption represents around 7 per cent of the household budget, comprising transport, electricity, gas and household fuels. Households also consume energy indirectly, through use of public transport and energy embodied in the manufacture, transport and disposal of goods and services over their lifecycle.

Chart 4.23: Aggregate household spending, 2012-13



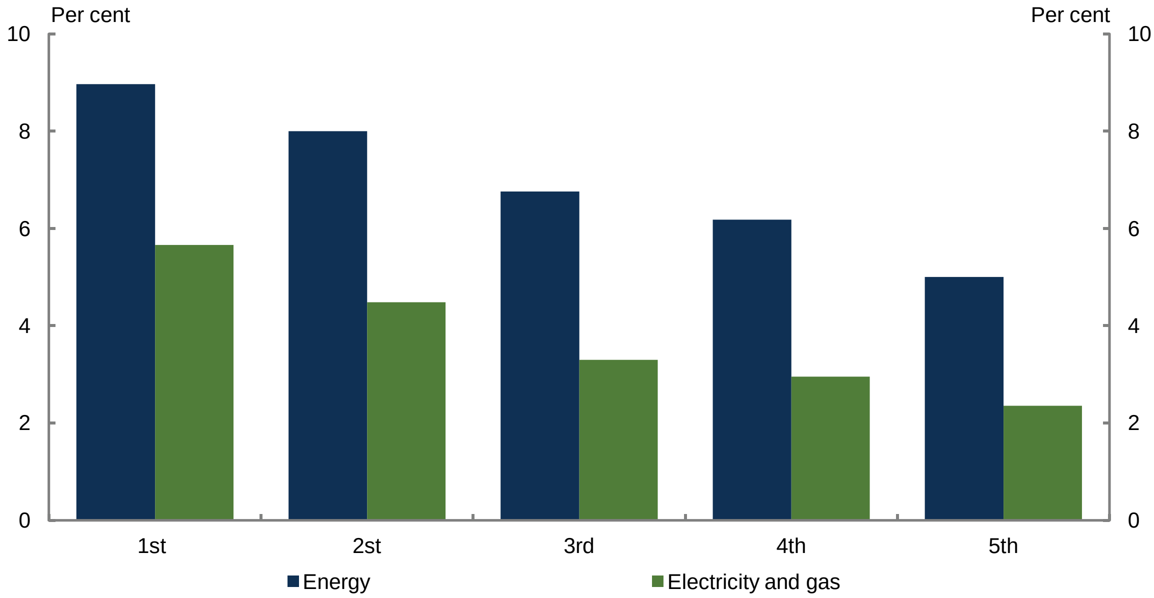
Note: Spending shares are based on aggregate spending for all households included in the Household Expenditure Survey sample. Figures may not add to 100 per cent due to rounding.
Source: Treasury.

Income, household composition and location affect household spending patterns. Spending shares on energy have increased since previous modelling as stationary energy prices have risen more than other prices.

4.6.1 Distributional analysis

Low income household spending on stationary energy is proportionately higher than for middle and higher income households. Low income households in the first quintile spend around 9 per cent of their total budget on energy, and 6 per cent on stationary energy.

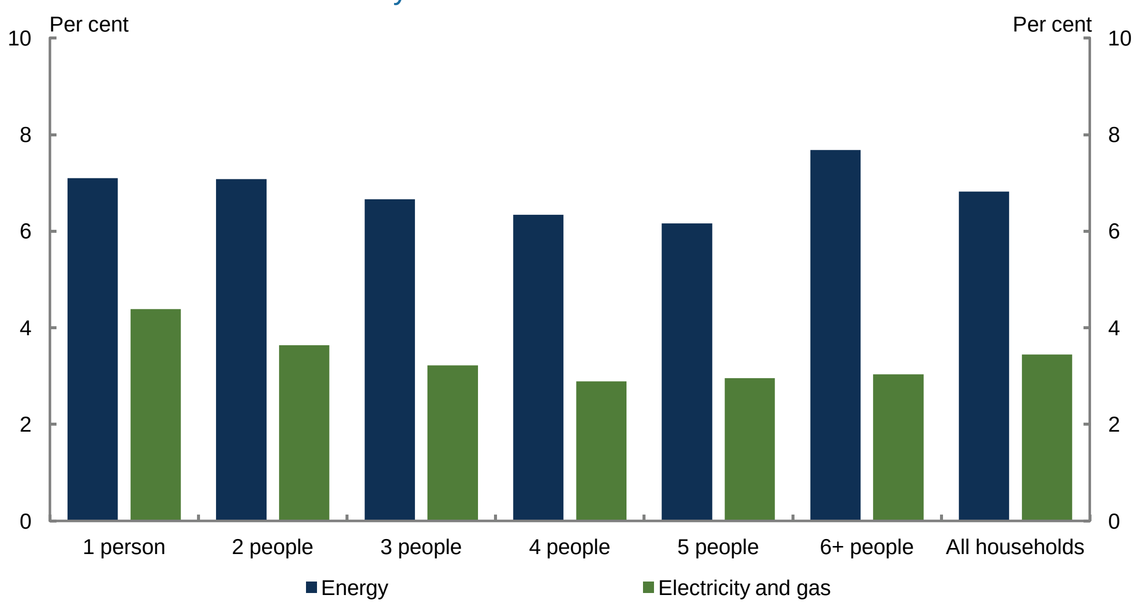
Chart 4.24: Median spending on energy as a percentage of all spending
By equivalised disposable income quintile in 2012-13



Source: Treasury.

The proportion of spending on energy varies markedly with household size, partly due to economies of scale and government transfer payments supplementing the incomes of families with children. Households with two people appear to spend a similar proportion of their total budget on energy as households with one person. In contrast, spending on stationary energy is a higher proportion of the household budget for single-person households.

Chart 4.25: Median spending on energy as a percentage of all spending
By household size in 2012-13



Note: The picture for households with six or more people appears to differ from the trend for smaller households. However, conclusions about their spending patterns are limited due to their small sample size in the Household Expenditure Survey.
Source: Treasury.

Low income households receiving government transfers as their principal source of income spend a higher proportion of their budget on energy than other households (particularly on stationary energy). These households include a high proportion of single and couple pensioners, and the majority of couple allowees with and without children, and single allowees and Parenting Payment Single recipients.

Table 4.5: Median spending on energy as a percentage of all spending

	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	9.3	8.3	6.2	*	*
Other households	8.0	8.1	7.0	6.2	5.1
Spending on electricity and gas					
Households where government payments are the principal source of income	5.9	5.0	3.2	*	*
Other households	4.7	4.0	3.3	3.0	2.4

Note: * indicates that the sample size is too small to derive reliable estimates.
Source: Treasury.

Chapter 5: Australia with carbon pricing

Key points

The Australian economy will continue to prosper as we cut pollution to reduce the risks of dangerous climate change.

Average incomes will continue to rise. In the core policy scenario, gross national income (GNI) per person in today's dollars will be around $9,000 higher in 2020 than it is today and more than $30,000 higher in 2050. From 2010 to 2050, GNI per person grows at an average rate of 1.1 per cent per year in the core carbon pricing policy scenario, compared to 1.2 per cent per year without carbon pricing.

Jobs continue to grow under carbon pricing. In the core policy scenario, around 1.6 million jobs will be created to 2020 and a further 4.4 million to 2050.

Carbon pricing will reduce emissions in Australia and overseas. In the core policy scenario, Australia will meet the emission reduction target of 5 per cent below 2000 levels in 2020 and 80 per cent below 2000 levels in 2050 while the economy continues to grow. Sourcing abatement overseas allows Australia to reduce global emissions at lower cost.

Carbon pricing will drive a structural change towards low emission-intensive products and production processes, and away from more emission-intensive sectors. Most of the economy will be unaffected by these structural changes. Industries employing more than 90 per cent of the workforce account for less than 10 per cent of emissions. While impacts vary widely across industries, the broad sectoral effects are small compared to the normal variation over time driven by productivity, the terms of trade or changing tastes.

Electricity generation will be transformed away from a reliance on coal and towards cleaner technologies, reducing emissions by 60 per cent by 2050 compared to today's levels. The renewable energy sector (excluding hydro) is 18 times as large in 2050 as it is today.

Household consumption continues to grow. The impact on the overall price level is modest at 0.7 per cent in 2012-13 for a $23 carbon price.

All states will continue to prosper while cutting pollution. Effects will differ depending upon their emission intensity and opportunities to diversify to low-emission activities.

The results are broadly similar to the previous modelling exercise in 2008.

Table 5.1: Headline national indicators

	At 2010	At 2020				At 2050			
		Medium global action reference	Core policy scenario	Ambitious global action reference	High price scenario	Medium global action reference	Core policy scenario	Ambitious global action reference	High price scenario
Emission target, change from 2000 level, per cent	-	-	-5	-	-25	-	-80	-	-80
Carbon price, real, $/t CO_2-e	-	-	29	-	62	-	131	-	275
Domestic emissions, Mt CO_2-e	578	679	621	664	534	1008	545	951	323
Change from reference, Mt CO_2-e	-	-	-58	-	-130	-	-463	-	-628
Change from 2000 level, per cent	-	22	12	20	-4	82	-2	71	-42
Emission intensity of GDP, kg CO_2-e/$	0.45	0.39	0.36	0.38	0.31	0.28	0.15	0.26	0.09
Emissions per person, t CO_2-e per person	26.1	26.5	24.2	25.9	20.8	27.9	15.1	26.4	8.9
Internationally-sourced abatement, Mt CO_2-e	-	-	94	-	118	-	434	-	212
GNI per person, $ '000	55.8	65.1	64.8	65.0	64.1	91.2	86.9	90.6	84.2
Change from reference, per cent	-	-	-0.5	-	-1.4	-	-4.7	-	-7.1
Average annual growth, per cent per year	-	1.6	1.5	1.5	1.4	1.2	1.1	1.2	1.0
GDP, $ '000 billion	1.28	1.73	1.72	1.73	1.71	3.66	3.56	3.65	3.47
Change from reference, per cent	-	-	-0.3	-	-0.9	-	-2.8	-	-4.7
Average annual growth, per cent per year	-	3.0	3.0	3.0	2.9	2.7	2.6	2.6	2.5
Employment, million people	11.4	13.0	13.0	13.0	12.9	17.4	17.4	17.4	17.4
Household consumption per person, average annual growth, per cent per year	-	1.6	1.6	1.6	1.5	1.2	1.1	1.2	1.0
Real wages, average annual growth, per cent per year	-	1.9	1.9	1.9	1.7	1.2	1.0	1.1	0.9
Real investment, average annual growth, per cent per year	-	3.2	3.1	3.1	2.9	2.4	2.3	2.4	2.2
Capital stock, average annual growth, per cent per year	-	4.1	4.1	4.1	4.0	2.9	2.8	2.8	2.6

Note: All dollar values are in Australian dollars at 2010 prices. Annual growth rates are from 2010. Initial employment is for 2011.
Source: Treasury estimates from MMRF; and ABS.

5.1 Description of carbon price scenarios

This chapter explores the effects carbon pricing is expected to have on emissions, the Australian economy, the states, the electricity sector, the transport sector and households. The comparison is between medium global action or ambitious global action scenarios, in which Australia does not price carbon, and core policy or high price scenarios, in which Australia prices carbon.

The Australian policy scenarios assume Australia introduces a domestic carbon price into a world where other countries also act to mitigate climate change. They assume a fixed price scheme from 1 July 2012, with the price rising each year, before the Government establishes a flexible price cap-and-trade scheme from 1 July 2015.

The two policy scenarios are:

- Core policy scenario — Assumes a world with a 550 ppm stabilisation target and an Australian emission target of a 5 per cent cut on 2000 levels by 2020 and an 80 per cent cut by 2050. Assumes a nominal domestic starting price of A$20/t CO_2-e in 2012-13, rising 5 per cent per year, plus inflation, before moving to a flexible world price in 2015-16, projected to be around A$29/t CO_2-e.

- High price scenario — Assumes a world with a more ambitious 450 ppm stabilisation target and an Australian emission target of a 25 per cent cut on 2000 levels by 2020 and an 80 per cent cut by 2050. Assumes a nominal domestic starting price of A$30/t CO_2-e in 2012-13, rising 5 per cent per year, plus inflation, before moving to a flexible world price in 2015-16, projected to be around A$61/t CO_2-e.

The policy scenarios cover emissions from stationary energy, some business transport emissions, industrial processes (other than existing synthetic gases), waste (other than legacy waste) and fugitive emissions (other than from decommissioned coal mines). Overall, this covers around two-thirds of Australia's emissions directly and through other means. Agricultural and land sector emissions are assumed to be excluded from a carbon price, although the Carbon Farming Initiative will reduce emissions in both the global and domestic action scenarios. A carbon price with broad coverage from the start provides more scope for low-cost domestic abatement, maximising domestic emission reductions and reducing the need for Australia to source abatement overseas.

The modelling estimates the economic effects of domestic climate change mitigation policy scenarios to 2050. It does not estimate the benefits of averting dangerous climate change.

The Treasury modelling has been prepared to inform policy design and public discussion about carbon pricing. Treasury has modelled a range of scenarios which explore different environmental targets and design features of a carbon pricing scheme. The modelling provides important insights into the economic impacts of carbon pricing at global, national, sectoral and household levels.

Given the long lead times in commissioning detailed modelling of the electricity generation and other sectors, it was necessary to settle on the broad architecture of the global scenarios in late 2010 and the starting prices for the economy-wide modelling analysis in early 2011. As a consequence, the economy-wide modelling presents scenarios with starting carbon prices in 2012-13 of $20 and $30 /t CO_2-e, growing at 5 per cent per year plus inflation before moving to a flexible price. The $20 core policy scenario has a slightly lower carbon price path over the first three years than agreed by the Multi-Party Climate Change Committee (MPCCC), which is for a $23/t CO_2-e starting price, growing at 2½ per cent per year plus inflation.

As it is a separate modelling exercise, with shorter lead times, the modelling of household impacts reflect the agreed starting carbon price of A$23/t CO_2-e in 2012-13.

The Government's plan has been negotiated with the MPCCC, which has agreed on a comprehensive set of measures to tackle climate change. The Government is separately proposing additional transition and abatement measures, which are separately identified in the policy documentation and fiscal costings. These measures include support for jobs in the coal and steel industries and the inclusion of heavy on-road transport in carbon price coverage from 2014-15.

The economy-wide modelling contained in the modelling report does not include all elements of the final policy package as agreed by the MPCCC. For example, in addition to the slightly lower start price, the core policy scenario assumes unlimited international permits over the entire period, a binding 100 per cent facility allocation cap and that heavy on-road vehicles are subject to an effective carbon price from 2014-15.

Even so, it is expected that the outcome of any updated modelling would closely match the results of the core policy scenarios.

Table 5.2: Policy scenario assumptions

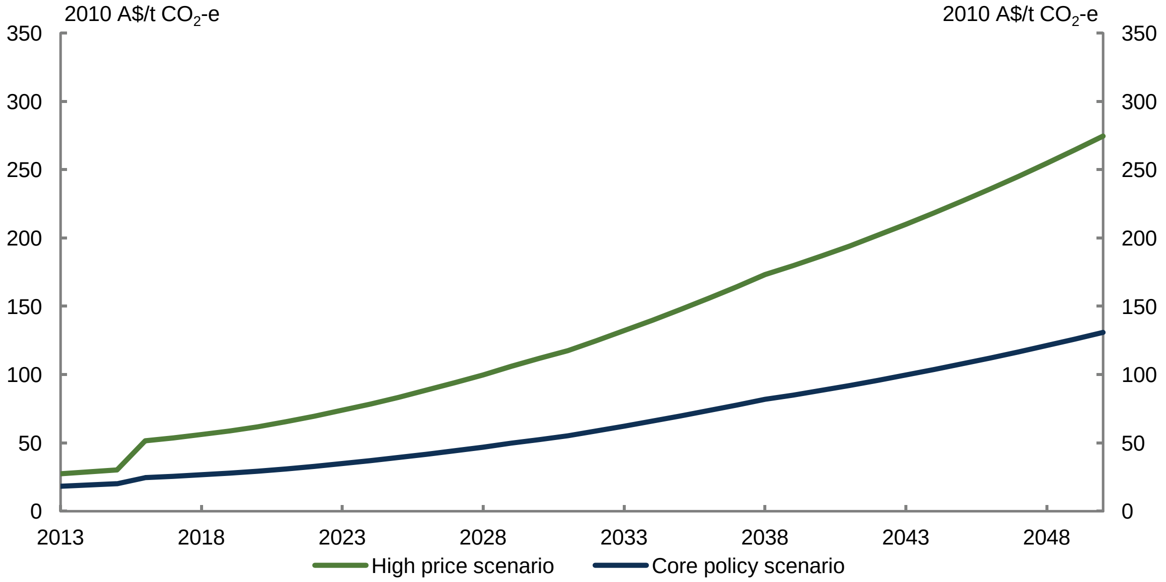
		Core policy	High price
Carbon price nominal A$/t CO_2-e	2012-13	$20 $23 for household modelling	$30
	Escalator	5 per cent per year plus inflation for two years	
	Flexible price	Projected to be $29 in 2015-16	Projected to be $61 in 2015-16
World stabilisation target		550 ppm	450 ppm
Australian emission reduction target		5 per cent below 2000 levels by 2020; 80 per cent below 2000 levels by 2050	25 per cent below 2000 levels by 2020; 80 per cent below 2000 levels by 2050
Emission-intensive trade-exposed industries (EITE)		Assistance starts at 94.5 per cent or 66 per cent, depending on intensity, and declining at an annual rate of 1.3 per cent per year.	
Fuel		An effective carbon price is applied to: businesses' combustion of liquid fuels from 2012-13 (except light vehicles, agriculture, forestry and fishing) and heavy on-road vehicles from 2014-15, through the fuel tax credit system; and aviation fuel from 2012-13 through the domestic aviation excise system. Private passenger cars are excluded.	Based on the Carbon Pollution Reduction Scheme as at 24 November 2009.
Household assistance		Remaining scheme revenue is allocated to households as lump sum payments.	
International linking		Unrestricted from 2015-16.	
Exclusions		Agriculture, forestry (in terms of mandatory liability for emissions), decommissioned mines, legacy waste and emissions of synthetic gases.	
Allocation		Set as straight line reductions: from the end of the Kyoto commitment period to achieve the 2020 targets; and from 2020 to achieve an 80 per cent reduction on 2000 levels in 2050.	

5.1.1 Carbon prices

The modelling assumes domestic carbon prices are fixed initially. After the initial fixed price period, the Australian price follows the international price through linking, either bilaterally or through a multilateral market. Australia's carbon price equals this global price, adjusted for exchange rate changes. From the start of the flexible price period to 2050, Australian carbon prices rise by an average 5 per cent per year plus inflation, reflecting growth in the foreign currency carbon price (based on the Hotelling rule discussed in Appendix B) and gradual depreciation of the Australian dollar.

More ambitious global stabilisation targets require higher carbon prices. The high price scenario assumes the world agrees to a more ambitious stabilisation target and the subsequent global carbon price is more than twice as high (in Australian dollars) as in the core policy scenario.

Chart 5.1: Australian carbon price



Source: Treasury estimates from MMRF.

5.2 Impact on emissions

As part of its plan to secure a clean energy future, the Australian Government has adopted a stronger long-term target. The Government's new target is to reduce greenhouse gas emissions by 80 per cent below 2000 levels by 2050.

Australia's stronger long-term target is consistent with the findings of the Intergovernmental Panel on Climate Change's (IPCC's) Fourth Assessment Report (IPCC, 2007a). It found that, to stabilise carbon pollution concentrations at 450 ppm, developed countries should reduce emissions by between 80 and 95 per cent of 1990 levels by 2050. For Australia, this is equivalent to a reduction of between 80 and 95 per cent below 2000 levels because Australia's emissions grew only slightly between 1990 and 2000. The IPCC judges that stabilisation of carbon pollution concentrations at 450 ppm would provide about a 50 per cent chance of limiting global temperature increases to less than 2 degrees Celsius.

This long-term target of reducing pollution by 80 per cent by 2050 is consistent with targets announced by other developed countries. For example, the United Kingdom has a target of 80 per cent below 1990 levels by 2050, while the European Union has proposed a target of 80 to 95 per cent below 1990 levels by 2050.

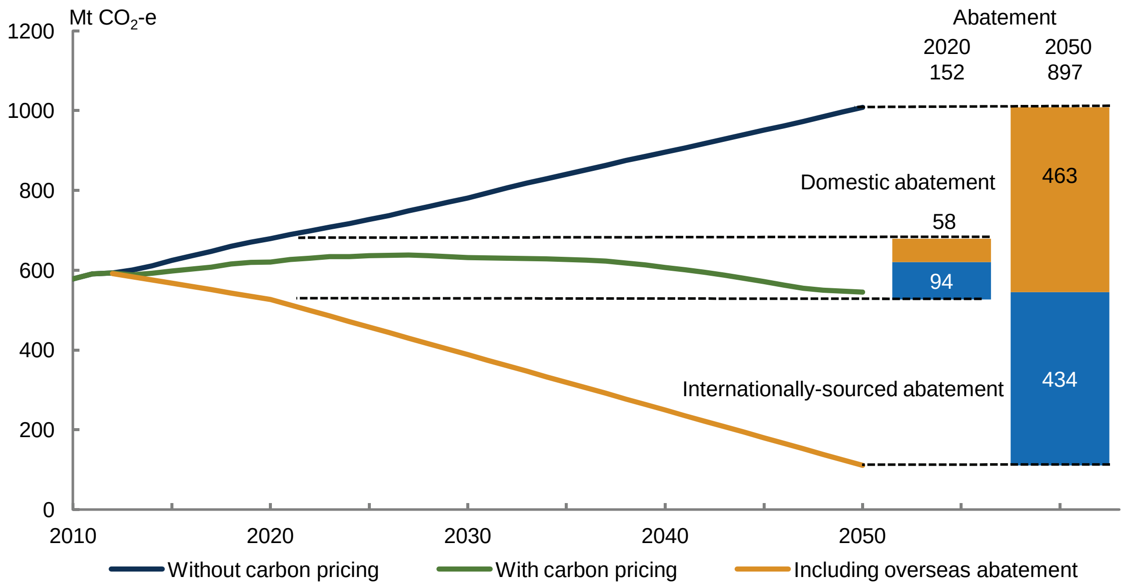
The two domestic policy scenarios reflect this stronger long-term target. To meet these targets, Australia can abate domestic emissions or source international abatement by purchasing permits overseas. As climate change is a global problem, a global response that facilitates abatement across borders will deliver environmental outcomes at least economic cost.

5.2.1 Abatement

Australia's abatement task is substantial, as outlined in Chapter 4. To meet the unconditional -5 per cent target, Australia's emissions need to fall 152 Mt CO_2-e in 2020. To achieve the -80 per cent target by 2050, Australia's emissions need to fall 897 Mt CO_2-e. These figures assume that Carbon Farming Initiative credits, worth 7 Mt CO_2-e in 2020 and 22 Mt CO_2-e in 2050, are sold back into the domestic carbon pricing scheme and help to reduce the abatement task.

Pricing carbon results in deep cuts in domestic greenhouse gas emissions. In the core policy scenario, the carbon price produces: around 58 Mt CO_2-e of domestic abatement and 94 Mt CO_2-e of international abatement in 2020; and 463 Mt CO_2-e of domestic abatement and 434 Mt CO_2-e of international abatement in 2050. Despite these cuts, Australia's domestic emission levels continue to rise for some time. In the core policy scenario, Australia's domestic emissions increase around 10 per cent from 2010 to the late 2020s. They then fall significantly as decarbonisation of the electricity sector accelerates.

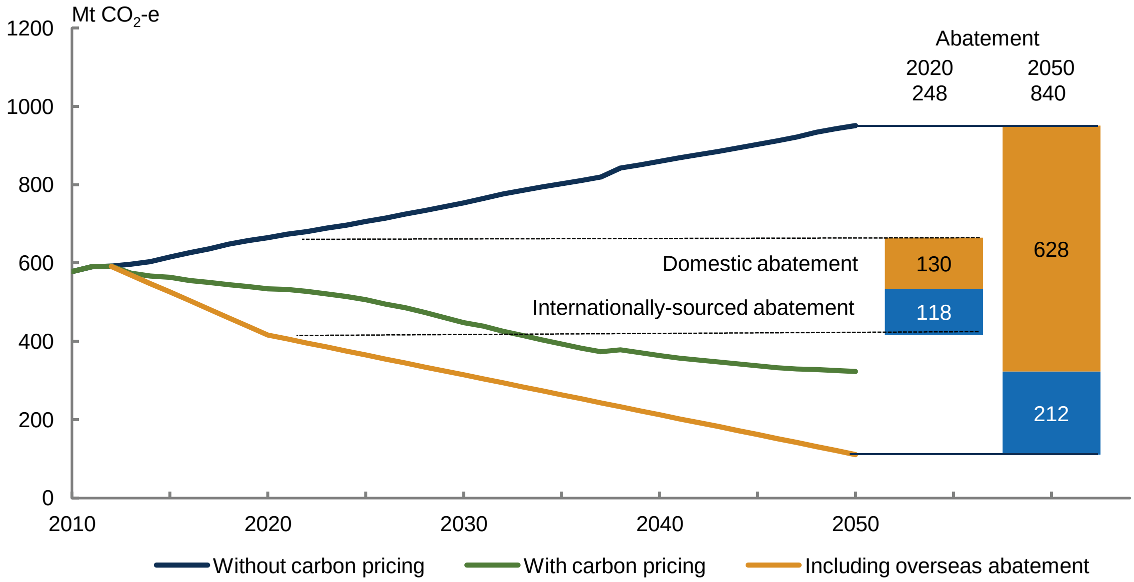
Chart 5.2: Australian emissions in the core policy scenario



Note: Emissions without carbon pricing include CFI abatement.
Source: Treasury estimates from MMRF.

In the high price scenario, carbon pricing produces significantly more domestic abatement in the short term, resulting in emission levels that are lower than today's levels in the first year and that decline thereafter. Around 130 Mt CO_2-e of domestic abatement is achieved in 2020 and 628 Mt CO_2-e in 2050. Emissions are 8 per cent lower than today's levels in 2020 and 44 per cent below today's level in 2050. In the high price scenario, the abatement task in 2050 is slightly smaller than in the core policy scenario because ambitious global action lowers demand for Australia's energy exports slightly and this reduces Australian emission levels slightly without carbon pricing.

Chart 5.3: Australian emissions in the high price scenario

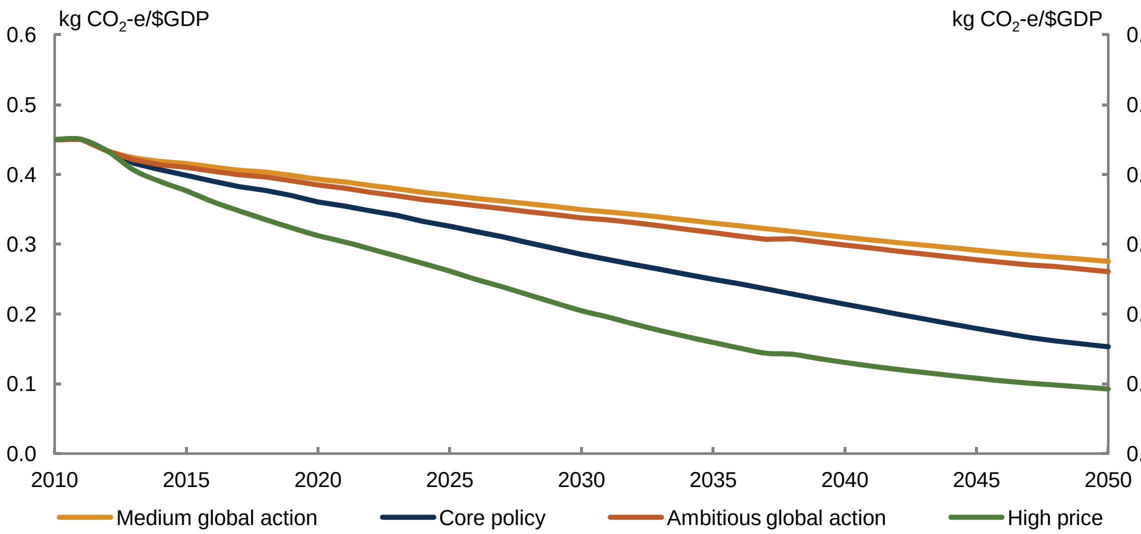


Note: Emissions without carbon pricing include CFI abatement.
Source: Treasury estimates from MMRF.

Pricing carbon breaks the link between economic growth and emissions growth, so large cuts in emissions have modest economic costs. The modelling shows growth in the economy as a whole is only marginally slowed, but in both policy scenarios the emission intensity of the economy — measured as the amount of carbon pollution created per dollar of output produced — falls sharply. In the core policy scenario, the emission intensity of the Australian economy falls from around 0.45 kg CO_2-e/$GDP in 2010 to around 0.15 kg CO_2-e/$GDP in 2050.

Reductions in the emission intensity of the economy occur in two ways: changes in production processes within industries through the adoption of cleaner technology; and the movement of resources towards lower emission-intensive industries, which makes them grow more rapidly, and away from the relatively small proportion of higher emission-intensive industries, which grow slower. In the core policy scenario, reductions in emission intensities within industries account for two-thirds of the reduction in the emission intensity of the whole economy in 2050. The restructuring of the economy to take advantage of new opportunities in a low carbon world accounts for the other one-third of the reduction in the economy's emission intensity.

Chart 5.4: Emission intensity of Australian GDP



Source: Treasury estimates from MMRF.

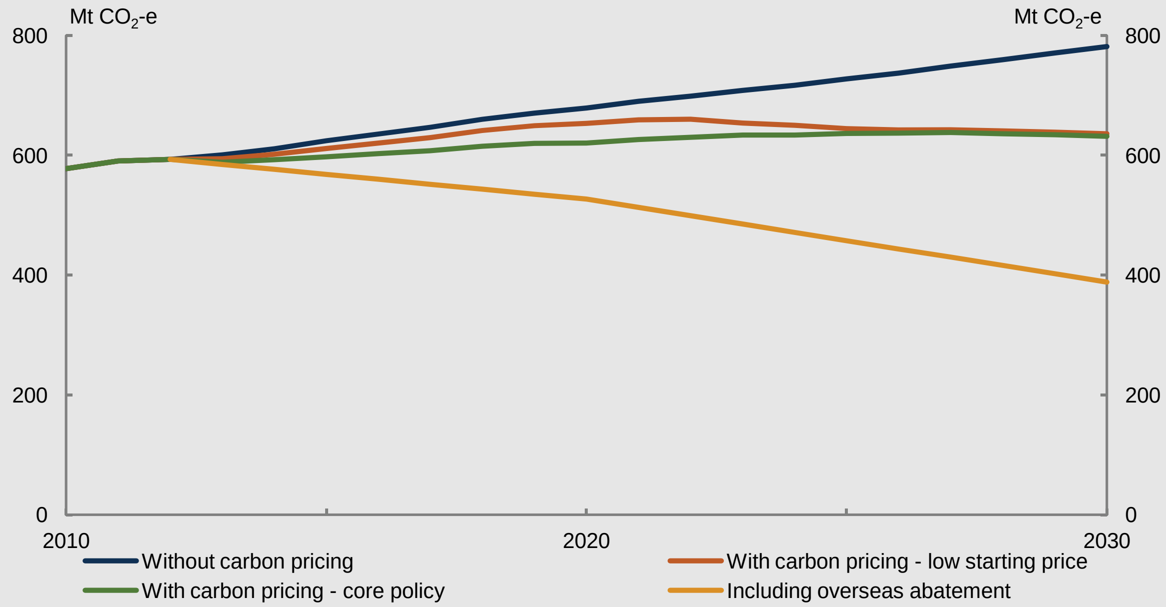
Box 5.1: A lower starting price means slower transformation of the economy

Starting with a lower carbon price and a longer fixed price period would slow the decarbonisation of the economy and result in a larger jump in carbon prices when eventually the economy transitions to a flexible price cap-and-trade scheme.

A sensitivity analysis was run with a nominal domestic starting price of A$10/t CO_2-e in 2012-13 rising 5 per cent per year plus inflation over a fixed price period of ten years. The scenario assumes a transition from a fixed price of around A$19/t CO_2-e in 2022 to a world price projected to be around A$49/t CO_2-e. Like the core policy scenario, it assumes a world with a 550 ppm stabilisation target and an Australian target of a 5 per cent cut in emissions on 2000 levels by 2020 and an 80 per cent cut by 2050.

In this 'low starting price' scenario, much less domestic abatement is achieved in the first decade. The lower carbon price induces only 26 Mt CO_2-e of abatement in 2020, less than half of the domestic abatement in the core policy scenario. Since domestic abatement is lower in 2020, the emission target is met with more abatement sourced overseas.

Chart 5.5: Australian emissions to 2030 with a lower starting price



Note: Emissions without carbon pricing include CFI abatement.
Source: Treasury estimates from MMRF.

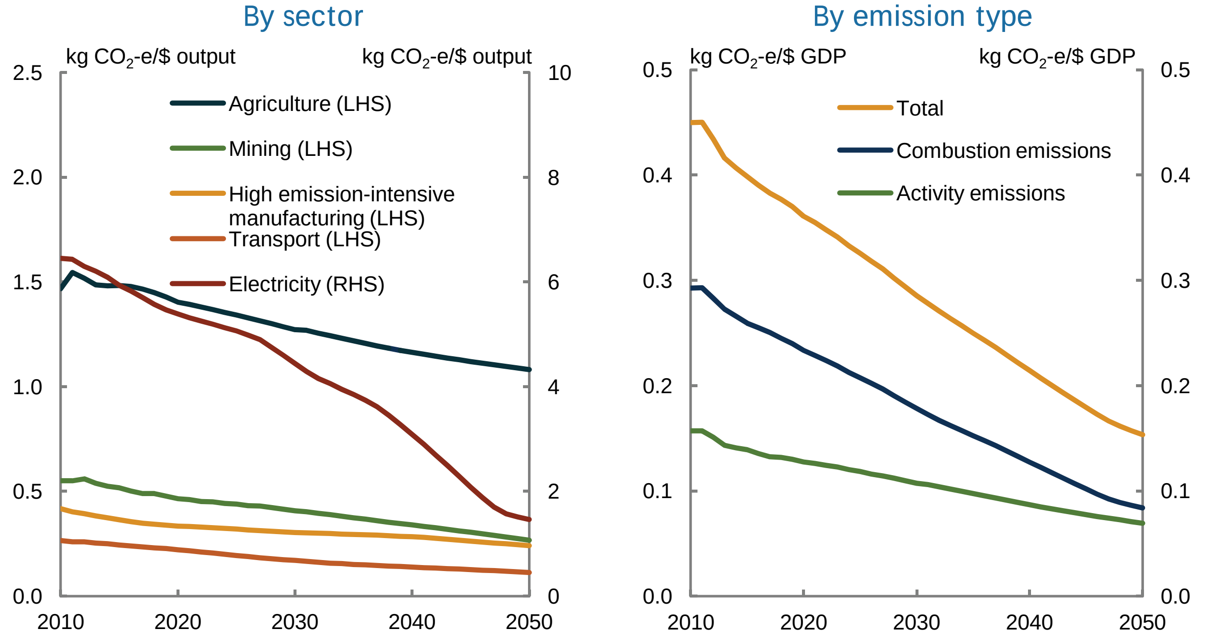
5.2.2 Emissions by sector

Emission reductions occur at different rates across sectors and over time, reflecting differences in mitigation opportunities. While it is hard to know in advance where the cheapest mitigation opportunities will arise, a carbon price mechanism ensures that abatement occurs at minimum cost to the economy and international linking ensures that domestic abatement does not occur where it would be more expensive than sourcing abatement overseas.

Although all sectors show reductions in emission intensity under carbon pricing, higher mitigation costs slow reductions in emission intensities in some sectors. Over the period to 2050, high emission-intensive manufacturing reduces its emissions intensity by 42 per cent, mining by 52 per cent and the electricity sector by 77 per cent. All economic activities become less emission intensive over time, with larger reductions in combustion emissions than activity emissions.

Chart 5.6: Emission intensity

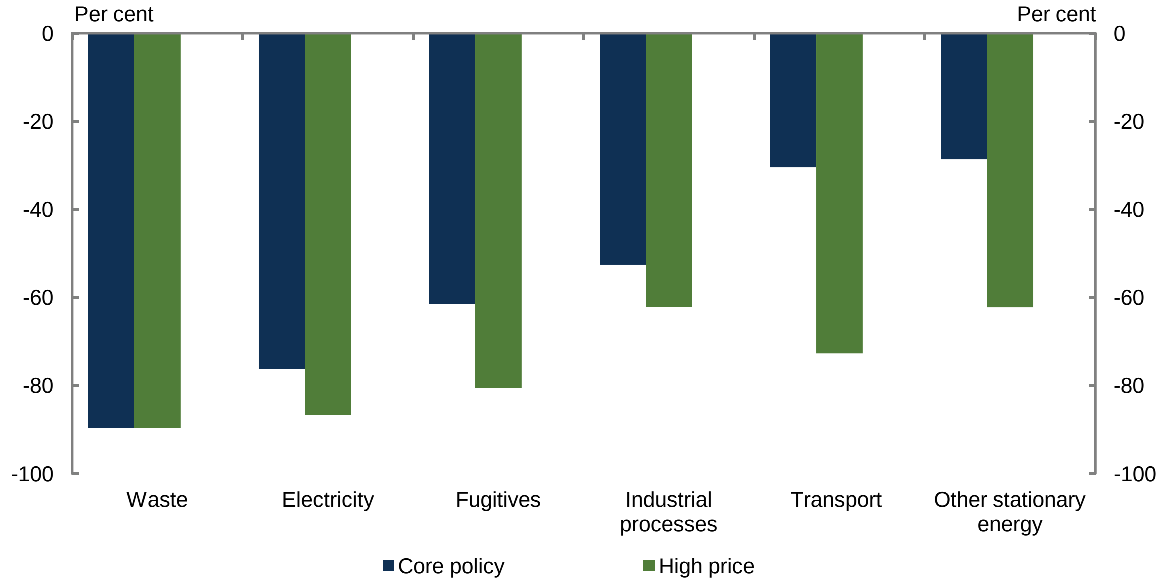
Core policy scenario



Note: The agriculture sector excludes forestry in these two charts. Levels of emission intensity are not comparable across the two panels; the left panel shows the emission intensity of gross output, the right panel the emission intensity of GDP.
Source: Treasury estimates from MMRF.

Chart 5.7: Emission reductions by sector

Change from global action scenarios, 2050



Source: Treasury estimates from MMRF.

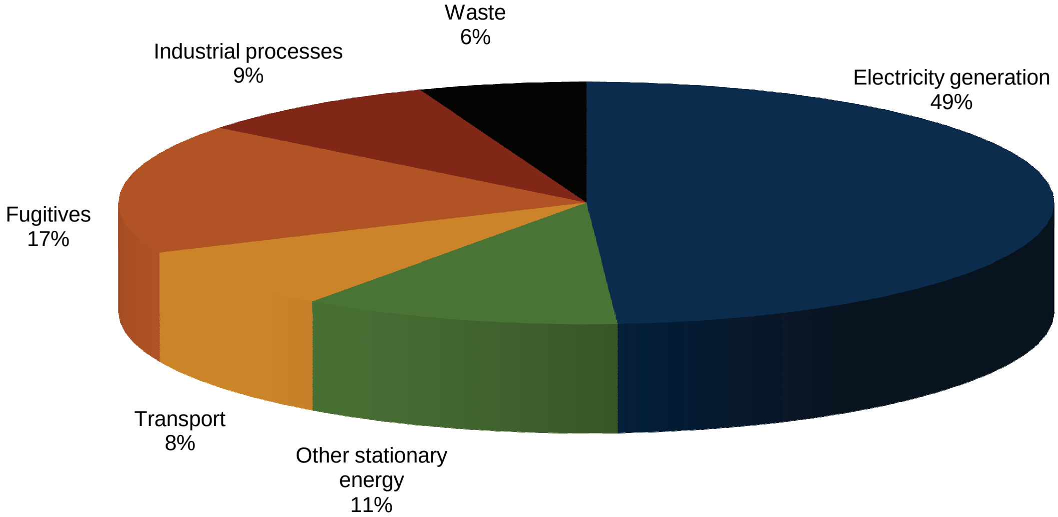
The reduction in the emissions of each sector compared with the global action scenario reflects both changes in emission intensity of production and changes in the output of each sector. Industrial processes reduce their emissions by around half. The other stationary energy and transport sectors reduce their emissions by a smaller proportion.

One way to assess each sector's contribution to meeting Australia's abatement task is to add up the cumulative emission reductions in the policy scenario compared to the global action scenario over the period to 2050. The shares of emission reductions by sector reflect each sector's overall production of emissions, with sectors with more emissions in the global action scenario more able to contribute to emission reductions, and each sector's potential mitigation costs. By 2050, the electricity generation and fugitives sectors deliver the greatest share of the reduction in domestic emissions.

In the electricity generation sector, emissions decline slowly until the mid 2030s when they start to fall faster as new technology becomes available, such as carbon capture and storage. By 2050, the electricity generation sector provides almost half of total emission reductions. This sector moves towards low-emission technology, such as carbon capture and storage and renewable sources, including wind, solar and geothermal. Reduced electricity sector emissions 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.

Take up of public transport, fuel switching and purchases of more fuel-efficient vehicles reduce transport sector emissions. Opportunities for water and air transport mitigation cost more, and consumers with higher incomes keep demand strong in these sectors.

Chart 5.8: Share of cumulative emission reductions by sector
Core policy scenario, 2010 to 2050

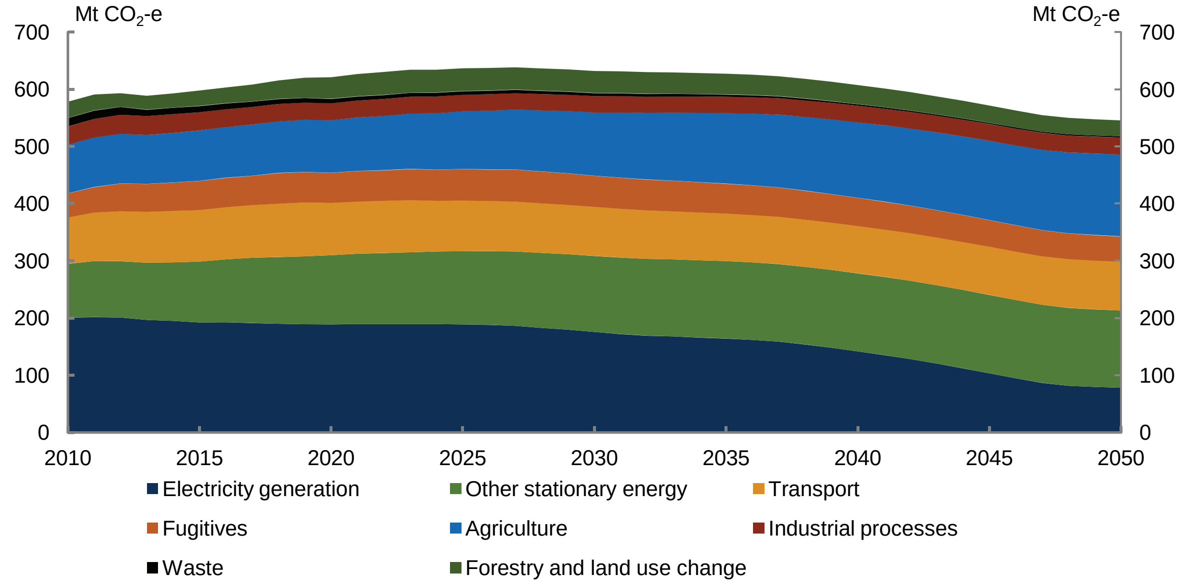


Note: The uncovered sectors of agriculture, forestry and fisheries are excluded from this chart. Abatement due to the CFI is incorporated in the level of Australian emissions in both the medium global action and core policy scenario.
Source: Treasury estimates from MMRF.

Emissions growth in some sectors continues to reflect output growth with relatively low abatement. For example, agriculture emissions continue to grow, almost doubling to 2050, driven by strong output growth. The Carbon Farming Initiative (CFI) achieves some abatement; however, its voluntary nature and strict additionality requirements means abatement is significantly less than in the previous climate change mitigation modelling (Australian Government, 2008).

Chart 5.9: Sector emissions

Core policy scenario



Source: Treasury estimates from MMRF.

5.2.3 Sourcing international abatement

While pricing carbon cuts domestic emissions, it is inefficient to meet the whole abatement task through domestic abatement. Sourcing abatement overseas plays an important role. Purchasing recognised international permits leads to real reductions in global emissions, just like reducing our domestic carbon pollution. Abatement is more expensive in Australia than in most developed economies due to its large share of emission intensive industries. From a global perspective, investment across borders to secure least cost abatement ensures that environmental outcomes are delivered at least cost to the world economy.

Relying entirely upon domestic abatement opportunities, whether through a carbon pricing mechanism or direct government action, would be a much more expensive way to meet Australia's emission targets. In the high price scenario, with a world carbon price of A$62/t CO_2-e in 2020 (2010 $), domestic emissions fall by less than 4 per cent by 2020 compared to 2000 levels. Achieving the target of a 5 per cent cut in emissions by 2020 compared to 2000 levels through domestic abatement alone would require a higher domestic carbon price, or more expensive direct action.

Sourcing abatement overseas transfers income from Australia to other countries. The cost depends on the prevailing world carbon price and the exchange rate. In a world where other countries pursue more ambitious abatement targets, the carbon price will be higher and this increases the cost in terms of domestic production and income forgone in achieving a given allocation.

Box 5.2: What would a scenario with less global ambition show?

The scenarios modelled show the implications for Australia of domestic policy action to price carbon in a world that is moving to tackle climate change.

Over 89 countries, including all major emitters, covering 80 per cent of global emissions have pledged action through the Copenhagen Accord and Cancun agreements. Uncertainty remains about the exact pace and extent of international action to tackle climate change, so two plausible global action scenarios are modelled as backdrops for the Australian carbon pricing scenarios: the medium global action scenario is based on the low-end of pledges and a target of stabilising greenhouse gas concentrations at 550 ppm CO_2-e by 2100; the ambitious global action scenario is based initially on the high-end of pledges initially and a target of stabilising greenhouse gas concentrations at 450 ppm CO_2-e just beyond 2100.

Notwithstanding this progress, some commentators suggest Australia is 'going it alone' and as a result, Australia's mitigation costs will be far greater than reported because impacts on domestic competitiveness will be far greater. This argument is misconceived.

If the extent of global action is less than assumed, then Australian mitigation costs will be lower, not higher, than reported for two main reasons.

First, less stringent world action would strengthen export demand and output for our energy exports.

Second, if global action is less than assumed, world carbon prices will be lower, making it less expensive to source abatement overseas.

Carbon markets already exist through the European Union, the United Nations Framework Convention on Climate Change flexibility mechanisms, the Regional Greenhouse Gas Initiative in the United States, and in Switzerland and New Zealand. Voluntary markets also exist in a range of countries, including Japan. These markets are expected to continue and others to develop. In a linked scheme, Australian firms will be able to meet their obligations by purchasing a domestic permit or by reducing emissions overseas (whether by sponsoring an emissions reduction project or by purchasing a permit from an overseas scheme). As the cost of reducing pollution overseas falls, the economic cost of meeting any emissions reduction target falls.

To be very clear, what this all means is that a hypothetical scenario with less global ambition to tackle climate change would likely result in lower mitigation costs for Australia than reported, not higher as claimed elsewhere.

The modelling only considers the economic costs of climate change mitigation and not the costs of climate change itself. If global action fails, global temperatures will move higher and the impact of climate change will be that much greater.

5.3 The macroeconomy

Real income continues to grow with carbon pricing. This section focuses on the effects of carbon pricing on real gross national income (GNI) per person and how those effects come about. Gross domestic product (GDP) is a measure of the value of production in Australia and is the most common measure of the size of the economy. GNI is a better measure of welfare because it also accounts for that part of domestically generated income that accrues to non-residents, including that part required to pay for abatement sourced overseas. It also accounts for foreign generated income that accrues to domestic residents.

5.3.1 Gross national income

Australia's GNI per person (or real income) in both domestic policy scenarios — core and high price — grows at rates only slightly below those expected without carbon pricing. In the core policy scenario, GNI per person in today's dollars will be $9,000 higher in 2020 than it is today and more than $30,000 higher in 2050 — an increase that is smaller than in the medium global action scenario, in which Australia does not price carbon, by just $320 per person in 2020 and $4,300 in 2050.

Table 5.3: GNI per person

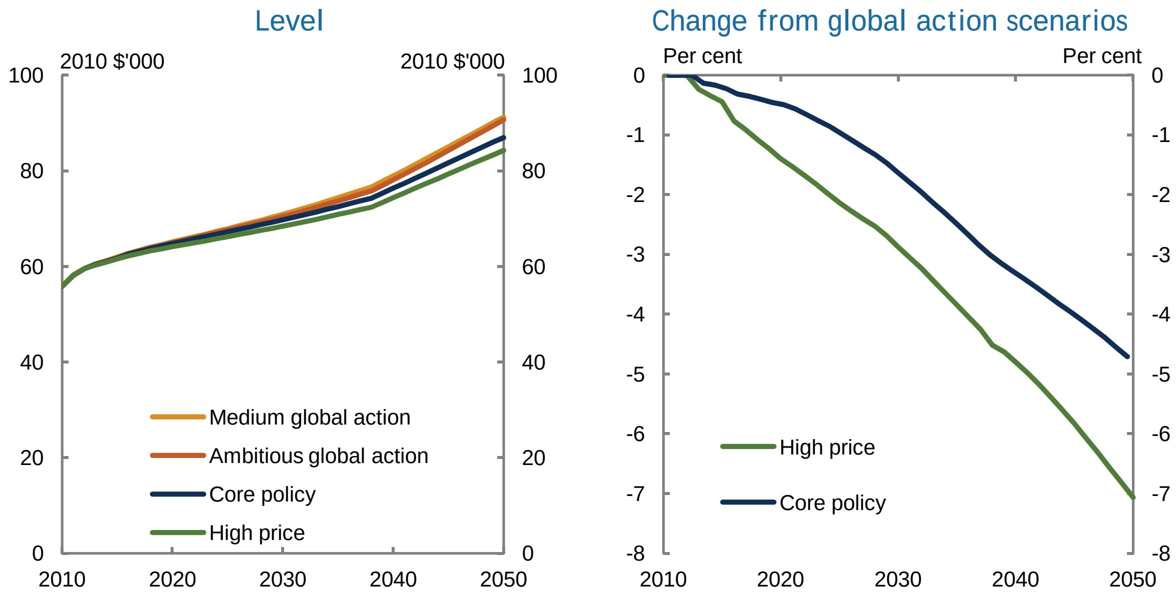
Average annual growth

	Medium global action	Core policy	Ambitious global action	High price
	Per cent	Per cent	Per cent	Per cent
2010s	1.6	1.5	1.5	1.4
2020s	0.9	0.7	0.8	0.6
2030s	1.1	0.9	1.0	0.8
2040s	1.5	1.3	1.5	1.3
Average	1.2	1.1	1.2	1.0

Note: Average is from 2010 to 2050. Numbers are influenced by rounding.
Source: Treasury estimates from MMRF.

Real income will continue to grow under a carbon price, but at a slightly reduced rate as the domestic economy transforms to be more carbon efficient and as sourcing international abatement causes income outflow. From 2010 to 2050, GNI per person grows at an average rate of 1.1 per cent per year in the core policy scenario compared to 1.2 per cent per year, if carbon levels continue unabated along their upward trajectory. That is, Australia's GNI per person continues to grow at a rate only around 0.1 of a percentage point per year slower than it would without carbon pricing.

Chart 5.10: GNI per person



Source: Treasury estimates from MMRF.

Decomposition of the effect on GNI

Carbon pricing affects incomes by affecting a range of links within the economy. Links between firms at successive stages of production, between producers and consumers, and between the domestic economy, import and export markets all play a role. The general equilibrium modelling of the Australian economy incorporates many of these links. Carbon pricing policies can affect economic welfare, measured by GNI, by (Harberger, 1971):

- changing the supply or productivity of factors (technical change and primary factor endowments);
- reallocating existing resources within the economy (allocative efficiency);
- changing foreign income flows through sourcing abatement overseas; and
- changing the terms of trade and exchange rate.

Table 5.4: Decomposition of the effect on the level of GNI

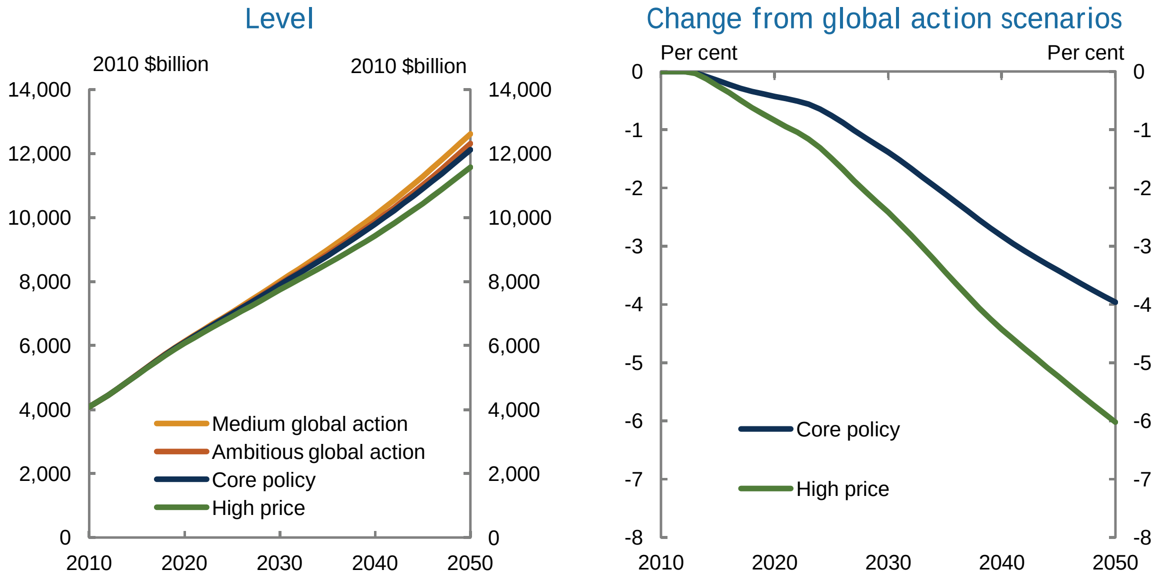
	Core policy scenario		High price scenario	
	2020	2050	2020	2050
	Per cent	Per cent	Per cent	Per cent
Primary factors	-0.4	-2.0	-0.8	-3.3
Allocative efficiency	0.0	-0.3	-0.2	-0.8
International permit income	-0.2	-2.4	-0.5	-2.6
Technical change	0.0	0.0	0.1	-0.2
Terms of trade	0.0	-0.2	-0.1	-0.2
Other foreign income	0.1	0.0	0.1	-0.3
Total effect on GNI	-0.5	-4.7	-1.4	-7.1

Note: Contributions may not sum to total due to rounding.
Source: Treasury estimates from MMRF.

The largest effect of carbon pricing comes through effects on primary factors of production such as labour, capital and land.

Carbon pricing increases the cost of constructing and running some capital equipment. In aggregate, across the economy, this reduces slightly firms' incentives to invest in capital. It also reduces the rate of growth of emission-intensive sectors, which are typically more capital intensive than the rest of the economy. To 2050, the capital stock grows by 2.8 per cent per year in the core policy scenario, compared with 2.9 per cent per year in the medium global action scenario.

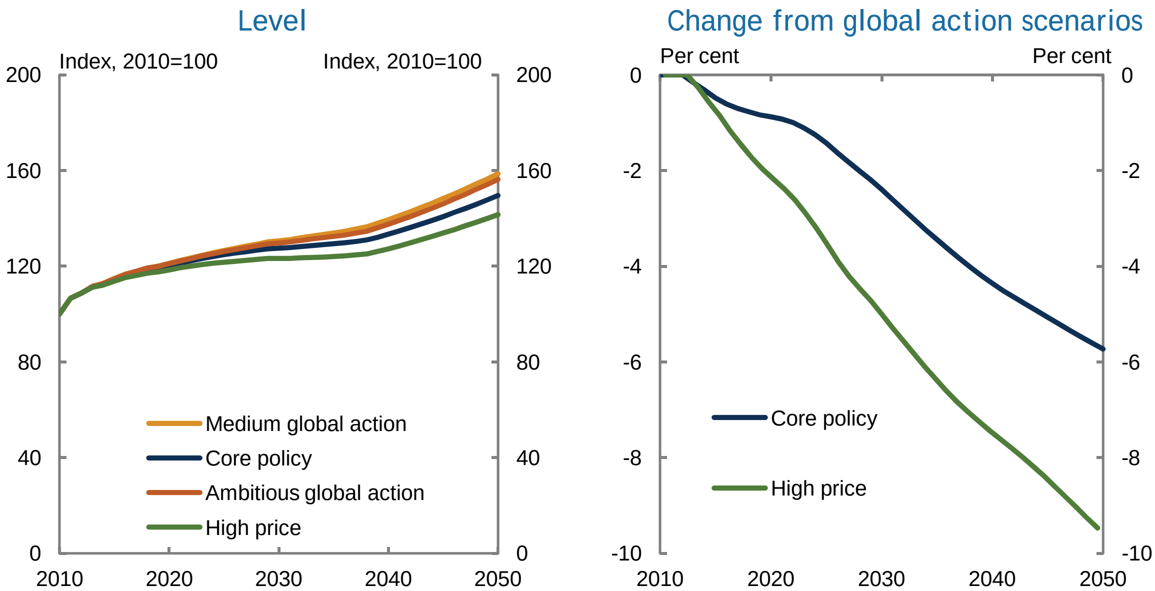
Chart 5.11: Capital stock



Source: Treasury estimates from MMRF.

Much like other structural adjustments the Australian economy has moved through in the past, carbon pricing also will have an effect on the labour market. Pricing carbon affects the demand for labour, as a result of slower output and capital growth. Real wages grow slightly more slowly than in the global action scenario. The level of employment is largely unaffected. Around 1.6 million jobs are added to 2020 in both the core policy and global action scenario, with a further 4.4 million jobs added by 2050 with or without carbon pricing. Labour moves across industries during the transition to a lower carbon economy, but the rate of movement is low compared with normal rates of job turnover from year to year (Chapman and Lounkaew, 2011).

Chart 5.12: Real wages



Source: Treasury estimates from MMRF.

Changes in how the economy's resources are allocated between different industries also affects GNI. The current structure of the Australian economy is 'allocatively efficient', in the sense that total output is as large as possible, but this is not socially optimal. Since businesses do not currently pay for the long-term damage done by the carbon pollution they emit, they produce too much pollution.

Carbon pricing will change the mix of activities in the economy. Some goods that would have been produced without a carbon price are forgone, and new goods that would not have been cost effective to produce without a carbon price go ahead. This tends to reduce slightly the rate of output growth within the model because the cost of producing the forgone goods, such as coal-powered electricity, is lower than the cost of producing new goods, such as renewable electricity. This change in the mix of activities results in important reductions in emissions.

Finally, sourcing abatement from overseas involves transferring income from Australia to secure reductions in emissions in other countries.

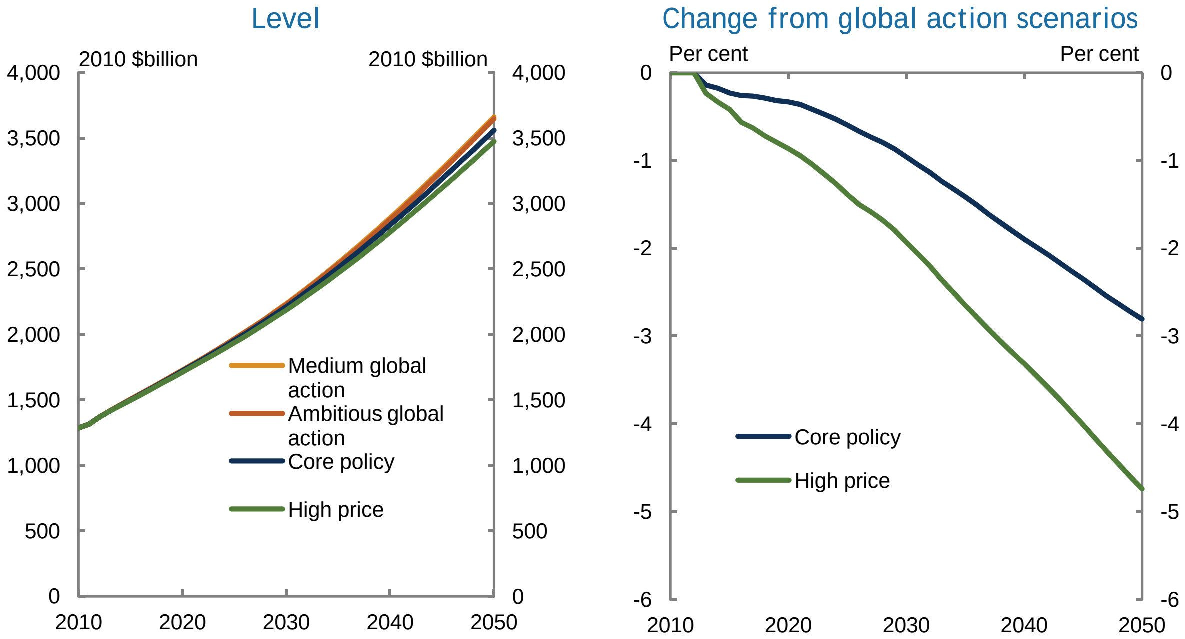
The other paths by which carbon pricing can affect GNI generally have a smaller effect. Different industries have different rates of technical change and carbon pricing can affect the overall rate of technical change by moving resources into low emission-intensive sectors. Some of these low emission-intensive sectors, such as communications, tend to experience rapid technological change over time, while others, such as public services, tend to change less rapidly. This effect could increase or decrease the rate of growth in GNI from year to year, but in practice, the effect is very small.

Similarly, domestic carbon pricing has little effect on Australia's terms of trade. International action tends to reduce Australia's terms of trade over time by reducing international demand for the fossil fuels, like coal, that we export. This has effects on the level of the terms of trade, but these effects are part of the medium and ambitious global action scenarios. Rather, domestic carbon pricing will tend to lower slightly the Australian exchange rate, by an amount estimated at around 3 per cent by 2050. This will improve the international competitiveness of domestic producers of low emission-intensive goods, but also increase somewhat the cost of other foreign income payments to foreign investors in the Australian economy.

5.3.2 Gross domestic product

GDP continues to grow with carbon pricing, and will be nearly three times as large by 2050 compared to what it was in 2010. GDP grows in the core policy scenario by 2.6 per cent per year to 2050, slightly lower than the rate of 2.7 per cent per year in the medium global action scenario.

Chart 5.13: Gross domestic product



Source: Treasury estimates from MMRF.

The aggregate economic impacts of carbon pricing are similar regardless of whether SKM MMA or ROAM electricity modelling is incorporated. While GDP growth in the global action scenarios is the same, technology costs, wholesale prices and profits differ between the two. A lower emission intensity in ROAM's global action scenario, than in SKM MMA's, means that the abatement task is smaller. With a smaller abatement task, the estimates of the economic impacts of carbon pricing incorporating ROAM's electricity modelling also are slightly smaller. Nevertheless, using either set of electricity sector modelling results in an aggregate impact of carbon pricing on growth in GNI per person of 0.1 of a percentage point per year.

Achieving a target of an 80 per cent reduction will be slightly more challenging than achieving a target of a 60 per cent reduction of 2000 levels by 2050. For a given world carbon price, the most efficient way for Australia to meet the stronger target will be to source additional abatement from overseas. Australia's GNI per person will continue to grow while meeting the stronger target, but somewhat more slowly, to be 0.6 per cent lower in 2050 compared to what it would have been with a 60 per cent target. The size of the economy, measured by GDP, grows at the same rate with an 80 per cent target as with a 60 per cent target.

Box 5.3: Comparison of costs with other studies of mitigation policy

A number of recent studies explore the potential economic impacts of mitigation policy on the Australian economy.

The costs of emission mitigation in this report are within the range of previous estimates. Studies find that even substantial emission reductions can be achieved while maintaining robust economic growth.

The wide range of estimates from published studies reflect the uncertainty about mitigation costs. Studies differ owing to different policy assumptions, model parameters and technology availability and cost assumptions. In addition, cost estimates are strongly affected by emission levels in the global action scenario (which varies across studies) as this determines the scale of economic restructuring required to achieve any given emission reduction goal.

Table 5.5: Mitigation cost estimates: reductions in real GDP and GNI

Change from reference

Scenario/source	GDP reduction in 2020 per cent	GDP reduction in 2050 per cent	GNI reduction in 2020 per cent	GNI reduction in 2050 per cent	Mitigation task(a) in 2050 Mt CO_2-e
Core policy	0.3	2.8	0.5	4.7	463
High price	0.9	4.7	1.4	7.1	628
CPRS -5(b)	1.1	3.7	1.3	5.1	619
Garnaut-25(b)	1.6	5.8	2.0	6.7	868
Access Economics(c)	0.8-2.5	1.1-2.7	1.0-3.0	1.3-3.7	23-26%
Frontier Economics	0.3-0.5	0.9-1.3	0.6-0.8	1.8-2.0	23%
Climate Institute(c)	0-2.0	2.3-4.2	0-1.8	0.3-3.4	912-1205
Allen Consulting	1.4	6-13	n/a	n/a	714-888
ABARES	0.7-2.7	1.7-10.7	n/a	n/a	307-573
Concept Economics(c)	0.7-3.9	1.1-6.1	0.6-3.8	1.0-5.4	241-418

(a) Mitigation task is the difference between emissions in the reference and policy scenarios.
(b) CPRS-5 and Garnaut-25 results are from the previous modelling exercise in 2008 (Australian Government 2008).
(c) Climate Institute results are for 2030 (not 2020); Concept Economics and Frontier Economics results are for 2030 (not 2050). For Frontier Economics and Access Economics, the reduction of domestic emissions is reported.
Source: Access Economics, 2009; ABARE (Ahamaad et al, 2006); Australian Government, 2008; Climate Institute (Hatfield-Dodds et al, 2007); Allen Consulting Group, 2006; Concept Economics, 2008; and Treasury estimates from MMRF.

5.4 Trends at the sectoral level

Pricing carbon affects the composition of the Australian economy. It drives a structural change to low emission-intensive products and a movement within industries to cleaner technologies and processes. Taking advantage of the economic opportunities in new areas and the cheapest abatement requires a reallocation of resources across the economy.

The impacts of carbon pricing on output and employment growth vary widely across sectors, with some sectors growing faster, and others more slowly. A number of factors influence sectoral impacts: the relative emission intensity of goods and services; the availability of lower emission substitutes; the degree of pricing power domestic firms have, which is influenced by their trade exposure; the degree of pricing power their suppliers have; the relative emission intensity of domestic production compared to international competitors; the cost of potential mitigation options; coverage of the carbon price scheme; and the extent of government assistance.

Industries that provide relatively low emission-intensive substitutes for other goods will grow fastest, as households switch their consumption in response to differences in prices. For example, coal-powered electricity generation becomes relatively more expensive, and gas-powered electricity generation expands rapidly.

This section explores the effects on the economy's overall structure, followed by output profiles and the flow of resources across and within the five major sectors: agriculture, forestry and fisheries; manufacturing; mining; construction; and services. Detailed analysis of the electricity, transport and forestry sectors, using bottom-up modelling, follows. Results are aggregated to an industry level, so impacts on individual firms are not explored.

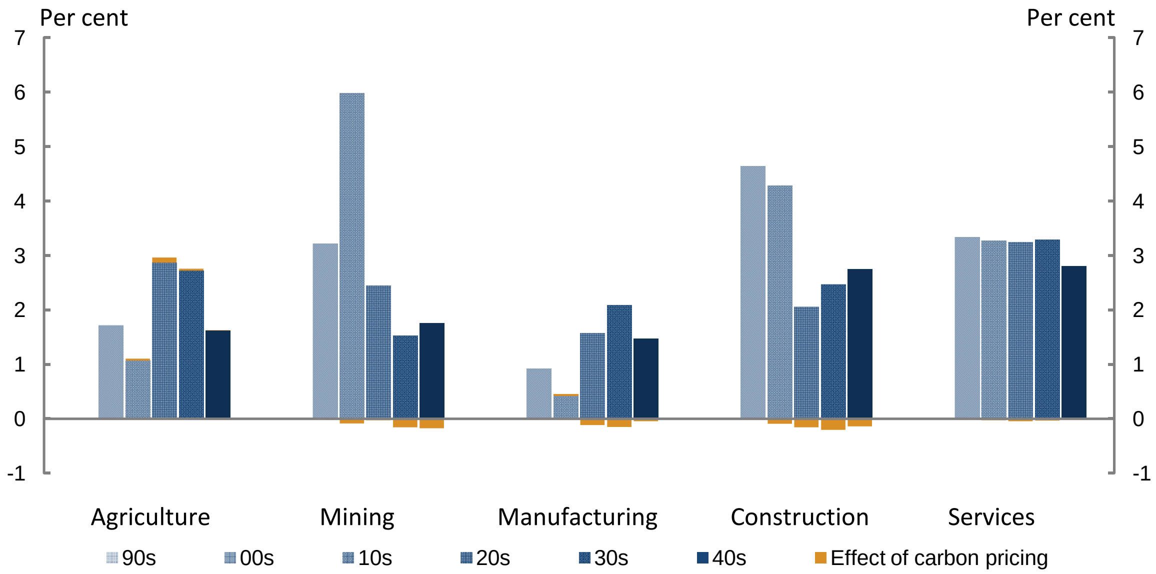
5.4.1 Structural change and the effects of carbon pricing

The structure of Australia's economy is always evolving. The jobs of the future will be in different industries to those of the past, as discussed in Chapter 4. This will be the case with or without carbon pricing.

The large increase in the relative price of resource commodities in recent years has driven, and will continue to drive, substantial changes. As a result, mining and construction will grow faster. Similarly, as incomes continue to increase and tastes change, the long-term trend towards a service-driven economy continues, as does the relative decline in importance of goods production.

At the broad sectoral level, structural changes due to carbon pricing are much smaller than the effects of ongoing changes in the terms of trade or tastes. Some sectors, such as mining and construction, grow more slowly with carbon pricing, while agriculture grows faster. However, these effects are small compared to the difference in underlying growth trends between sectors, or compared with variation in underlying growth rates within sectors from one decade to the next. Sectors will grow at similar rates with or without carbon pricing.

Chart 5.14: Output growth by broad sector, 1990 to 2050
Annual average growth rates
Medium global action scenario and effect of carbon pricing



Source: Treasury estimates from MMRF.

Much of the effect is due to the transition of resources between different industries within the same sector. Australia continues to have strong manufacturing, mining and construction sectors with carbon pricing. Within manufacturing, some areas are more emission intensive in production and, over time, decline in relative size, while others grow. Slower growth in some areas allows employment and investment to flow into less emission-intensive manufacturing sectors. Within mining, energy extraction industries grow less quickly than they otherwise would, but other parts of the mining industry continue to grow strongly.

The bulk of the economy is unaffected by these structural changes. More than 95 per cent of industries (by employment share) see their level of employment in 2020 change by less than 1 per cent, up or down, compared to the medium global action scenario. Even industries that experience larger changes in employment, experience small changes as a consequence of carbon pricing compared to the normal flows in and out of employment without carbon pricing (Chapman and Lounkaew, 2011).

Table 5.6: Gross output, by industry, 2020

Industry	Change from global action scenarios		Change from 2010	
	Core policy	High price	Core policy	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture	**0.4**	**0.6**	**12**	**12**
Sheep and cattle	0.3	0.6	10	11
Dairy cattle	0.2	0.3	1	1
Other animals	0.4	0.8	14	14
Grains	0.5	0.8	15	15
Other	0.2	0.1	19	18
Agricultural services and fisheries	0.6	0.9	7	8
Forestry	0.3	0.2	5	6
Mining	**-0.8**	**-1.2**	**77**	**76**
Coal	-2.3	-4.5	45	37
Oil	0.0	0.0	1	1
Gas	-1.5	-2.3	100	99
Iron ore	0.8	2.0	104	106
Non-ferrous ore	-0.9	-1.3	92	94
Other	0.6	1.9	87	89
Manufacturing	**0.2**	**0.6**	**5**	**7**
Meat products	0.2	0.3	12	12
Other food	0.1	0.1	3	2
Textiles, clothing and footwear	0.7	1.9	-34	-33
Wood products	-0.1	-0.3	3	2
Paper products	0.3	0.6	-7	-7
Printing	0.0	-0.1	14	14
Refinery	0.0	-0.1	-8	-7
Chemicals	1.8	4.5	9	17
Rubber and plastic products	0.6	1.6	5	9
Non-metal construction products	-0.7	-1.6	6	6
Cement	-0.8	-2.1	34	32
Iron and steel	0.4	0.8	9	10
Alumina	-0.2	0.4	49	50
Aluminium	0.3	-4.5	0	-5
Other metals	-0.3	0.1	70	86
Metal products	-0.2	-0.6	3	2
Motor vehicles and parts	0.6	1.1	-39	-39
Other	0.1	0.4	-20	-20
Construction	**-0.9**	**-2.1**	**51**	**48**
Services	**-0.3**	**-0.8**	**38**	**37**
Electricity: coal-fired	-9.6	-41.2	-9	-41
Electricity: gas-fired	0.8	68.2	26	112
Electricity: hydro	-1.5	-2.7	-1	-2
Electricity: other	20.4	37.0	521	600
Electricity supply	-3.3	-7.6	12	7
Gas supply	-1.2	1.5	27	31
Water supply	-0.3	-1.0	20	19
Trade	-0.2	-0.7	30	30
Accommodation and hotels	-0.4	-1.4	21	20
Road transport: passenger	-0.1	-0.9	23	21
Road transport: freight	-0.2	-0.5	38	38
Rail transport: passenger	0.2	0.4	10	11
Rail transport: freight	-0.1	0.1	61	61
Water transport	-0.1	0.1	31	32
Air transport	-0.2	-0.2	9	10
Communication	-0.3	-0.9	56	55
Financial	-0.2	-0.5	40	39
Business	-0.2	-0.5	53	53
Public	0.0	-0.1	32	32
Other	-0.4	-1.4	33	32
Ownership of dwellings	-0.1	-0.4	33	32

Source: Treasury estimates from MMRF.

Table 5.7: Gross output, by industry, 2050

Industry	Change from global action scenarios		Change from 2010	
	Core policy	High price	Core policy	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture	**1.7**	**1.9**	**130**	**135**
Sheep and cattle	0.5	0.6	93	96
Dairy cattle	2.2	2.5	88	92
Other animals	2.2	2.0	140	146
Grains	1.1	1.2	126	128
Other	1.3	1.4	179	182
Agricultural services and fisheries	3.9	4.6	167	172
Forestry	2.0	2.0	130	164
Mining	**-4.3**	**-7.9**	**201**	**181**
Coal	-17.1	-31.9	109	46
Oil	-0.1	-0.4	-73	-73
Gas	-7.2	-14.8	155	121
Iron ore	8.8	13.4	408	430
Non-ferrous ore	-6.5	-11.0	261	249
Other	5.3	8.2	255	261
Manufacturing	**-2.8**	**-4.6**	**69**	**69**
Meat products	1.1	1.1	137	139
Other food	2.2	2.4	108	113
Textiles, clothing and footwear	7.1	8.9	30	34
Wood products	0.5	-0.2	116	118
Paper products	-1.4	-3.6	60	59
Printing	1.6	2.0	147	148
Refinery	-6.7	-16.7	30	19
Chemicals	-1.5	-4.6	3	5
Rubber and plastic products	-0.2	-1.4	42	45
Non-metal construction products	0.6	0.0	100	100
Cement	-6.8	-10.3	130	119
Iron and steel	-21.3	-31.1	79	48
Alumina	-44.1	-54.3	72	36
Aluminium	-61.7	-74.0	-49	-64
Other metals	-8.9	-14.0	44	53
Metal products	-4.7	-7.9	58	52
Motor vehicles and parts	4.1	3.9	25	27
Other	5.2	6.5	54	58
Construction	**-5.6**	**-8.5**	**195**	**181**
Services	**-1.2**	**-1.8**	**242**	**239**
Electricity: coal-fired	-71.4	-91.1	-47	-83
Electricity: gas-fired	97.6	164.8	238	342
Electricity: hydro	-2.6	5.9	3	16
Electricity: other	289.7	442.7	2458	3310
Electricity supply	-13.6	-8.0	67	78
Gas supply	1.8	2.8	167	163
Water supply	-2.5	-3.9	107	104
Trade	-1.6	-2.7	176	172
Accommodation and hotels	-2.6	-3.6	151	148
Road transport: passenger	0.2	-1.3	205	199
Road transport: freight	0.2	-0.5	225	223
Rail transport: passenger	13.9	19.6	415	448
Rail transport: freight	4.3	6.4	330	332
Water transport	-1.2	-2.0	194	192
Air transport	2.6	4.5	373	389
Communication	-3.0	-4.4	319	312
Financial	-0.8	-1.3	257	255
Business	-0.3	-0.6	353	351
Public	-0.5	-0.8	243	241
Other	-4.6	-7.0	164	157
Ownership of dwellings	-4.0	-6.0	167	160

Source: Treasury estimates from MMRF.

Table 5.8: Employment share, by industry, 2020

Industry	Medium global action	Core policy	Ambitious global action	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture	**2.4**	**2.4**	**2.4**	**2.4**
Sheep and cattle	0.5	0.5	0.5	0.6
Dairy cattle	0.2	0.2	0.2	0.2
Other animals	0.1	0.1	0.1	0.1
Grains	0.4	0.4	0.4	0.4
Other	0.5	0.5	0.5	0.5
Agricultural services and fisheries	0.6	0.6	0.6	0.6
Forestry	0.1	0.1	0.1	0.1
Mining	**1.7**	**1.7**	**1.7**	**1.7**
Coal	0.4	0.4	0.4	0.3
Oil	0.0	0.0	0.0	0.0
Gas	0.1	0.1	0.1	0.1
Iron ore	0.2	0.2	0.2	0.2
Non-ferrous ore	0.6	0.6	0.6	0.6
Other	0.4	0.4	0.4	0.4
Manufacturing	**6.4**	**6.4**	**6.4**	**6.5**
Meat products	0.4	0.4	0.4	0.4
Other food	0.9	0.9	0.9	0.9
Textiles, clothing and footwear	0.2	0.2	0.2	0.2
Wood products	0.3	0.3	0.3	0.3
Paper products	0.1	0.1	0.1	0.1
Printing	0.8	0.8	0.8	0.8
Refinery	0.0	0.0	0.0	0.0
Chemicals	0.4	0.4	0.4	0.4
Rubber and plastic products	0.3	0.3	0.3	0.3
Non-metal construction products	0.2	0.2	0.2	0.2
Cement	0.1	0.1	0.1	0.1
Iron and steel	0.3	0.3	0.3	0.4
Alumina	0.1	0.1	0.1	0.1
Aluminium	0.1	0.1	0.1	0.1
Other metals	0.2	0.2	0.2	0.2
Metal products	0.6	0.6	0.6	0.6
Motor vehicles and parts	0.3	0.3	0.3	0.3
Other	1.1	1.1	1.1	1.1
Construction	**9.6**	**9.6**	**9.6**	**9.4**
Services	**79.9**	**79.9**	**79.9**	**79.9**
Electricity: coal-fired	0.1	0.1	0.1	0.1
Electricity: gas-fired	0.0	0.0	0.0	0.1
Electricity: hydro	0.0	0.0	0.0	0.0
Electricity: other	0.0	0.0	0.0	0.0
Electricity supply	0.1	0.1	0.1	0.1
Gas supply	0.0	0.0	0.0	0.0
Water supply	0.2	0.2	0.2	0.2
Trade	18.2	18.2	18.3	18.3
Accommodation and hotels	4.8	4.8	4.8	4.7
Road transport: passenger	0.5	0.5	0.5	0.5
Road transport: freight	1.2	1.2	1.2	1.2
Rail transport: passenger	0.0	0.0	0.0	0.0
Rail transport: freight	0.3	0.3	0.3	0.3
Water transport	1.1	1.1	1.1	1.1
Air transport	0.3	0.3	0.3	0.3
Communication	1.1	1.1	1.1	1.1
Financial	3.6	3.6	3.6	3.6
Business	16.3	16.3	16.4	16.4
Public	20.6	20.6	20.6	20.6
Other	11.3	11.3	11.3	11.2
Ownership of dwellings	0.0	0.0	0.0	0.0

Source: Treasury estimates from MMRF.

Table 5.9: Employment share, by industry, 2050

Industry	Medium global action	Core policy	Ambitious global action	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture	**3.9**	**4.1**	**4.0**	**4.3**
Sheep and cattle	0.9	1.0	1.0	1.1
Dairy cattle	0.3	0.3	0.3	0.3
Other animals	0.1	0.1	0.1	0.1
Grains	0.8	0.9	0.8	0.9
Other	0.9	1.0	1.0	1.0
Agricultural services and fisheries	0.8	0.8	0.8	0.8
Forestry	0.1	0.1	0.1	0.1
Mining	**1.2**	**1.2**	**1.1**	**1.1**
Coal	0.3	0.2	0.2	0.2
Oil	0.0	0.0	0.0	0.0
Gas	0.1	0.1	0.1	0.1
Iron ore	0.2	0.2	0.2	0.2
Non-ferrous ore	0.4	0.4	0.4	0.4
Other	0.2	0.3	0.2	0.3
Manufacturing	**4.4**	**4.4**	**4.4**	**4.4**
Meat products	0.3	0.3	0.3	0.3
Other food	0.6	0.7	0.7	0.7
Textiles, clothing and footwear	0.1	0.2	0.1	0.2
Wood products	0.3	0.3	0.3	0.3
Paper products	0.1	0.1	0.1	0.1
Printing	0.6	0.6	0.6	0.6
Refinery	0.0	0.0	0.0	0.0
Chemicals	0.1	0.1	0.2	0.2
Rubber and plastic products	0.1	0.1	0.1	0.1
Non-metal construction products	0.1	0.1	0.1	0.1
Cement	0.1	0.1	0.1	0.1
Iron and steel	0.4	0.3	0.4	0.3
Alumina	0.1	0.1	0.1	0.1
Aluminium	0.1	0.0	0.1	0.0
Other metals	0.1	0.1	0.1	0.1
Metal products	0.3	0.3	0.3	0.3
Motor vehicles and parts	0.2	0.2	0.2	0.2
Other	0.7	0.7	0.7	0.8
Construction	**7.6**	**7.3**	**7.5**	**7.1**
Services	**82.9**	**83.0**	**82.9**	**83.0**
Electricity: coal-fired	0.1	0.0	0.1	0.0
Electricity: gas-fired	0.0	0.0	0.0	0.0
Electricity: hydro	0.0	0.0	0.0	0.0
Electricity: other	0.0	0.1	0.0	0.1
Electricity supply	0.1	0.1	0.1	0.1
Gas supply	0.0	0.0	0.0	0.0
Water supply	0.1	0.1	0.1	0.1
Trade	14.0	14.0	14.0	14.0
Accommodation and hotels	5.3	5.3	5.3	5.3
Road transport: passenger	0.3	0.3	0.3	0.3
Road transport: freight	0.8	0.8	0.8	0.8
Rail transport: passenger	0.0	0.0	0.0	0.0
Rail transport: freight	0.3	0.3	0.3	0.3
Water transport	0.7	0.7	0.7	0.7
Air transport	0.5	0.5	0.5	0.6
Communication	0.6	0.6	0.6	0.6
Financial	3.2	3.3	3.2	3.3
Business	23.8	24.0	23.8	24.1
Public	21.1	21.2	21.0	21.2
Other	11.9	11.6	11.9	11.4
Ownership of dwellings	0.0	0.0	0.0	0.0

Source: Treasury estimates from MMRF.

Box 5.4: Manufacturing abatement technology

Emission reductions depend partly upon the take up of cleaner production processes and technologies. Some technologies are already available but adoption is not economic without carbon pricing, such as scrubbers to reduce nitrous oxide emissions in ammonium nitrate production; others are at an early stage of development and may or may not prove cost effective on an industrial scale, such as HIsarna steelmaking technology. Of course, how fast efficiency improvements become available, and at what cost, remains uncertain.

The modelling makes assumptions about the marginal cost of abatement opportunities in industrial processes and fugitive emissions from mining. (See Appendix B.) The take up of these opportunities depends on the carbon price, and for a given carbon price, the modelling assumes it takes some time for firms to change production processes. Higher carbon prices result in larger reductions in emission intensity — the volume of emissions produced per unit of output.

The particular assumptions made about abatement opportunities have little effect on industry growth rates because the change in production processes is assumed to be cost neutral. That is, the take up of new technology is costly, offsetting the savings in carbon costs. However, different assumptions affect the amount of domestic abatement achieved, and hence, the amount of abatement sourced from overseas.

Large changes in the assumptions only slightly change the estimated effects of carbon pricing on GNI. For example, were abatement opportunities in manufacturing more costly, so that only half the reduction in the emission intensity of production was achieved in 2050, then domestic emissions would be higher by around 9 Mt CO_2-e, and the estimated impact of carbon pricing on the level of GNI in 2050 would be larger by only 0.04 percentage points.

Box 5.5: Assistance to emission-intensive trade-exposed activities

Emission-intensive trade-exposed (EITE) activities are affected by domestic and international carbon pricing. International carbon pricing makes Australian emission-intensive industries more competitive, while domestic carbon pricing rebalances that effect. Coordinated global mitigation efforts would help ensure Australia's comparative advantage reflects actual differences in the emission intensity of production across countries.

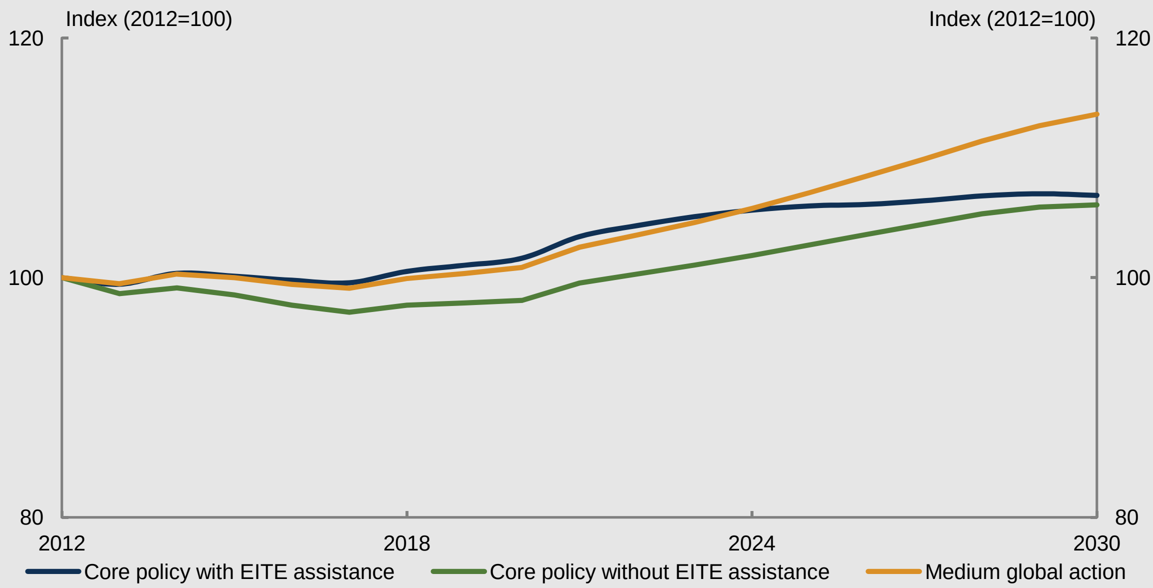
The Government's transitional assistance to firms assessed as emission intensive and trade exposed supports the transition to a carbon-constrained economy. The assistance ensures firms face a strong incentive to reduce emissions.

Modelling results show this transitional assistance will support output in emission-intensive industries. Output remains as high as, or higher than, it would be in the medium global action scenario without domestic carbon pricing. The modelling assumes comparable carbon pricing in other major economies from 2015-16, and the phase out of transitional assistance over five years starting in 2022.

The assistance also slows the transition of resources, including employment, from these sectors to other parts of the economy, and redistributes costs from shielded to unshielded sectors. In the long term, this transition is necessary to achieve Australia's emission targets at lowest cost.

Chart 5.15: Output in seven emission-intensive industries

Alumina, aluminium, cement, chemicals, refinery, paper and steel



Source: Treasury estimates from MMRF.

Table 5.10: Gross output, by sector, 2020

Change from 2010 to 2020

	Medium global action	Core policy	Ambitious global action	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture, forestry and fishing	**11**	**12**	**11**	**12**
Mining	**79**	**77**	**78**	**76**
Coal, oil and gas	62	60	60	55
Other mining industries	94	94	95	95
Manufacturing	**4**	**5**	**6**	**7**
High emission-intensive manufacturing	23	23	28	29
Low emission-intensive manufacturing	-7	-7	-7	-7
Construction	**52**	**51**	**51**	**48**
Services	**38**	**38**	**38**	**37**

Note: Sector aggregate gross output based on industry average growth rates and 2005-06 gross output weights.
Source: Treasury estimates from MMRF.

Table 5.11: Gross output, by sector, 2050

Change from 2010 to 2050

	Medium global action	Core policy	Ambitious global action	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture, forestry and fishing	**127**	**130**	**130**	**135**
Mining	**215**	**201**	**205**	**181**
Coal, oil and gas	129	101	105	58
Other mining industries	294	294	297	294
Manufacturing	**74**	**69**	**77**	**69**
High emission-intensive manufacturing	60	41	66	37
Low emission-intensive manufacturing	82	86	84	89
Construction	**212**	**195**	**206**	**181**
Services	**246**	**242**	**245**	**239**

Note: Sector aggregate gross output based on industry average growth rates and 2005-06 gross output weights.
Source: Treasury estimates from MMRF.

5.4.2 Differences within sectors

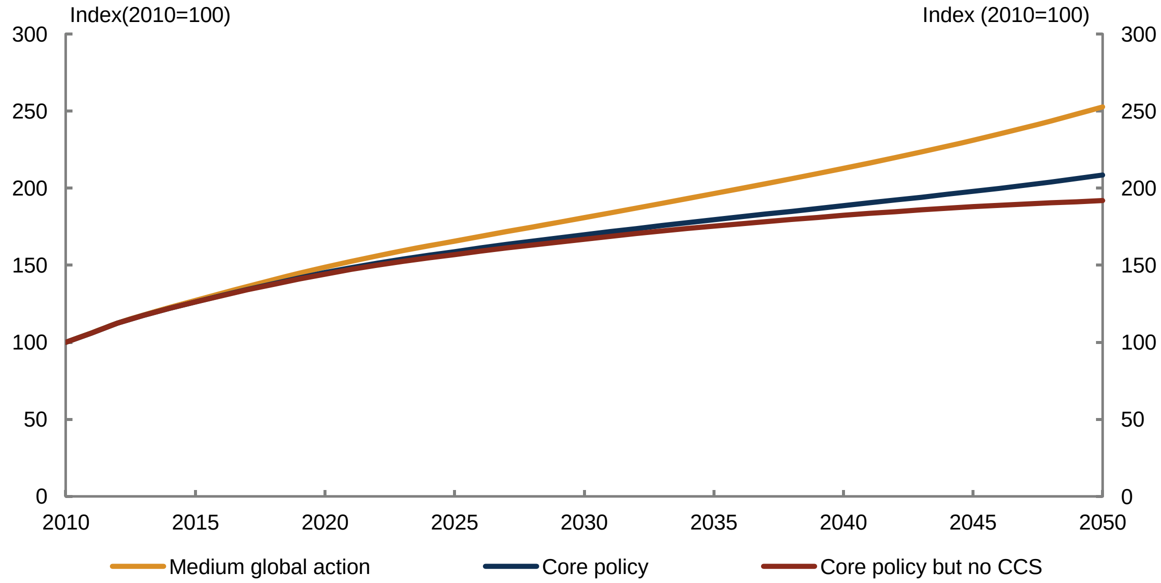
While the overall effects by broad sector are small, the effects on individual industries vary widely. Relative carbon intensity affects how industries respond to pricing carbon. For example, pricing of fugitive emissions in coal and gas production slows their output and export growth. This tends to lower Australia's exchange rate, making other trade-exposed industries more competitive. Slower productivity growth in carbon-intensive sectors slows growth in wages and costs of production in other parts of the economy. Other industries grow faster, if they are outside the scope of carbon pricing, engage in assisted emission-intensive trade-exposed activities or have relatively low carbon intensity.

Agricultural activity emissions are assumed to be excluded from carbon price coverage in both policy scenarios. The carbon intensity of agriculture, forestry and fishing ranges from potentially negative in forestry, to relatively low in grain production, through to highly emission-intensive sectors such as cattle grazing. As agricultural output is traded, the industries gain a competitive advantage from lower wages and exchange rates in the carbon pricing scenarios, and all parts of the sector grow more rapidly.

Carbon pricing affects different parts of the mining sector differently. Energy extraction industries grow less rapidly due to higher costs of extraction, associated with fugitive emissions, and weaker demand due to the cost of combusting coal and gas domestically. Other parts of the mining sector are less affected and some, such as iron ore mining, grow faster with a carbon price than without. Overall, the mining industry maintains very strong growth with a carbon price over the decade ahead, but grows more slowly over later decades.

The expansion of Australia's coal industry will be affected by the development of carbon capture and storage technology (CCS). Carbon capture and storage starts in the mid 2030s in the core policy scenario and in the mid 2020s in the high price scenario. Without this technology, Australia's coal production would grow by 92 per cent over the period to 2050, instead of 109 per cent in the core policy scenario. Without the development and take up of CCS, domestic emissions would be higher by around 25 Mt CO_2-e in 2050 and the estimated impact of carbon pricing on the level of GNI would be larger by 0.2 percentage points in 2050.

Chart 5.16: The effect of carbon capture and storage on coal production



Note: Projections incorporate electricity sector modelling by SKM MMA.
Source: Treasury estimates from MMRF.

Construction sector output varies in line with demand for infrastructure and non-residential buildings from the mining sector, and so follows a similar pattern to that sector.

Some parts of the manufacturing sector grow faster, and some parts grow more slowly, with carbon pricing. Overall, the effect on manufacturing output is small. Some emission-intensive sectors such as iron and steel production, alumina and aluminium refining grow more slowly with a carbon price after the assumed phasing out of assistance to emission-intensive trade-exposed activities. On the other hand, many other less emission-intensive industries, including printing; textiles, clothing and footwear; motor vehicle and part manufacturing; and food manufacturing, are more competitive, growing faster with domestic carbon pricing than in the global action scenarios.

Services continue to grow strongly and their economy-wide share of employment is higher than current levels. Service-oriented sectors tend to be low emission intensive, except waste, which forms part of the other services industry. Carbon pricing excludes emissions from legacy waste, but pricing emissions from new waste reduces growth in the sector.

5.4.3 Electricity generation

Electricity generation accounts for the largest share of Australia's current emissions, so Australia's transition to a low-emission future requires a significant transformation in this sector. Australia has a range of options available to assist with this transition, including gas, wind, solar and geothermal resources. Furthermore, Australia's coal resources could play an important role in an emission-constrained world if carbon capture and storage technology proves commercial.

The modelling shows that introducing a carbon price changes the composition of electricity generation in Australia. The carbon price drives significant changes in the mix of technologies and fuels used in the electricity sector in both policy scenarios. Demand for electricity is also an important source of abatement in the early years of the electricity sector's transition to a cleaner future.

Generation from renewable technology is significantly higher in both policy scenarios. Initially, most renewable generation that comes online is wind generation; later this is overtaken by geothermal energy which becomes a major source of renewable generation. Gas also becomes an important component of Australia's generation mix, increasing across all policy scenarios. The extent of switching towards gas-fired generation depends on future gas prices and availability of alternative, cleaner technology, such as coal carbon capture and storage.

Electricity demand

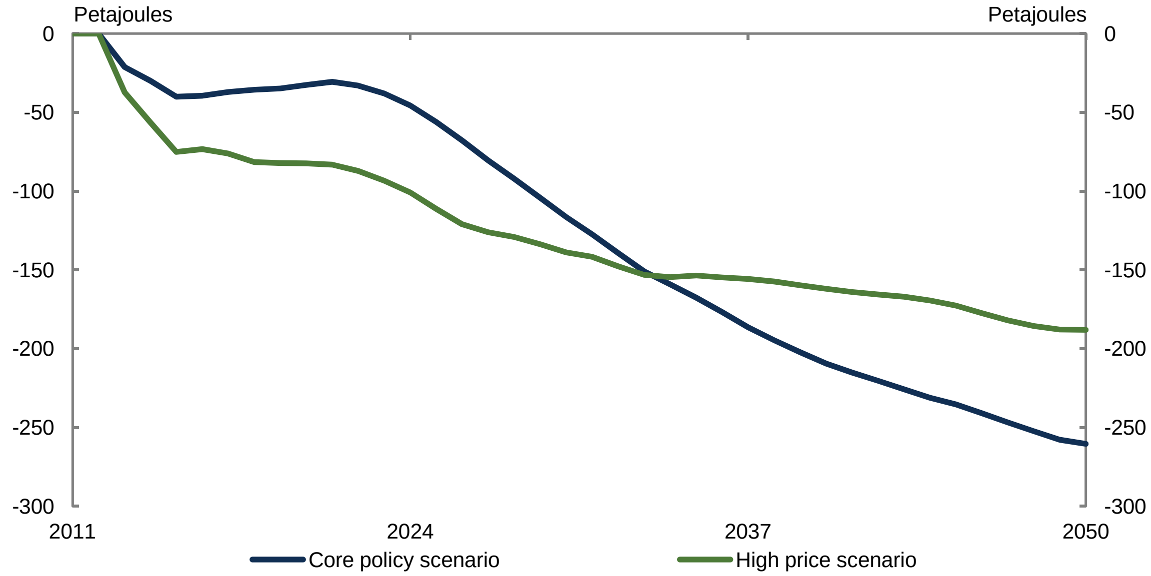
In all sectors, electricity demand falls relative to the global action scenarios after a carbon price is introduced. Increasing electricity prices drive changes in electricity consumption. This occurs through both substitution by households and firms to more efficient consumption choices and production processes, and through restructuring of the economy towards less electricity-intensive industries. There is already evidence of reducing consumption of electricity by households in response to recent electricity price rises.[1]

In 2050, electricity demand is around 17 per cent lower than the global action scenarios in the core policy scenario and 12 per cent lower in the high price scenario.

Towards 2050, electricity demand is greater in the high price scenario, driven by stronger demand from the transport sector. The higher carbon price, combined with the broader coverage of the transport sector in the high price scenario, drives a much larger shift to electric vehicles.

1 For example, in its household expenditure survey, the Independent Pricing and Regulatory Tribunal of New South Wales (IPART) found that average household demand for electricity fell by around 6 per cent between 2005-06 and 2009-10 for the Sydney metropolitan, Blue Mountains and Illawarra areas (IPART, 2009).

Chart 5.17: Electricity demand
Change from global action scenario



Source: Treasury estimates from MMRF, SKM MMA and ROAM.

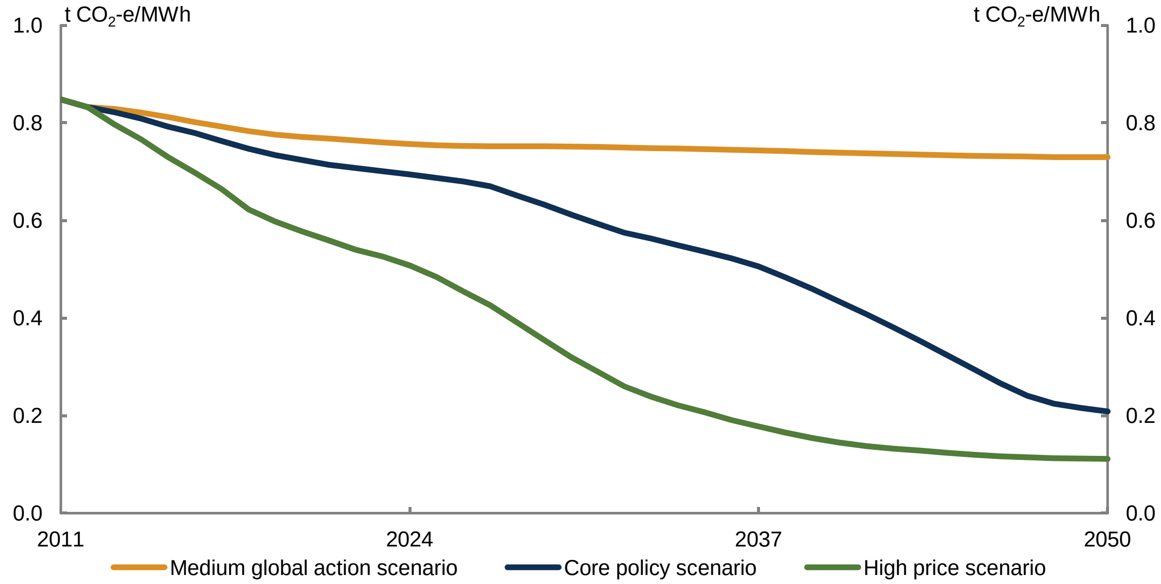
Transformation of the electricity sector

A carbon price drives significant changes in the mix of technologies and fuels used in the electricity sector in both policy scenarios. A carbon price makes gas and renewable energy sources more competitive relative to coal, leading to a progressive transition away from conventional coal-fired generation. However, coal continues to play an important role in electricity generation, particularly following the adoption of carbon capture and storage.

The high price scenario drives a far quicker transformation of the electricity generation sector, with gas and renewables together contributing over 75 per cent of the generation mix by 2050.

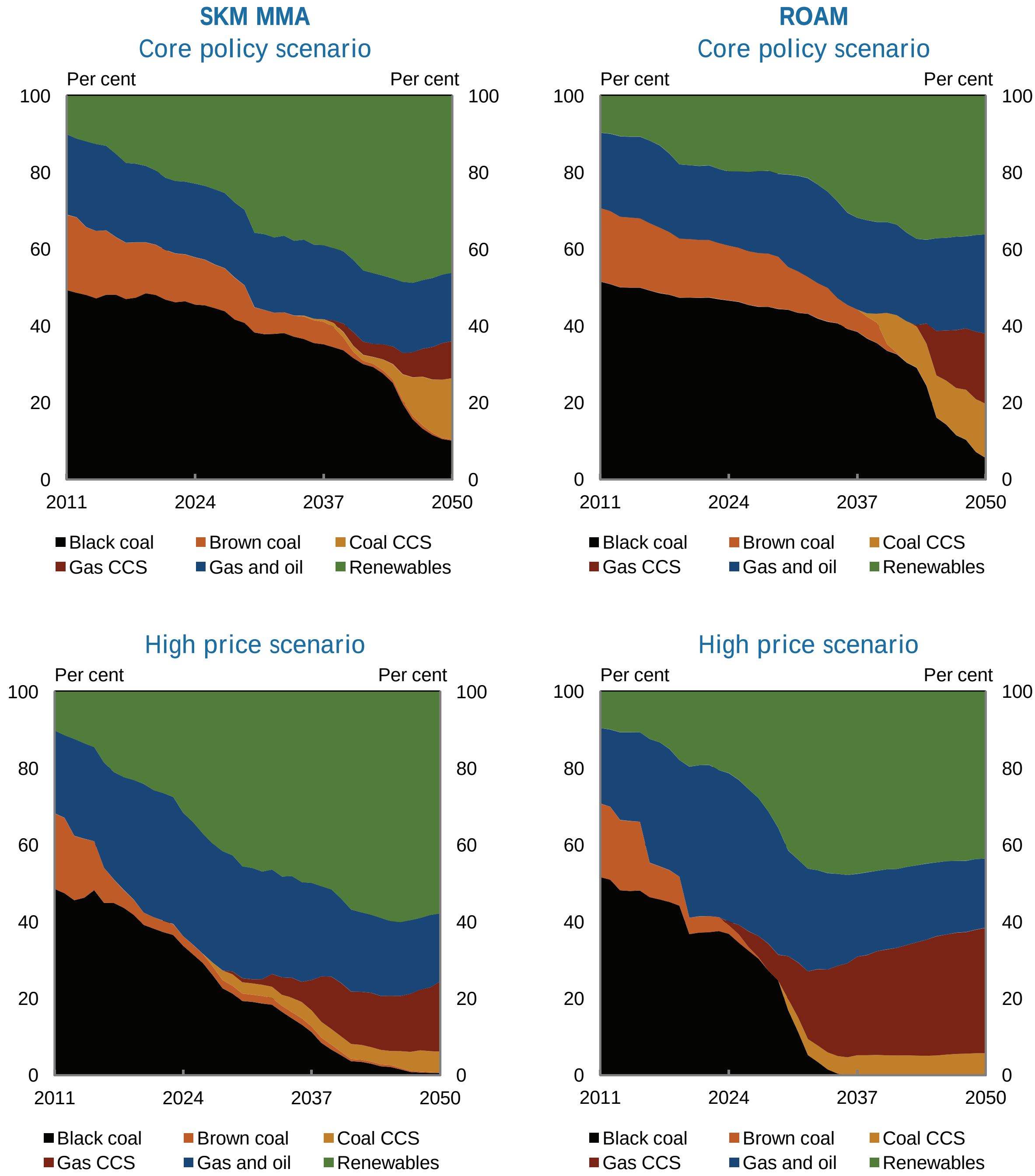
Transforming the fuel and technology mix reduces the emission intensity of electricity supply. While electricity demand falls in the policy scenarios compared with the global action scenarios, most emission reductions are through reduced emission intensity over the longer term. Across the policy scenarios, emission intensity is projected to improve by over 75 per cent by 2050.

Chart 5.18: Emission intensity of electricity generation



Source: Treasury estimates from MMRF, SKM MMA and ROAM.

Chart 5.19: Sources of electricity generation



Source: SKM MMA; and ROAM.

Coal

Coal-fired electricity declines as a share of total generation across all scenarios after carbon is priced. In particular, cleaner sources replace generation from the most emission-intensive generators. However, rising gas prices help coal-fired electricity remain competitive for baseload generation.

No new commercial-scale coal-fired power stations without CCS are approved and commissioned in Australia once the carbon price is introduced. The exception is under one scenario modelled by ROAM. Assuming the world is still in a 550 ppm scenario in 2030, ROAM predicts that one supercritical black coal plant will open in Western Australia at that time.

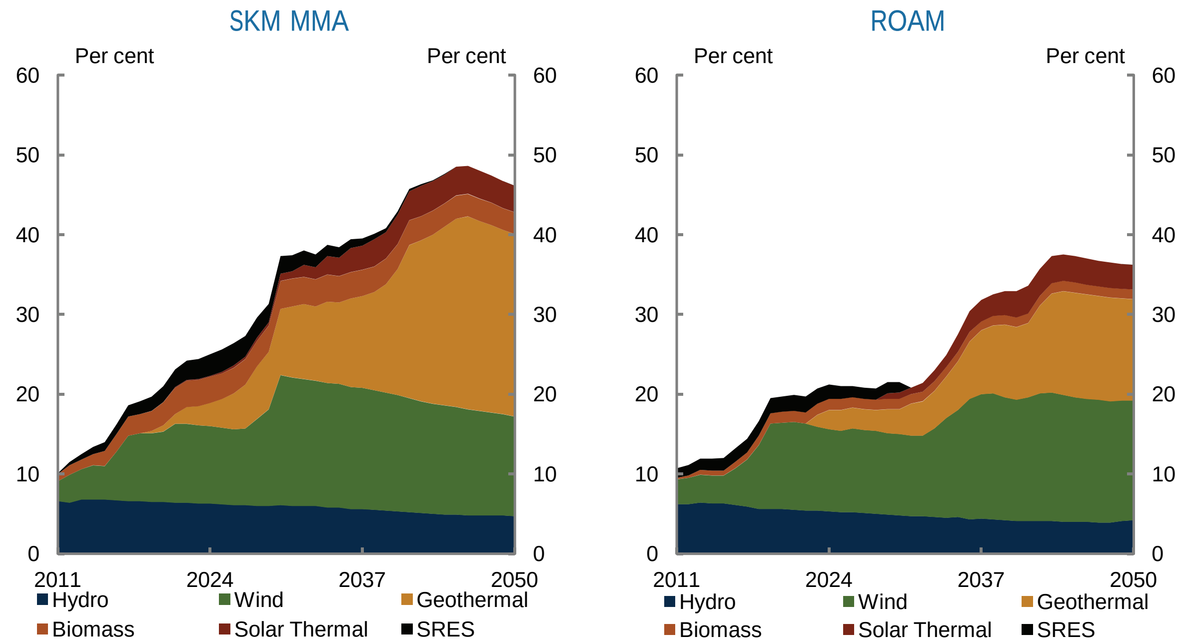
Sensitivity analysis suggests that higher coal prices would result in marginally higher wholesale prices and negligible impacts on the sources of generation.

Renewables

As in the global action scenarios, an increase in renewables driven by the large scale renewable energy target (LRET) satisfies most growth in demand to 2020. Renewable generation reaches 20 per cent of total generation by 2020 in the core policy scenario and between 21 and 26 per cent of total generation by 2020 in the high price scenario. This includes renewable generation driven by the small renewable energy scheme (SRES).

Chart 5.20: Renewables by technology — share of total generation

Core policy scenario



Note: ROAM provided estimates of generation from the SRES for the life of the program (to 2030). SKM MMA estimates also cover the ongoing effects of the program beyond 2030.
Source: SKM MMA and ROAM.

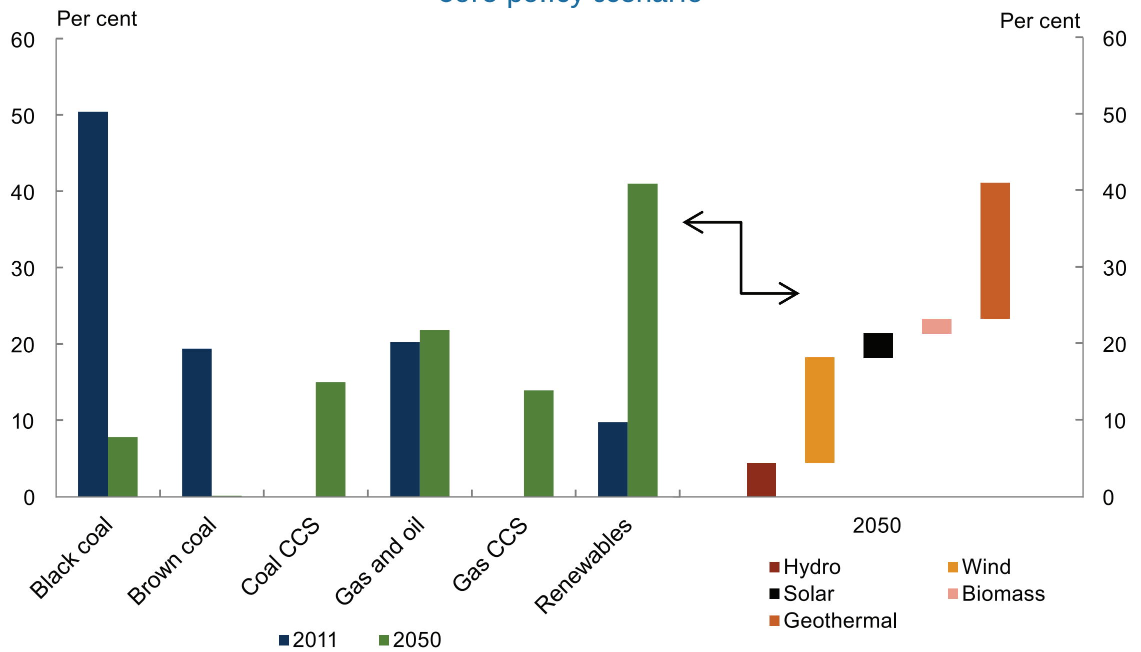
The relatively small additional increase in renewable generation in 2020 under the policy scenarios is the result of offsetting impacts of carbon pricing on the revenues of renewable generators. Increased wholesale prices under carbon pricing deliver higher revenues to renewable generators and increased investment in renewables. However, the increased supply of renewable energy certificates from additional renewable capacity also reduces the price for these certificates, offsetting to some extent the revenue benefits of higher wholesale prices.

Renewable generation continues to grow strongly to 2050, to around 40 per cent of total generation in the core policy scenario and around 50 per cent in the high price scenario.

The early increase in renewables is largely driven by increased wind generation. However, over time, other renewables become increasingly competitive. By 2050, geothermal is a major source of renewable generation, accounting for between 13 per cent (ROAM) and 23 per cent (SKM MMA) of total generation in 2050.

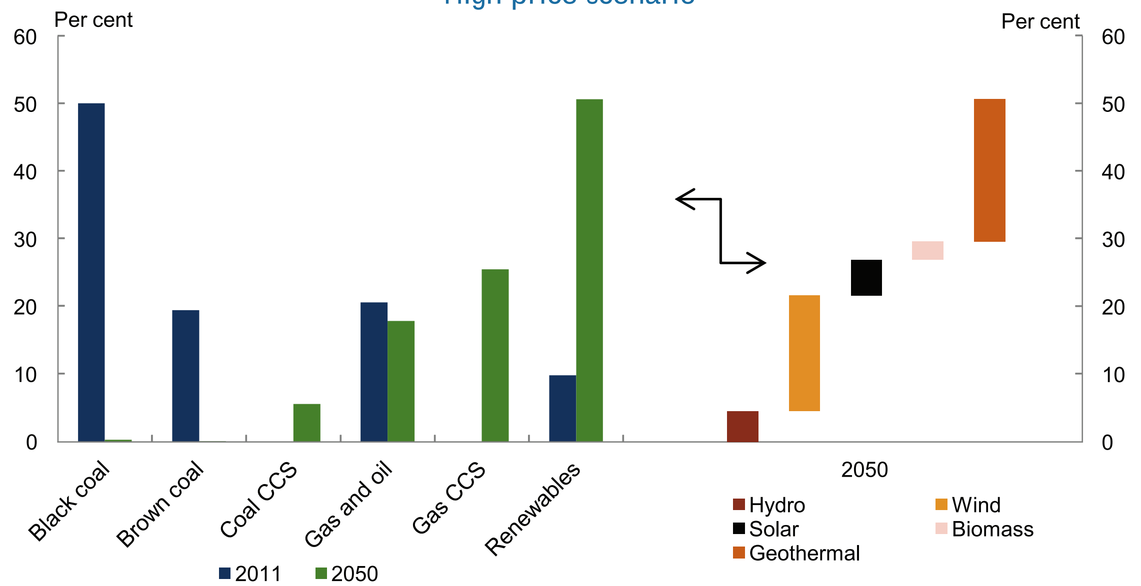
Intermittent generators such as wind produce less generation per unit of capacity on average, than other generators. As such, the higher proportion of intermittent wind generation in ROAM modelling requires the installation of a greater amount of total generation capacity, particularly additional gas generation capacity.

Chart 5.21: Renewable generation
Core policy scenario



Source: Average of SKM MMA and ROAM.

Chart 5.22: Renewable generation
High price scenario



Source: Average of SKM MMA and ROAM.

Sensitivity analysis suggests that lower costs for renewables would result in around 10 per cent more renewable generation in 2050 and 5 per cent lower emissions. Electricity prices would also be lower.

Gas

The outlook for gas generation depends heavily on the combined effect of lower electricity demand, rising gas prices and the carbon price. Gas remains an important component of Australia's generation, remaining around current levels over the next 15 years. However, in the core policy scenario it increases over 200 per cent by 2050.

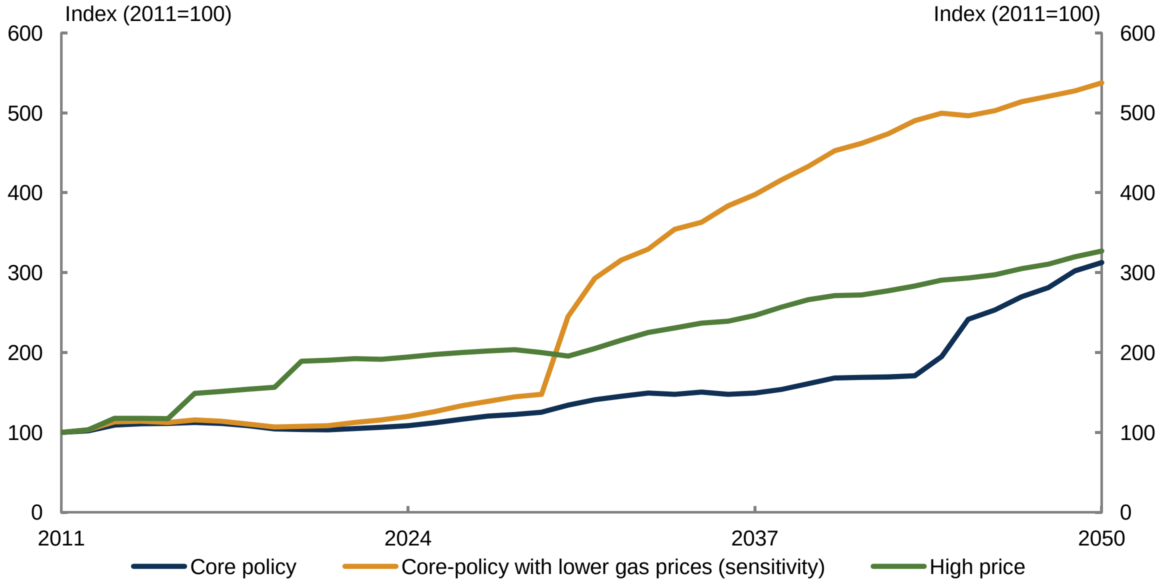
The modelling suggests a carbon price of around $60 per tonne is sufficient to drive significant increases in gas generation in the near term.

Increased gas-fired generation is projected, despite domestic gas prices more than doubling by 2050. This is partly because gas generation plays an important role as a back-up for renewable generation, such as wind, during peak periods of demand.

Sensitivity analysis shows that lower gas prices result in far greater gas-fired generation over the longer term and a significant fall in cumulative emissions (between 10 and 20 per cent lower to 2050). Cumulative emissions fall because gas-fired generation replaces coal-fired generation which has a higher emission intensity.

Chart 5.23: Gas-fired electricity generation

Increase from today's level



Source: Average of SKM MMA and ROAM.

Carbon capture and storage

Carbon capture and storage (CCS) is a technology that can reduce emissions from a range of activities, including the combustion of fossil fuels (oil, gas and coal) for electricity generation. CCS involves capturing emissions, compressing them, transporting them to a suitable site and storing them permanently deep underground.

The longer term role for coal in electricity generation depends in part on the development and deployment of CCS technology. In the core policy scenario, CCS does not become viable until the 2030s.

In the high price scenario, CCS becomes viable in the mid 2020s and grows to around 30 per cent of total generation in 2050 (average of SKM MMA and ROAM). Gas is the predominant form of CCS technology, as it is less emission intensive than coal CCS.

Table 5.12: Carbon capture and storage, estimated deployment year and carbon price

	Core price scenario	High price scenario
SKM MMA		
Year	2035	2027
Carbon price (A$2010/t$CO_2$e)	70	94
ROAM		
Year	2038	2024
Carbon price (A$2010/t$CO_2$e)	82	79

Source: SKM MMA; and ROAM.

Sensitivity analysis shows that if CCS does not become viable, gas will provide additional generation in place of CCS generation. This results in higher emissions and electricity prices, mainly after 2040.

Of course, the further out into the future one looks, the greater the uncertainty. It is possible that other technologies may develop, so the absence of CCS could have little impact in the longer term.

New investment

In the core policy scenario, over $200 billion in new generation investment is required between now and 2050. This includes around $50-$60 billion in gas, $100 billion in renewables, and around $45-$65 billion in coal, nearly all of which is for CCS plants.

Table 5.13: Cumulative investment in new generation capacity

	SKM MMA		ROAM	
$billion	2011 to 2020	2011 to 2050	2011 to 2020	2011 to 2050
Coal (CCS)(a)	0	66	0	44
Gas	1	49	9	58
Renewables	22	97	19	103
Total	23	212	27	206

(a) ROAM figure also includes $1.4 billion in capital expenditure on a supercritical black coal plant in Western Australia in 2030 and 2031.
Source: SKM MMA; and ROAM.

Electricity generation emissions

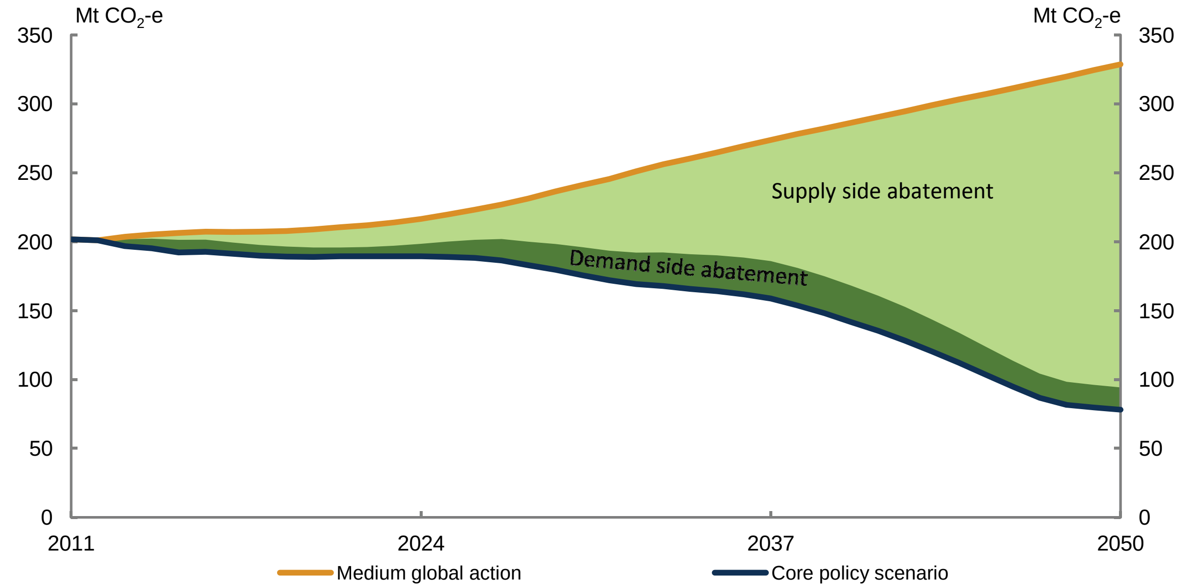
The electricity sector is the largest source of emission reductions, delivering over 40 per cent of total abatement over the period to 2020 in the core policy scenario.

The reduction in emissions occurs in two phases. Initially, abatement is driven by slower growth in demand and switching from existing high emissions generation towards existing lower emission generation, particularly wind. As the carbon price rises, newer technologies such as CCS and geothermal become commercially competitive with existing technologies, driving further reductions in emissions.

Instead of emissions growing by over 60 per cent in 2050 in the global action scenarios, emissions decline by around 60 per cent in the core policy scenario.

Electricity demand provides an important source of abatement in the early years of the sector's transition to a cleaner future. Reduced demand delivers almost half of the cumulative abatement to 2020 in the core policy scenario. If electricity was shielded from a carbon price, electricity emissions would remain at around current levels until the late 2020s in the core policy scenario.

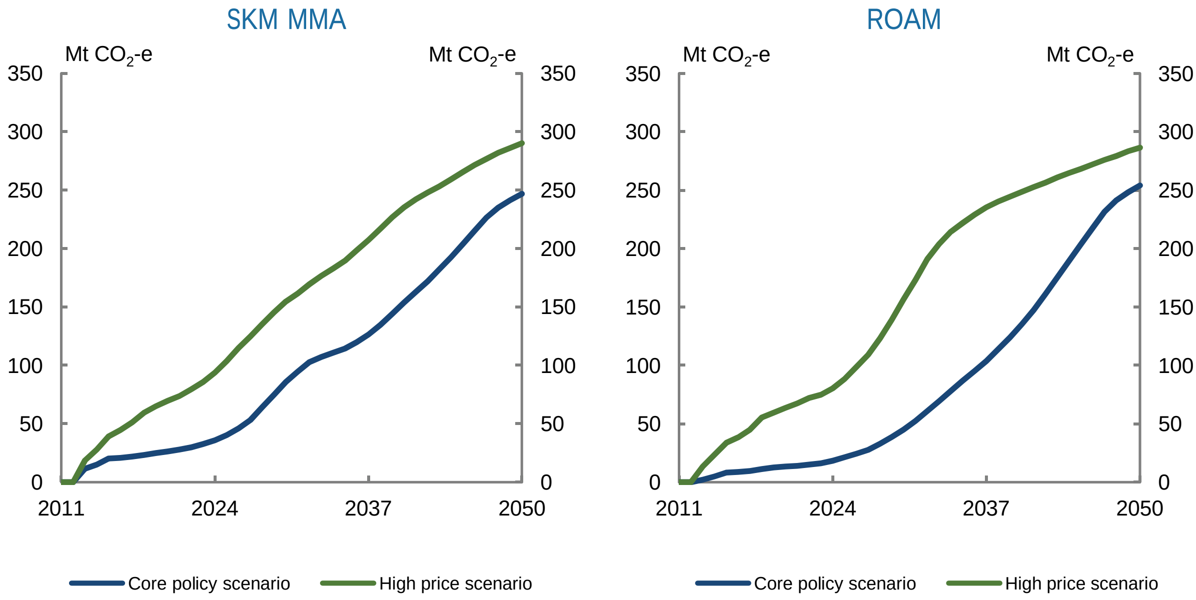
Chart 5.24: Electricity sector emissions



Source: Treasury estimates from MMRF, SKM MMA and ROAM.

Emission reductions vary with different carbon prices and between different modellers. Over time, the abatement projected by both modellers is fairly similar, with abatement increasing significantly after 2020 in the core policy scenario.

Chart 5.25: Electricity sector abatement

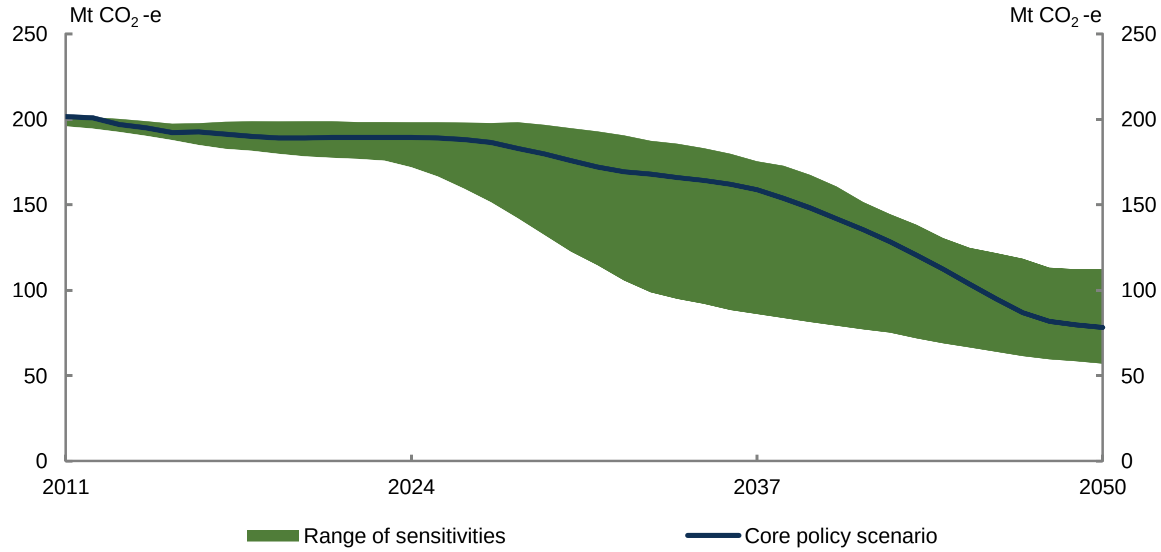


Source: Treasury estimates from MMRF, SKM MMA and ROAM.

The accelerated change in emissions in the high price scenario in ROAM modelling is the result of faster retirement of the existing coal-fired generation fleet. This significantly lowers the average emission intensity of the sector around this time.

Sensitivity analysis shows that the emission estimates are robust to a range of different assumptions. Adopting more conservative assumptions, such as CCS not becoming available or slower technological improvements, increases cumulative emissions by less than 5 per cent between 2013 and 2050. Conversely, assumptions such as lower gas prices and cheaper renewable technologies could result in cumulative emissions between 3 and 19 per cent lower than projected between 2013 and 2050.

Chart 5.26: Electricity sector emissions — sensitivity analysis



Source: Treasury estimates from SKM MMA and ROAM.

Wholesale electricity prices

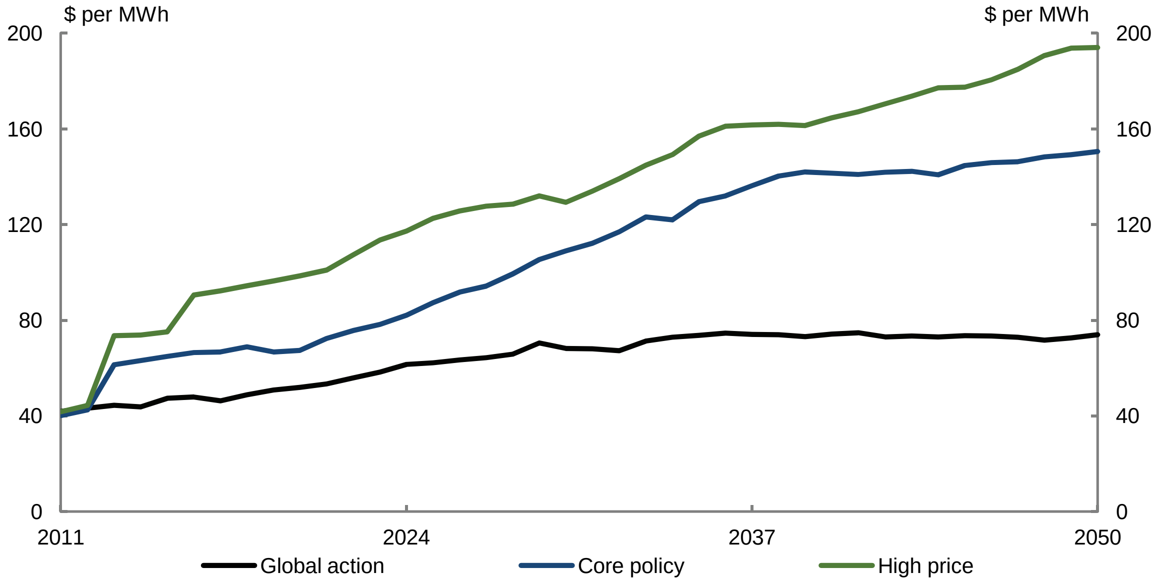
As previously outlined, without a carbon price wholesale electricity prices rise strongly to 2030, driven by rising gas prices and new, higher capital cost plants entering the market to meet growing demand.

The two modellers present different wholesale price increases, with higher costs for baseload capacity in ROAM's modelling leading to higher wholesale prices.

The cost of carbon pricing in the core policy scenario on existing fossil fuel power plants flows into electricity prices, making Australian wholesale electricity prices around $18 per MWh higher on average over the first five years. Deployment of cleaner, more expensive technologies causes electricity prices to continue to increase.

Wholesale electricity prices are sensitive to assumptions about energy commodity prices and capital costs. Changes in the prices of coal and gas have an immediate impact on electricity prices. In contrast, changes in the capital costs of new generators have a greater impact over time, as new generation capacity is required.

Chart 5.27: Average wholesale electricity prices



Note: Prices are in 2010 dollars. Global action is the average of medium and ambitious global action scenarios.
Source: Average of SKM MMA and ROAM.

Table 5.14: Average wholesale electricity price increases
Change from global action scenario (per cent)

	Core policy			High price		
	2013-2017	2018-2022	2046-2050	2013-2017	2018-2022	2046-2050
NSW	38	35	123	76	89	189
VIC	45	39	85	86	105	140
QLD	47	43	122	94	100	192
WA	32	37	98	48	84	143
SA	38	35	69	75	91	121
TAS	40	42	80	76	104	130
Average	40	38	106	78	94	166

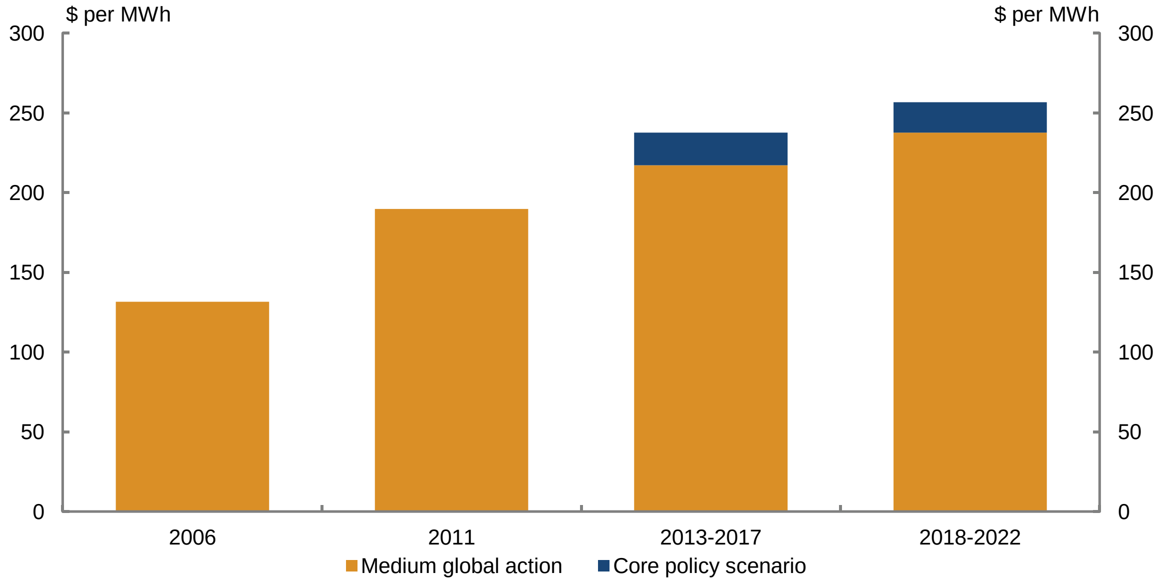
Note: Prices are in 2010 dollars.
Source: Average of SKM MMA and ROAM.

Household electricity prices

Higher wholesale electricity prices flow into retail prices paid by households. Household retail electricity prices are projected to increase by 10 per cent on average, compared to the global action scenario, over five years after carbon pricing starts. The percentage impact is lower than for wholesale prices, as wholesale prices form only part of total retail prices.

Previous Treasury climate change mitigation modelling projected a 20 per cent increase over the period 2010 to 2015. The projected increase is now lower largely due to higher retail prices in the global action scenario. This reflects strong growth in network costs to pay for upgrades of existing infrastructure.

Chart 5.28: Household electricity prices



Note: Prices are in 2010 dollars.
Source: Average of SKM MMA and ROAM.

Table 5.15: Average household electricity price increases
Change from global action scenario (per cent)

	Core policy			High price		
	2013-2017	2018-2022	2046-2050	2013-2017	2018-2022	2046-2050
NSW	9	8	35	16	19	52
VIC	10	8	31	20	25	52
QLD	10	9	35	20	21	57
WA	10	10	37	14	23	55
SA	8	7	23	16	19	40
TAS	9	9	28	16	23	45
NT	8	6	24	18	20	53
Average	10	8	33	17	21	51

Note: Prices are in 2010 dollars.
Source: Average of SKM MMA and ROAM.

Profits of existing generators

The extent to which carbon costs incurred by generators translate into general increases in electricity prices depends on the carbon cost pass-through. The degree of pass-through under a carbon price depends on a range of factors, including electricity demand and costs of alternative fuels, such as gas. The impact on an individual generator's profits is determined by the increase in its costs under a carbon price (higher for more carbon intensive generators) and the rate of carbon cost pass-through in the market.

Individual generator profits would also be affected by any assistance provided by the Government to generators. However, no generator assistance was assumed for the purposes of assessing impacts on profits, or for the modelling more broadly.

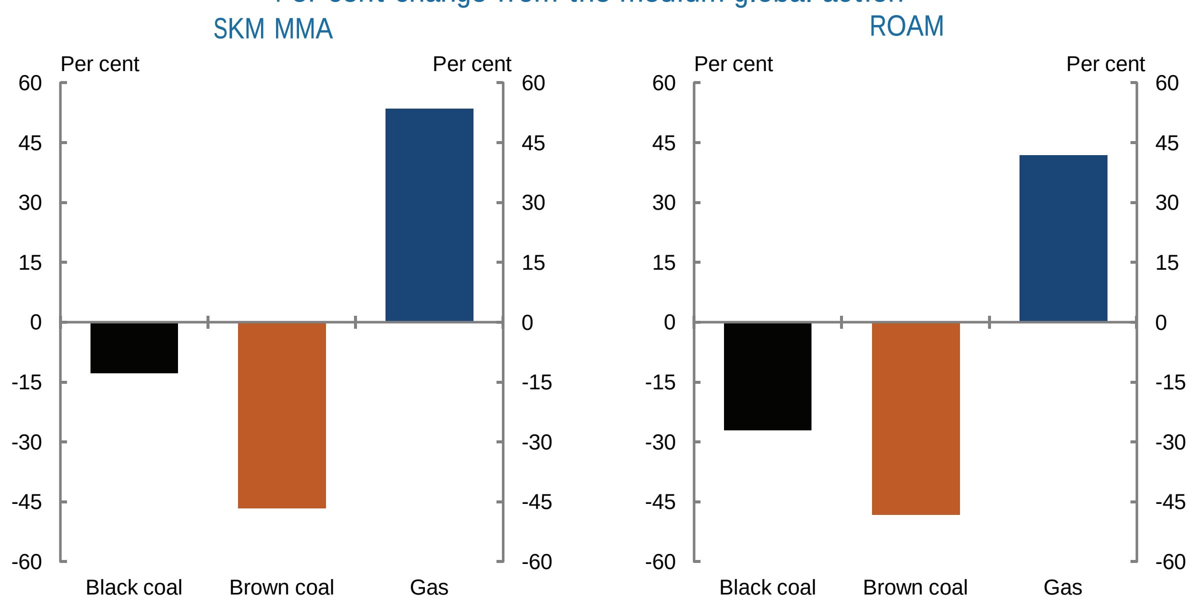
Both modellers show that profits for all brown coal generators decline in the core policy scenario. ROAM modelling also shows that profits decline for all black coal generators, though results vary from around $1 billion to as low as $9 million.[2] Declining profits for brown and black coal generators are partially offset by increased profits for lower emission generators, such as gas.

Gas and hydroelectric generators can benefit from increased wholesale prices if their carbon costs are lower than the increase in wholesale prices from the carbon price. Both SKM MMA and ROAM modelling show losses for coal generators but increases in profits for some lower emission generators.

ROAM results generally show higher losses than SKM MMA for coal generators, largely due to higher profits in the global action scenarios. This is driven by higher wholesale prices in the ROAM global action scenario, and consequently higher cash flows for existing generators.

Chart 5.29: Impact of a carbon price on profits of existing generators

Per cent change from the medium global action



Source: SKM MMA; and ROAM.

The impact of carbon pricing on generator profits will depend on a range of factors. These include the cost structures of individual generators, the extent of demand growth, the costs of new electricity generation technologies and fuel prices.

Higher future wholesale prices, driven by higher gas prices or more expensive future capital costs, would increase the profits of existing coal generators. Conversely, lower capital costs of low emission generators would decrease the profits of coal fired generators, as would lower gas prices.

2 Impacts on profits are calculated as a net present value of trading profits, calculated from 2013 to 2022 using a real, pre-tax weighted average cost of capital of 9.7 per cent (consistent with the discount rates adopted by SKM MMA and ROAM).

Box 5.6: Carbon cost pass-through

For the most emission-intensive generators, typically brown coal generators, carbon costs per unit of generation will be higher. How much of the carbon cost individual generators can recoup depends on how much electricity prices increase in each market. The emission intensity of the marginal generator at different times through the day and over the year largely determines this. If the marginal generator is less emission intensive than a particular generator, this compresses the margins of that generator, reducing its profits.

The carbon price pass-through varies between SKM MMA and ROAM, partly due to different assumptions about the emission intensity of the marginal generator at particular points in time. The carbon price pass-through is similar for the two modellers in the first five years of a carbon price (with each dollar of the carbon price adding around 85 cents to wholesale electricity prices) but falls more rapidly in ROAM's modelling over the subsequent five years due to a greater reliance on gas fired generation.

Chart 5.30: Carbon price pass-through — stylised example

Source: Treasury.

The stylised example shows carbon price pass-through to wholesale prices during periods of peak demand. In this example, before a carbon price, open cycle gas is the marginal generator and sets the market price. Coal generators have the lowest cost of generation and therefore make the largest profits, with combined cycle gas also making profit (but less than coal).

Once a carbon price is introduced, open cycle gas remains the marginal generator and passes through all its carbon costs, increasing wholesale prices. Its profit is unchanged. Due to their higher emission intensity, coal generators pay a higher carbon price per unit of generation and their profit is reduced. Combined cycle gas has the lowest emission intensity, faces the lowest carbon cost and as a result, increases profitability.

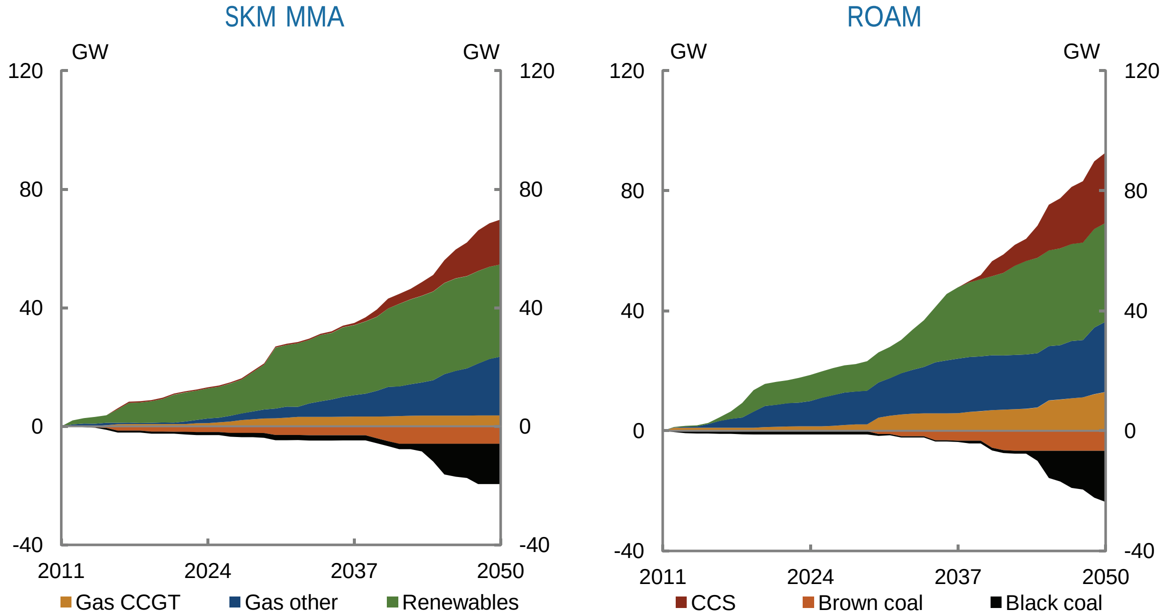
Retirement of existing power plants

As with other industries, a carbon price will affect the economics of existing power generators. Emission-intensive brown and black coal generators will find the additional cost of the carbon price reduces their profitability and some may retire. Conversely, a carbon price will make existing lower emission generators, such as renewable and gas generators, more profitable.

The core policy scenario suggests early closure of the most emission-intensive brown coal power stations and a reduced reliance on black coal generators. It also shows investment in renewables, various gas technologies and after around 2040, CCS technology, more than offsets lost generation capacity as coal plants retire.

Nonetheless, the modelling also shows great uncertainty around the timing of retirement. Potential closure of assets depends on the prospects for wholesale electricity prices, with higher prices enabling incumbent generators to pass on carbon costs for longer before becoming unviable.

Chart 5.31: Changes in generation capacity by fuel type



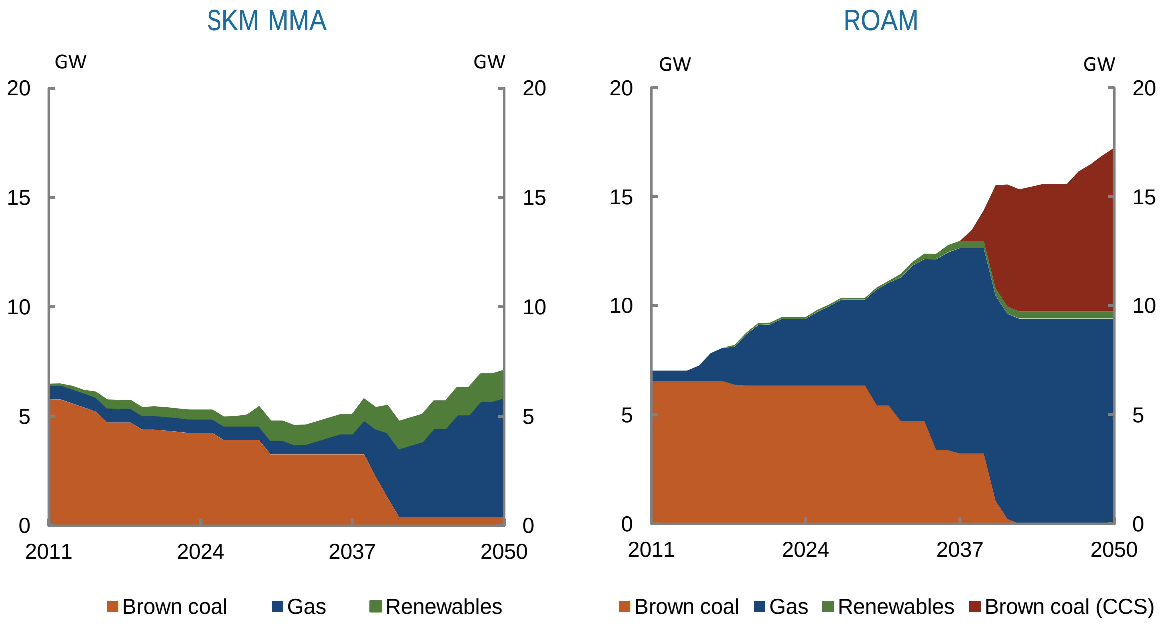
Source: SKM MMA; and ROAM.

Despite this uncertainty, electricity prices adjust to ensure either existing or new generators can operate profitably while meeting electricity demand in each policy scenario.

This report projects retirement of electricity generation units by modelling them as economic assets requiring a commercial rate of return. It does not take account of financial considerations, such as debt-equity ratios or ownership structures, on retirement decisions. These may be interrelated. However, a profitable asset is likely to continue operating with existing owners or sold to new owners.

The Latrobe Valley remains an important energy exporting region, even as existing coal plant is retired. The Latrobe Valley has significant transmission and distribution networks, making it ideal for investment in new and cleaner energy sources. Both modellers show more generation capacity located in the Latrobe Valley in 2050 than today, despite the eventual retirement of all existing emission-intensive brown coal generators. However, the results of the modellers vary considerably in the timing of retirements, and the composition and timing of new generation capacity.

Chart 5.32: Generation capacity in the Latrobe Valley/Gippsland region



Source: SKM MMA; and ROAM.

Sensitivity analysis

Given the uncertainty around future commodity prices, technological progress and capital costs, a number of sensitivity scenarios were conducted to test the implications of changes to the assumptions. The analysis shows that the projections are generally robust to changes in the assumptions, with only minor changes to the projections in most sensitivity scenarios.

Aside from the alternate assumptions outlined below, the sensitivities are based on the assumptions adopted in the core policy scenario, such as electricity demand.

Table 5.16: Implications of sensitivity analysis

Sensitivity	Summary	Impacts relative to the core policy scenario in 2050	Cumulative emissions 2013 to 2050 ROAM	Cumulative emissions 2013 to 2050 SKM MMA	Emissions 2050 ROAM	Emissions 2050 SKM MMA	Wholesale price SKM MMA 2020	Wholesale price SKM MMA 2050
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Lower gas prices	Lower gas prices: - 40 per cent in 2030 - 60 per cent in 2050	CCGT capacity increases doubles in 2050	↓ 18	↓ 11	↑ 20	↓ 34	↓ 4	↓ 24
Higher coal prices	Higher coal prices: + 30 per cent in 2020 + 60 per cent in 2050	Black coal CCS down 60 per cent (SKM MMA) Brown coal CCS down 1 per cent (ROAM)	↓ <1	↓ 1	↑<1	↓ 8	↑ 5	↑ 1
Slower capital cost improvements	Half the rate of decline in capital costs for all technologies	Investment in renewables down CCS generation down 23 per cent (ROAM), and down 6 per cent (SKM MMA) by 2050	↑ 4	↑ 2	↑ 20	↑ 3	↓<1	↑ 4
Lower capital costs for renewables	Lower captial costs: wind and solar	Renewables (excluding hydro) in 2050: up 9 per cent (ROAM) up 12 per cent (SKM MMA)	↓ 4	↓ 5	↓ 5	↓ 5	↑ 3	↓ 5
No carbon capture and storage	CCS technology is considered unavailable	A significant increase in CCGT with minor increases in renewables causing an overall increase in emissions	↑ 3	↑ 3	↑ 45	↑ 36	↓ <1	↑ 6

Source: SKM MMA; and ROAM.

5.4.4 Transport

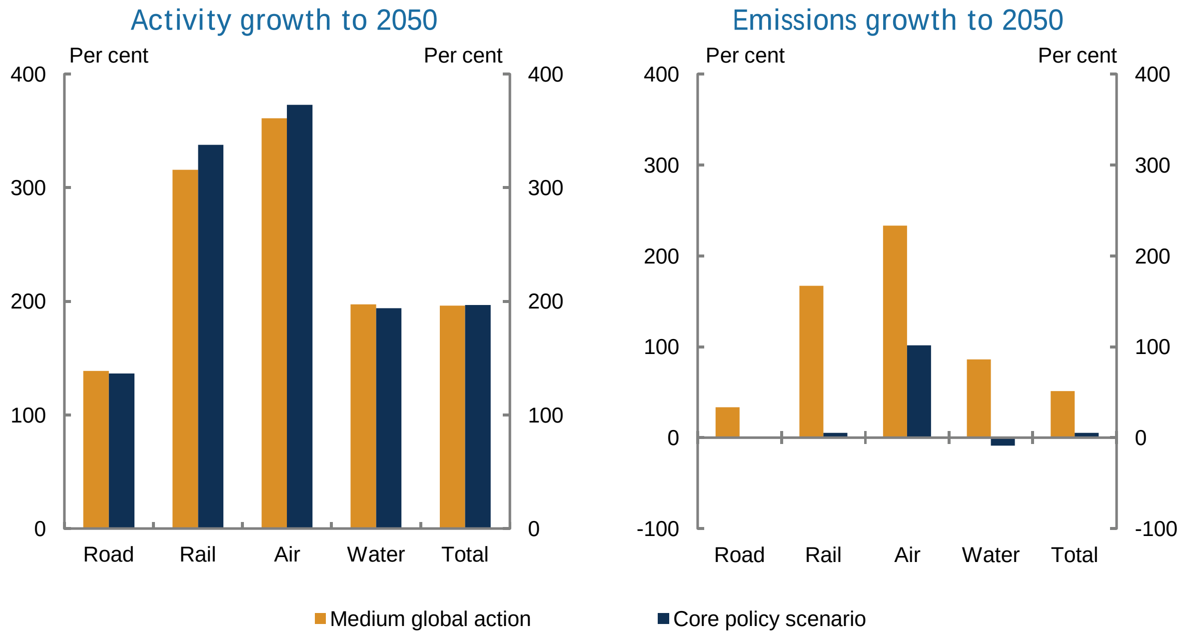
Despite continued growth in transport activity across the economy, carbon pricing results in lower emissions in the transport sector. Transport delivers between 8 and 11 per cent of total domestic abatement out to 2050, with the road transport sector providing the vast majority of abatement.

The core policy scenario assumes all passenger and light commercial vehicles, all vehicles engaged in agriculture and fishing, and all vehicles using LPG and natural gas are excluded permanently from carbon pricing impacts. All other road freight vehicles are included from 2014-15.

In contrast, the high price scenario includes passenger vehicles, vehicles engaged in agriculture and fishing, and gas fuelled vehicles from 2015-16, while business vehicles and vehicles using natural gas are included from 2013-14. Once included, passenger vehicles face only the incremental increase in the carbon price over time, while other sectors face the full carbon price once included.

Transport activity is projected to be relatively unaffected by carbon pricing. Growth in activity remains similar across most sectors, though there is some substitution from road transport to rail. Air transport activity is stronger in the carbon price scenarios, as the benefits of a lower exchange rate for exports outweigh reduced domestic consumption of air transport.

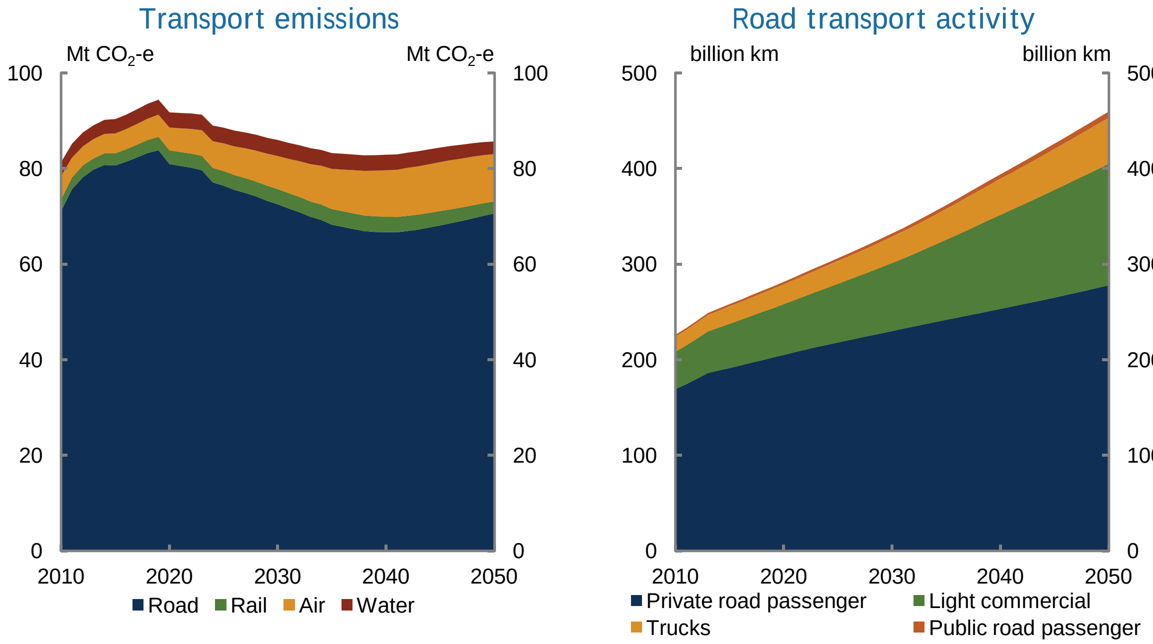
Chart 5.33: Transport activity and emissions



Source: Treasury estimates from MMRF and CSIRO.

Across the policy scenarios, total transport emissions range from 30 to 70 per cent below levels without a carbon price by 2050. Emissions continue to grow over the next ten years before falling back towards current levels by 2050. The higher level of abatement in the high price scenario reflects both the higher carbon price and broader coverage of road transport.

Chart 5.34: Emissions and activity, core policy scenario



Source: Treasury estimate from MMRF and CSIRO.

Road transport

While there is a small reduction in road transport activity from the introduction of a carbon price, the majority of abatement comes from changes in fuel use.

Table 5.17: Emissions and abatement by carbon price scenario

	2010	2020		2050	
	Emissions	Emissions	Abatement	Emissions	Abatement
Core policy	71	81	4	71	24
High price	71	79	6	31	63

Source: Treasury estimate from MMRF and CSIRO.

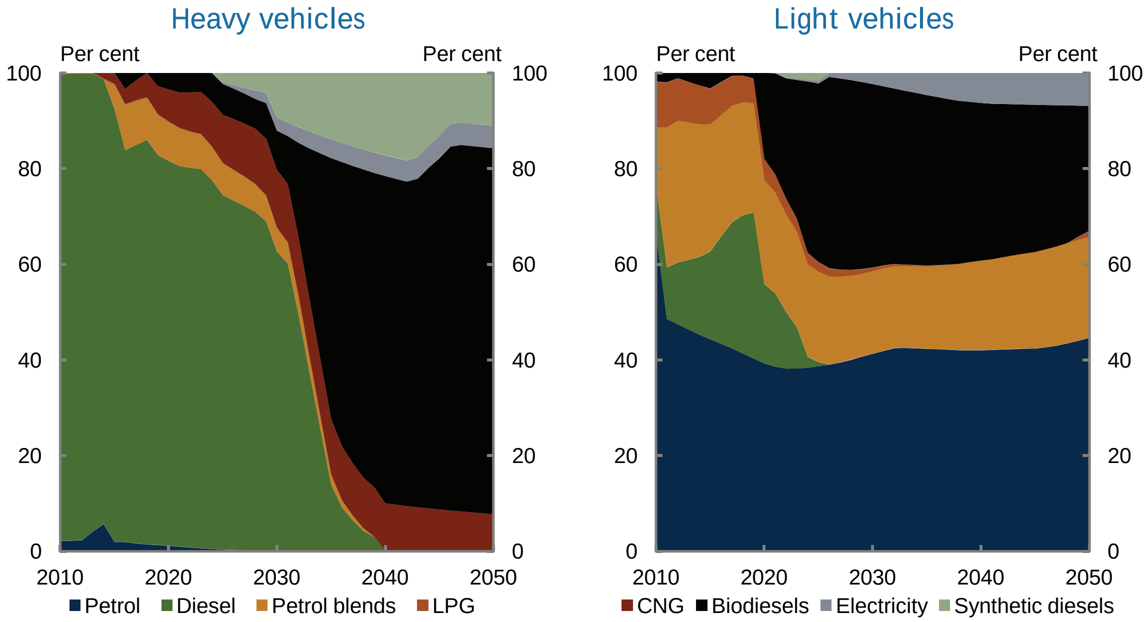
There is limited abatement in the near term due to the time required to turn over the existing vehicle fleet and the higher upfront costs of cleaner technologies. However, from 2020, road transport emissions fall substantially relative to the global action scenarios. Cumulatively, road transport contributes around 6 per cent of total domestic abatement out to 2050 in the core policy scenario.

Emissions from rigid trucks in 2050 are around 75 per cent below 2010 levels. Passenger vehicle emissions fall to nearly 30 per cent below today's levels, while emissions from articulated trucks, buses and light commercial vehicles increase, but at a slower rate than in the global action scenarios.

Continuing the trends in the global action scenarios, a carbon price drives even greater changes in the fuel mix over time, with greater adoption of alternative fuels.[3]

3 The adoption of both conventional and alternative fuels among heavy vehicles takes into account the impact of carbon pricing on the entire production cycle of the fuel.

Chart 5.35: Road transport fuel mix



Note: Biodiesels are B20, pure biodiesel and biomass-to-liquid. Synthetic diesels are coal-to-liquid and gas-to-liquid.
Source: CSIRO.

The most significant change in fuel mix is the adoption of biodiesel blends. By 2030, biodiesels become the dominant fuel used in heavy vehicles and represent more than 75 per cent of total fuel use by 2050.

There is also increased uptake of electric vehicles and synthetic diesels, although these remain fairly small shares of the overall fuel mix. The uptake of electricity among heavy vehicles is confined to rigid trucks and buses, as it is unsuitable for use in long haul transport. Higher carbon prices and carbon capture and storage make synthetic fuels more attractive.

Changes in transport fuels and technologies driven by heavy vehicle demand are also projected to provide spillover benefits to light vehicle users. In particular, strong heavy vehicle demand aids the development of the biofuels industry. This leads to cheaper and more widely available biofuels for light vehicles. Similarly, as heavy vehicle demand drives the development of the infrastructure required for electric vehicles, this will encourage the uptake of light electric vehicles. Nevertheless, conventional petrol remains the dominant fuel used in light vehicles.

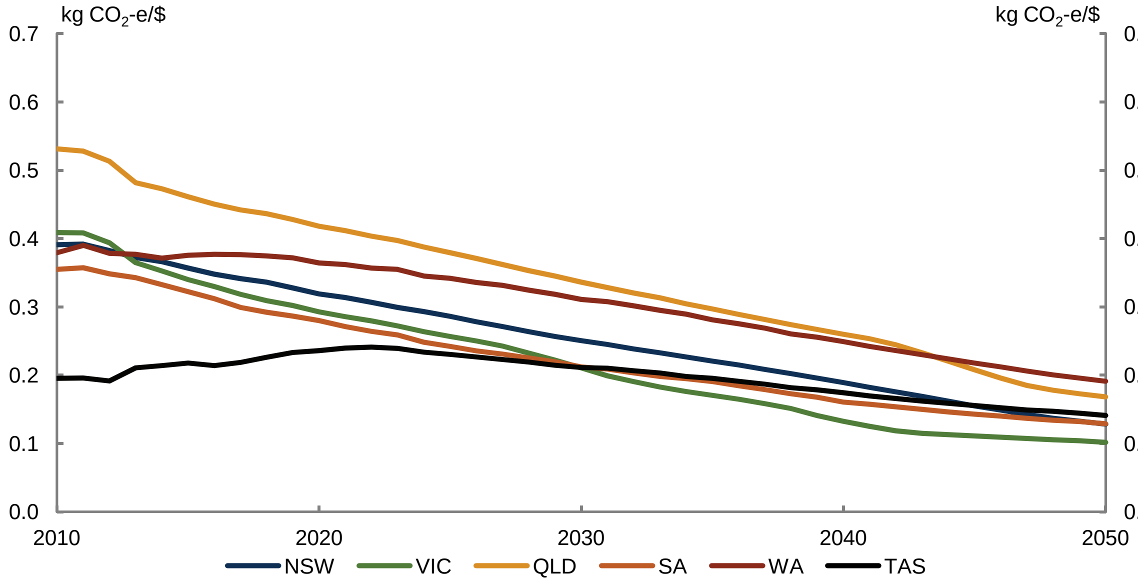
5.5 State analysis

All states are projected to continue to prosper while reducing their emission intensity of output.

The impact of carbon pricing on gross state product (GSP) depends on each state's emission intensity, which in turn depends on its industry structure. To the extent the carbon price affects the exchange rate, the state's trade intensity also matters.

Chart 5.36: Emission intensity by state

Core policy scenario



Source: Treasury estimates from MMRF.

South Australia, Tasmania and Victoria face more modest carbon pricing impacts than the national average. They are less emission intensive due to a greater concentration of industries, such as motor vehicles and parts production, textiles, clothing and footwear, and forestry, which grow somewhat faster with carbon pricing.

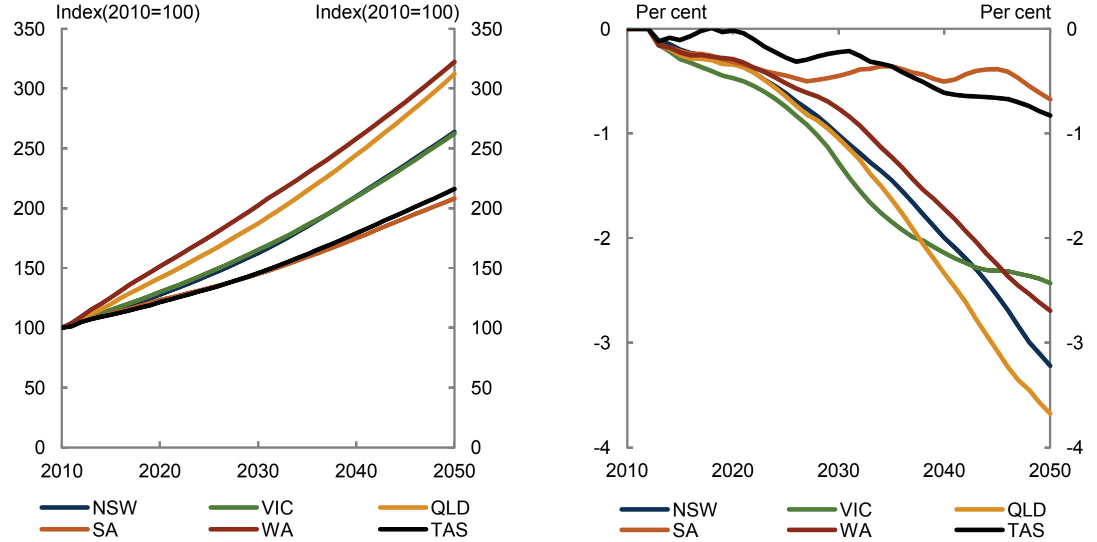
Queensland, Western Australia and New South Wales have more emission-intensive industrial structures, relying somewhat more on emission-intensive manufacturing, such as iron and steel production, alumina and aluminium production and petroleum refining, and energy extraction. For example, exports of liquefied natural gas from Western Australia and Queensland grow strongly with carbon pricing, but production growth may slow with a carbon price in the 2030s and 2040s. Similarly, while output of the black coal industry in New South Wales will continue to grow, the rate of output growth will be somewhat slower with carbon pricing.

It is difficult to quantify the impact of carbon pricing at a sub-state regional level due to limitations on the level and quality of data available. Over time, carbon pricing will encourage resources to move between regions, but reliable information on which to project these movements is not available.

Chart 5.37: Gross state product

Core policy scenario

Level — Change from global action scenario



Source: Treasury estimates from MMRF.

Table 5.18: Output by industry and state

Growth from 2010 to 2050

	New South Wales		Victoria		Queensland	
	Medium global action	Core policy	Medium global action	Core policy	Medium global action	Core policy
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Agriculture	124	127	117	121	147	152
Mining	195	118	27	18	236	219
Manufacturing	66	61	66	66	100	92
Construction	175	157	185	170	252	232
Services	224	221	242	238	311	305
	South Australia		**Western Australia**		**Tasmania**	
	Medium global action	Core policy	Medium global action	Core policy	Medium global action	Core policy
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Agriculture	120	123	122	125	129	134
Mining	-21	-24	306	301	250	194
Manufacturing	61	63	94	71	55	48
Construction	120	109	301	281	141	130
Services	172	169	289	283	143	140

Source: Treasury estimates from MMRF.

5.6 Households

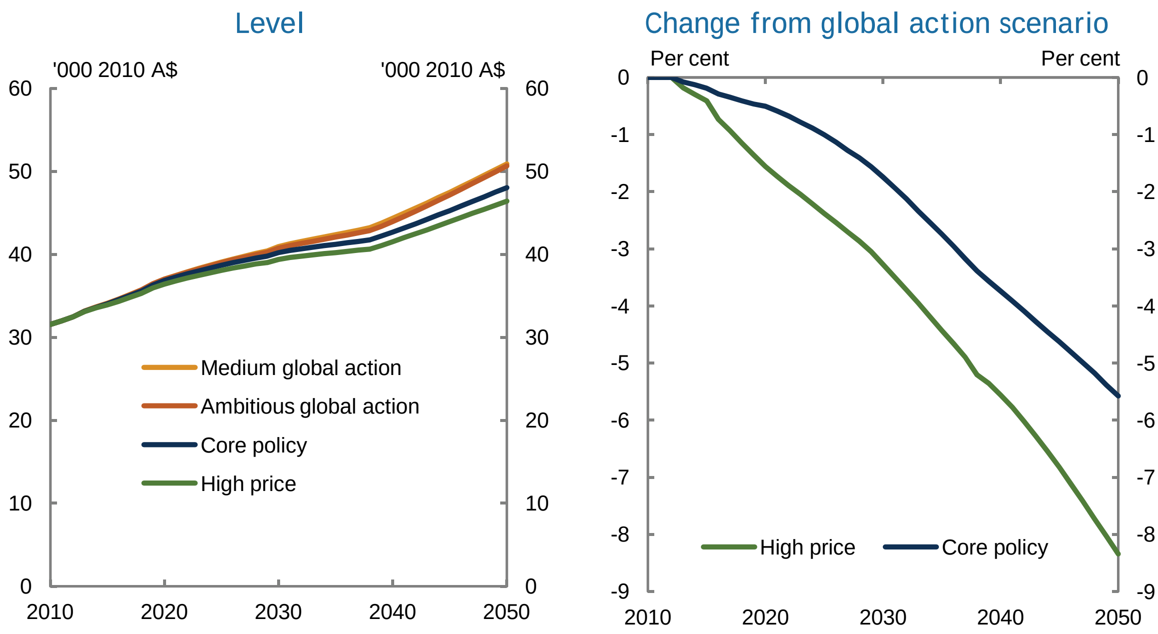
Aggregate household consumption will continue to grow with carbon pricing. Households face higher prices for emission-intensive products, such as electricity and gas used for heating, but most other products, including food and clothing, will see only minimal price increases. Impacts on individual households will depend on the specific goods and services they typically consume and how easily they can change their consumption in response to price changes.

5.6.1 Effects on aggregate household income

Household consumption continues to grow strongly over time in both policy scenarios. Real household consumption per person grows at an average annual rate of 1.1 per cent in the core policy scenario, compared with 1.2 per cent in the global action scenario.

Private consumption moves in line with household income growth, which slows mainly due to slower growth in labour income. The modelling assumes that net permit revenue is returned to households, which partially offsets the effect of slower growth in labour income.

Chart 5.38: Private per person consumption



Source: Treasury estimates from MMRF.

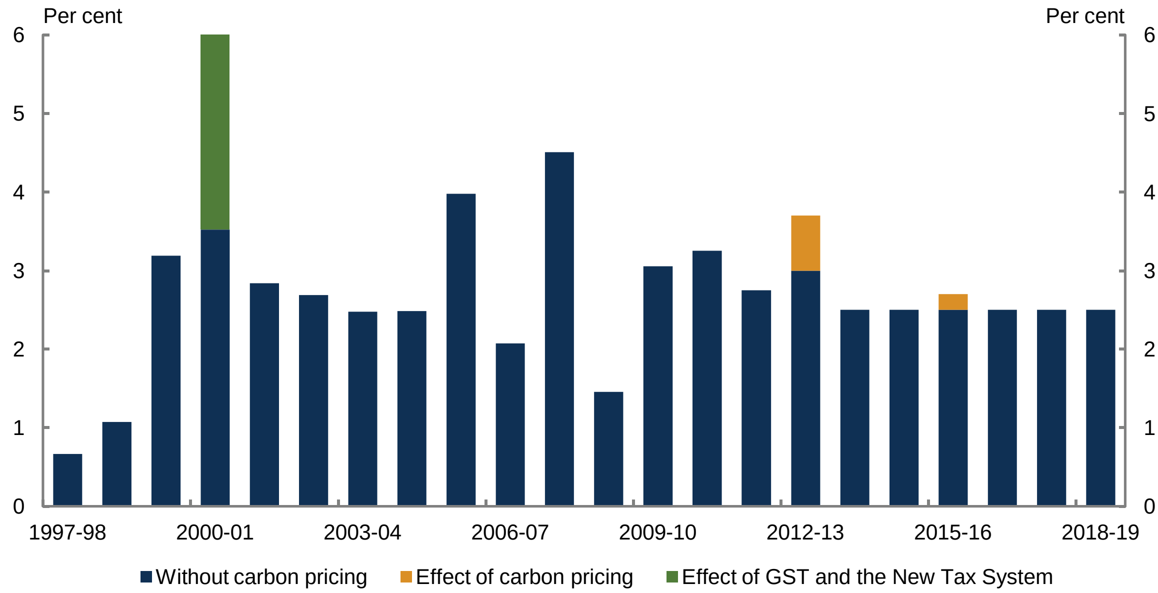
5.6.2 Effects on consumer prices

While average consumption levels continue to grow, carbon pricing changes the relative prices of high and low emission-intensive goods and overall consumer prices increase.

To help households with the move to a low carbon economy, the Government will provide assistance through increases in the Family Tax Benefit, pensions and allowances as well as tax cuts. This will ensure that households are provided with support as Australia moves to a clean energy future.

The analysis in this section overstates the effect of carbon pricing on the average level of consumer prices. It assumes emission costs to households are passed on fully, based on fixed consumption patterns. The true change in the average household cost of living is likely to be lower than the estimate here, as households substitute towards lower emission goods and services. Changes in consumption will start to have some effect immediately after the introduction of carbon pricing and become more important over time. The dynamic general equilibrium modelling accounts for these changes over time, allowing for households to adjust spending in response to changes in relative prices. That modelling projects that around one-half of the increase in prices of emission-intensive goods and services is offset by lower consumption of those products. The effect on average consumer prices also is likely to be overstated because it assumes production technology is not adjusted. Firms will move to less emission-intensive technology and substantially reduce the carbon intensity of the economy, but these changes will take time.

Chart 5.39: CPI impact from carbon pricing compared with history



Source: Treasury calculations from ABS.

Most of the effect on consumer prices occurs in the first year of the fixed price period. Overall consumer prices increase by 0.7 per cent in 2012-13 under a $23 carbon price. On average, household spending is expected to increase by less than $10 per week. The consumer price impact on different goods depends on the emissions intensity of their production. Household expenditure, on average, is expected to increase by $3.30 per week due to higher electricity prices and by $1.50 per week due to higher gas prices. Most items in consumer budgets will increase by less than 1 per cent, such as food where households are expected on average to spend only an additional $0.80 per week. These effects are small compared with the effect of the new tax system introduced in July 2000, which raised consumer prices by 2½ per cent. They are also small in the context of historical movements in consumer prices from year to year.

By 2015-16, with the transition to a flexible price cap-and-trade scheme with a world carbon price projected to be around A$29, it is estimated that carbon pricing will have raised the level of consumer prices by a further 0.2 per cent, for a total effect of 0.9 per cent. By 2015-16, households, on average, would spend around $13.40 per week more in the core policy scenario if they made no changes in their consumption patterns following the introduction of carbon pricing. Of course, the actual world price in 2015-16 may be lower or higher, resulting in different effects on consumer prices. Beyond 2015-16, carbon pricing is not expected to have a material impact on inflation.

Table 5.19: Effects on weekly expenditure and the consumer price

	In 2012-13 $23/tCO$_2$-e		By 2015-16 $29/tCO$_2$-e	
	$ per week	Per cent	$ per week	Per cent
Electricity	3.30	10	4.20	11
Gas	1.50	9	1.80	11
Food	0.80	< 0.5	1.10	< 1
Overall effect	9.90	0.7	13.40	0.9

Note: The dollar per week impacts are the average across households, not the impact on an average household. Effects on weekly expenditure are in 2012-13 dollars.
Source: Treasury estimates based on PRISMOD.

5.6.3 Distributional effects

Changes in consumer prices affect different households in different ways. The distribution of these effects depends on the initial emission intensity of consumption by different household types and their relative ability to alter their consumption.

Low income households are disproportionately affected by carbon pricing. They spend, on average, a higher proportion of their disposable income on emission-intensive goods, such as electricity and gas. For this reason, the average price impact for a single pensioner household in the lowest income quintile is estimated to be 1.0 per cent in 2012-13, while for a one-income household with no children in the highest income quintile the average price impact is estimated to be 0.6 per cent.

As outlined above, estimates of the impact of carbon pricing on average consumer prices are overstated because they ignore the ability of households to substitute towards lower emission products. The degree of overstatement is likely to be greatest for higher income households, as they are more able to shift consumption towards less emission-intensive goods through product substitution. Households that can change their consumption patterns will face lower price impacts than households that cannot do so.

These estimates do not incorporate the Government's commitment to provide financial assistance to households. Households will receive assistance, which they will be able to pocket if they transfer consumption to less emission-intensive goods to improve their energy efficiency.

Table 5.20: Estimated price impacts by household type

$23 carbon price in 2012-13

	Household income quintile[a]					
Household type and primary source of income	All Per cent	First quintile Per cent	Second quintile Per cent	Third quintile Per cent	Fourth quintile Per cent	Fifth quintile Per cent
All	0.7	0.9	0.9	0.7	0.7	0.7
Two income household, no children (b)	0.7	**	1.0	0.8	0.7	0.7
Two income household, with children (b)	0.7	**	0.8	0.8	0.7	0.7
One income household, no children (b)	0.7	**	0.8	0.7	0.7	0.6
One income household, with children (b)	0.7	**	0.8	0.8	0.7	0.7
One income single person household	0.7	**	0.9	0.7	0.7	0.7
Self-employed household	0.8	0.9	0.8	0.8	0.7	0.7
Household with primary income source from Commonwealth allowances (e.g. Newstart Allowance, Youth Allowance)	0.9	0.8	0.9	**	**	**
Married pensioner household	0.9	1.0	0.8	**	**	**
Single pensioner household	1.0	1.0	1.0	**	**	**
Sole parent pensioner household	1.0	1.1	1.0	**	**	**
Part-pension and self-funded retiree households	0.7	0.8	0.9	0.7	0.7	0.7

** indicates the sample size was too small to produce statistically reliable results.

(a) Income quintiles rank households from the lowest 20 per cent of disposable income to the highest 20 per cent. Modified OECD equivalence scales are applied to household disposable incomes to allow for comparisons across households of different sizes and compositions.

(b) Principal source of income is wages and salaries.

Notes: These estimates assume that the carbon price costs are immediately passed through to consumers; that firms do not change their production processes; and that households do not change their consumption behaviour in response to the scheme. To the extent that households reduce their consumption of goods whose relative prices have risen, and increase their consumption of goods whose relative prices have decreased, the real impact on households would be expected to be lower

Source: Treasury estimates based on PRISMOD.

Appendix A: Modelling framework

Introduction

No one 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 typically focus on one of these dimensions — a particular sector (for example, electricity generation) isolated from the broader national economy, or the national economy without a consistent global analysis.

In contrast, this analysis and previous Treasury modelling (Australian Government, 2008) use a suite of models that together span global, national, sectoral and household scales, to simultaneously explore these four dimensions.

The modelling includes two top-down, computable general equilibrium (CGE) models developed in Australia: the Global Trade and Environment Model (GTEM) and the Monash Multi-Regional Forecasting (MMRF) model. These CGE models are economy-wide models that capture the interactions between different sectors and among producers and consumers. GTEM models the global economy. MMRF models the Australian economy with state and territory level detail. A series of bottom-up sector-specific modelling for electricity generation, road transport, agriculture and forestry complement these CGE models.

This appendix provides a summary of Treasury's modelling framework.

Economy-wide modelling

GTEM global model

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) developed the recursively dynamic general equilibrium model, GTEM, to analyse policy issues with global dimensions, such as climate change mitigation costs. It is derived from the MEGABARE model and the static Global Trade Analysis Project (GTAP) model (Pant, 2007; Hertel, 1997; ABARE, 1996 and Australian Government, 2008). In this report, GTEM represents the global economy through 13 regions (including Australia, the United States, China and India) each with 19 industrial sectors and a representative household (for each whole regional society). Trade and investment link the regions and a range of taxes and subsidies capture government policies. The model assumes multiple production technologies for three energy-intensive sectors: the electricity, transport, and iron and steel sectors.

Table A1: Regions and sectors of GTEM

Regions			Industry sectors	
United States			**Coal mining**	
European Union (25)			**Oil mining**	
Austria	Belgium	Cyprus	**Gas mining**	
Czech Republic	Denmark	Estonia	**Petroleum and coal products**	
Finland	France	Germany	**Electricity**	
Greece	Hungary	Ireland	with 12 technologies:	
Italy	Latvia	Lithuania	Coal	Petroleum and coal products
Luxembourg	Malta	Netherlands	Gas	Nuclear
Poland	Portugal	Slovakia	Hydro	Wind
Slovenia	Spain	Sweden	Solar	Biomass
United Kingdom			Waste	Other renewables
			Coal CCS	Gas CCS
Japan			**Iron and steel**	
China			with 2 technologies:	
India			Electric arc	Blast furnace
Indonesia			**Non-ferrous metals**	
Other South and East Asia			**Chemical, rubber and plastic products**	
Brunei	Cambodia	Laos	**Other mining**	
Malaysia	Maldives	Myanmar	**Non-metallic minerals**	
Philippines	Korea	Singapore	**Manufacturing**	
Thailand	Timor-Leste	Vietnam	**Air transport**	
Former Soviet Union			**Water transport**	
Armenia	Azerbaijan	Belarus	**Other transport**	
Georgia	Kazakhstan	Kyrgyzstan	with 5 technologies:	
Moldova	Russia	Tajikistan	Non-road (rail)	Internal combustion engine
Turkmenistan	Ukraine	Uzbekistan	Advanced internal combustion engine	
OPEC(a)			Hybrids	Non-fossil fuel vehicles
Bahrain	Iran	Iraq	**Crops**	
Israel	Jordan	Kuwait	**Livestock**	
Lebanon	Palestine	Oman	**Fishing and forestry**	
Qatar	Saudi Arabia	Syria	**Food**	
UAE	Venezuela	Yemen	**Services**	
Canada				
Australia				
South Africa				
Lesotho	Namibia	South Africa		
Swaziland				
Rest of world				
Remaining countries in the GTAP database				

(a) Includes some non-OPEC countries.
Source: GTEM.

Modifications to GTEM

Some modifications have been made to GTEM for this exercise. They include: the implementation of capacity constraints for some electricity technologies; introduction of inequality constraints to implement constrained permit trading and the renewable energy target; and implementation of a border tax adjustment.

This report exploits Cao (2010), which made solving inequality constraints more efficient in GEMPACK (the software platform on which GTEM is implemented). Cao's method is used to replace the existing implementation of capacity constraints and implement the renewable energy target and constrained permit trading. The renewable energy target requires energy generators produce renewable energy cumulatively each year to be at least the target for that year. In addition, this method allows for the exploration of limits on the amount of abatement sourced from overseas.

An equation was introduced to calculate, if relevant, the import tariff which is equivalent to the import price increase that would occur if the carbon price of the destination country applied in the source country. This method only includes the direct carbon cost. Any indirect costs due to higher input costs, such as from electricity, are not measured in this calculation. For a given commodity, the calculation uses the direct emission intensity of producing the commodity in the source country and the carbon price in the destination country.

Similarly, an extra equation is introduced to calculate the export subsidy equivalent to the export price decrease, if the carbon price were not in place. As in the tariff calculation, this subsidy measurement only covers the direct carbon cost. For a given commodity, the calculation uses the direct emission intensity of production in the source country and the carbon price in the same country.

MMRF Australian model

The Centre of Policy Studies (CoPS) at Monash University developed MMRF as a detailed model of the Australian economy (Adams et. al., 2011 and Australian Government, 2008). MMRF is rich in industry detail and provides results for all eight states and territories. It is also dynamic, employing recursive mechanisms to explain investment and sluggish adjustment in factor markets.

Table A2: Sectoral aggregation in MMRF

Category	Sectors
Agriculture, forestry and fishing	Sheep and beef cattle; dairy cattle; other animals; grains; agriculture services and fishing; forestry; and other
Mining	Coal, oil, gas, iron ore, non-ferrous ore and other
Manufacturing	Meat products; other food, beverages and tobacco; textiles, clothing and 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; alumina; aluminium; other non-ferrous metals; metal products; motor vehicles and parts; and other
Utilities	Electricity generation (coal, gas, oil, hydro and other), electricity supply, gas supply and water supply
Services	Construction; trade; accommodation, hotels, cafes and restaurants; communication; finance and insurance; property and business; dwelling; public; and other
Transport	Road (passenger and freight), rail (passenger and freight), water and air
Households(a)	Household consumption (private electrical, private heating and private transport)

(a) The sectors ‘private electrical’, ‘private heating’ and ‘private transport’ in the MMRF model relate to provision of services from the private stocks of electrical equipment (not heating), heating equipment and motor vehicles only.
Source: Adams et. al. (2011).

Sector specific modelling

A series of bottom-up sector-specific models for electricity generation, road transport, agriculture and forestry complement the CGE models. Detailed analysis of these emission-intensive sectors is useful in understanding the economy’s likely response to carbon pricing, particularly over the short to medium term.

Electricity sector modelling

ROAM Consulting and SKM MMA part of the Sinclair Knight Merz group (SKM MMA) each provided detailed bottom-up modelling of the Australian electricity generation sector, providing projections which are averaged for the results presented. Using the average projections of two models provides a natural hedge against the inherent uncertainty of economic modelling. Projections are provided for levels of generation (on a sent out basis), total capacity (installed), emissions (of carbon dioxide equivalent), energy use (fuel use), wholesale and retail electricity prices and the profit streams of generators. The results are provided at the generator or unit level and provide insight into the transformation of the electricity generation sector.

Both sets of modelling are highly detailed and aim to represent actual market conditions as closely as possible. The models incorporate economic relationships between individual generating plants in the system and their technical and cost profiles. The models incorporate a range of fuel types, including brown coal, black coal, natural gas and renewables (including hydro, biomass, solar, wind and geothermal). The modelling also incorporates technologies such as carbon capture and storage, and differences between natural gas technologies (such as combined cycle gas turbines and open cycle gas turbines). The SKM MMA models use hourly data while ROAM uses half hourly data and aggregated electricity demand, capturing daily and seasonal fluctuations in energy use.

Reports covering the modelling of the electricity sector are available on the Treasury website (SKM MMA, 2011 and ROAM Consulting, 2011).

Road transport sector modelling

Australian road transport sector modelling was conducted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). CSIRO uses a partial equilibrium model, the Energy Sector Model (ESM) of the Australian energy sector, which includes detailed road transport sector representation (Graham and Reedman, 2011). The ESM was developed by CSIRO and ABARE in 2006. The model has an economic decision-making framework based around the cost of alternative fuels and technologies.

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, lead times in the availability of new vehicles or plant and the degree of flexibility in the existing fleet. Graham and Reedman (2011) document the ESM.

Consumers (both individuals and firms) are assumed to minimise cost, 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, in the current modelling, the average vehicle size is assumed to decrease over time as fuel costs increase. The availability of alternative technologies also depends, exogenously, on prices. The ESM supply-side exogenous assumptions are largely based on CSIRO's research in conjunction with other major stakeholders.

A report from CSIRO covering details of the road transportation sector modelling is available on the Treasury website (Graham and Reedman, 2011).

Agriculture, land use change and forestry modelling

The output of the Australian agricultural sector is driven by both international and domestic demand and productivity improvements. GTEM determines external demand for agricultural produce, while productivity growth is consistent with improvements used by the Department of Climate Change and Energy Efficiency (DCCEE) in their emissions projections.

The emissions of the agricultural sector to 2020, assuming there are no incentives for abatement, align with the DCCEE's detailed bottom-up projections (DCCEE, 2011d).[1] Both the global action and policy scenarios assume abatement from land use, land use change and the forestry sector are driven by the Carbon Farming Initiative (CFI).

DCCEE provided modelling of the abatement expected from the agriculture, land use change and legacy waste components of the CFI. Estimates of abatement in agriculture are updated to reflect the policy parameters of the CFI and recent developments in the availability and costs of abatement opportunities. The estimates are in line with previous bottom-up estimates by DCCEE.

DCCEE used a top-down approach to estimate proportional reductions in emissions in response to carbon prices under the CFI. The estimated price-emissions reduction relationship involves using a similar functional form to that used for the Marginal Abatement Cost (MAC) curves for non-energy emissions in previous Treasury modelling (Australian Government, 2008). The parameters of the MAC curves are calibrated to DCCEE's bottom-up preliminary estimates of CFI abatement in 2020. For each price scenario, the level of abatement is estimated by multiplying projected baseline emissions by the estimate of proportional emission reductions. A report from DCCEE about this modelling is available on the Treasury website (DCCEE, 2011b).

ABARES models the abatement expected from the reforestation component of the CFI. ABARES analysis is based on estimates of agricultural and forestry returns, the discount rate, costs, yields and sequestration rates across the regions using ABARES' spatially based land use models and MMRF. The framework used is spatially explicit, and involves analysing the opportunities for carbon sequestration provided by reforestation on cleared agricultural land. These opportunities are determined by comparing the net present value (NPV) of returns from reforestation investments with the corresponding expected agricultural value to estimate the potential area of clear agricultural land that is economically viable for reforestation within each spatial grid cell.

Reforestation options considered in ABARES's analysis included long rotation hardwood plantations and carbon plantations that may be eligible for CFI credits, as follows:

- a plantation of 'traditional species/rotation' that is planted with the intention of harvesting it for fibre (timber/chip) or biomass (energy) and selling these products and is planted in non-traditional, lower rainfall areas only because there will be revenue from the payment for both carbon sequestration and fibre and/or biomass sales;

1 Australia's emissions projections 2010 http://www.climatechange.gov.au/en/publications/projections/australias-emissions projections.aspx. Various assumptions are made about emission intensities beyond 2020.

- trees planted or direct seeded with no intention to harvest and planted solely for the revenue from the payment for carbon sequestration; and
- trees planted or direct seeded with no intention to harvest.

A report from ABARES about this modelling is available on the Treasury website (Burns et. al., 2011).

Price Revenue Incidence Simulation Model (PRISMOD.IO)

Treasury's Price Revenue Incidence Simulation Model (PRISMOD.IO) examines the inter industry transmission of price changes (also called second round effects) in addition to direct effects. PRISMOD.IO, a large-scale, highly disaggregated model of the Australian economy, captures the flows of goods between industries and final consumers. The data in PRISMOD.IO comprise the transactions and consumption patterns of 109 industry categories and seven categories of final demand. The 2011 version of PRISMOD.IO is based on data from the 2005-06 Input-Output Tables (ABS, 2009). Other key characteristics of PRISMOD.IO are set out below.

- 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 forth.
- Quantities are held fixed: only price impacts are modelled. Price changes are calculated for the 'morning after' the policy change, before production techniques or volumes adjust. Businesses 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 imposed carbon price will be passed through fully to domestic consumers in the form of higher prices.
- The model does not provide information as to the timing of price changes. All price impacts calculated by the model are long term in nature. This means PRISMOD.IO estimates of short-term price impacts may be overstated, if the transmission of the carbon price is slower or not fully passed on.

Price Revenue Incidence Simulation Model — Distribution (PRISMOD.DIST)

The distributional implication for households of carbon pricing is 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 key characteristics of PRISMOD.DIST include:

- the 2011 version of the model is based on data from the 2003-04 Household Expenditure survey (HES) (ABS, 2006b);
- the HES data were updated to 2011 using actual state CPI item price movements.[2] The totals for a variety of expenditure baskets are then projected to 2013 using headline CPI forecasts and projections;
- the HES data were 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 NATSEM's STINMOD model was used to re-weight the HES data for projected demographic changes;[3] and
- the income and household type variables also are taken from STINMOD.

The model projects household spending for 2012-13 based on projected growth in the CPI for expenditure classes, and projects incomes based on growth in wages and transfer payments and legislated tax rates and thresholds. Households purchase constant quantities of goods and services: 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 money on energy and have a positive disposable income. Excluding households with negative or nil disposable income results in slightly fewer households in the lowest quintile but it partially addresses ABS concerns that incomes in the lowest decile may not accurately reflect the level of their wellbeing. The analysis excludes around 0.8 per cent of households with positive disposable income that report no direct spending on energy and around 1.8 per cent of households with positive disposable income reporting no spending on stationary energy.

MAGICC overview

To examine whether the emission trajectories from the global action scenarios derived in GTEM meet specified concentration targets around 2100, the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) is used to estimate the atmospheric concentrations of the emission trajectories (Raper et. al., 1996; Wigley and Raper, 1992; and Wigley and Raper, 2001). MAGICC is calibrated against more complex climate models and was used in the IPCC's Fourth Assessment Report (IPCC, 2007b). GTEM covers emissions of seven gases, including both low and high global warming potential gases from various sources and sinks. As the global action scenarios project emission paths only to 2050 and the concentration targets are for around 2100, projections of emissions beyond 2050 for the estimation of

2 All results in this publication are in Australian financial years, ending 30 June of the year quoted.
3 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.

concentrations by MAGICC are based on emission trends before 2051 and draw on post-2050 emissions information from the Garnaut scenarios in previous Treasury modelling (Australian Government, 2008).

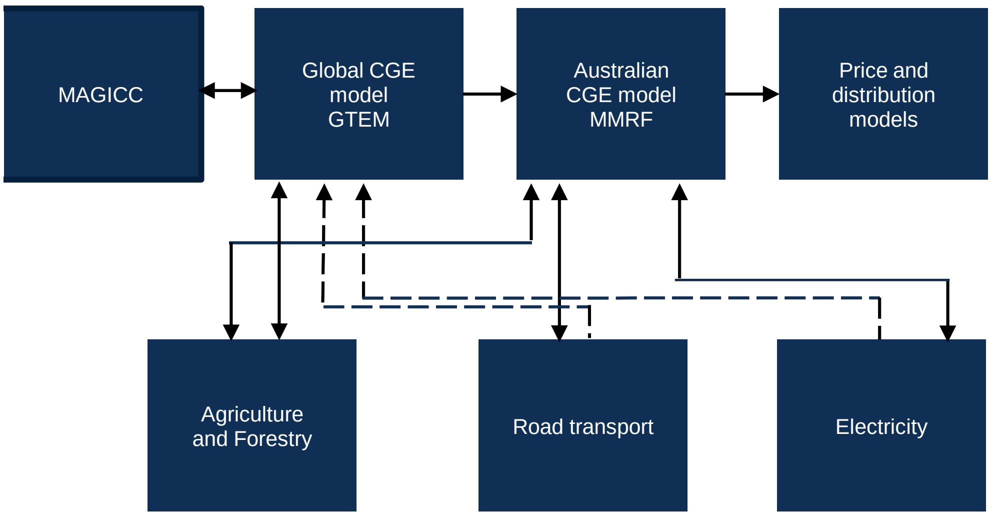
An integrated modelling framework

The results from each of these models are drawn together into an integrated set of projections that are consistent at the macroeconomic level and sufficiently detailed in key sectors to provide insights into the likely transformation of the Australian economy under carbon pricing.

Modelling of the global economy with GTEM 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 key sectors. MAGICC is used to estimate the greenhouse gas atmospheric concentration levels, with the world carbon price paths being set so atmospheric concentration levels of the emissions paths from the model broadly match the environmental targets.

Linking economic models with different economic structures is not straightforward. Significant research was involved to ensure the suite of models were linked sensibly.

Chart A1: 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. GTEM does not take input from the agriculture model but does take input from the forestry model.
Source: Treasury.

While input assumptions are harmonised as much as possible across GTEM and MMRF, the projections in these models for Australia are not identical. The differences arise primarily from the different structures of the models, and these differences reflect the uncertainty surrounding modelling estimates.

The MMRF takes world market conditions as given. This means it does not determine endogenously the prices Australia faces in world markets, nor does it project the changes that may occur in demand for Australian exports. GTEM determines such prices and quantities, aggregated over all other regions. This requires care to ensure the world demand curve determined within GTEM is appropriately linked with MMRF.

GTEM also determines the global carbon price that achieves the desired environmental target. The global carbon price trajectory is used as input into the MMRF model for the period after the transition to flexible cap and trade scheme.

Table A3: Concordance of GTEM and MMRF

GTEM (sectors)	MMRF (commodities)
Livestock	Sheep and beef cattle, dairy cattle and other animals
Crops	Grains, biofuels, other agriculture
Fishing and forestry	Agriculture services and fishing; and forestry
Coal mining	Coal mining
Oil mining	Oil mining
Gas mining	Gas mining
Other mining	3 commodities: 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 products, paper products, printing, publishing and recorded media, metal products, motor vehicles and other manufacturing
Petroleum and coal products	Gasoline, diesel, LPG, air fuel, other fuel.
Chemical, rubber and plastic products	2 commodities: Chemicals and rubber and plastic products
Non-metalic minerals	Non-metal construction products and cement
Iron and steel	Iron and steel
Non-ferrous metals	3 commodities: Alumina, aluminium and other non-ferrous metals
Electricity	Electricity generation (coal; gas; oil; hydro; other)
Services	15 commodities: Electricity supply, gas supply and water supply (3 commodities), construction, trade, accommodation, hotels, cafes and restaurants, communication, finance and insurance, property and business, dwelling, public, other and household consumption (3 commodities: electricity; heating; transport)
Other transport	Road (passenger; freight) and rail (passenger; freight)
Air transport	Air transport
Water transport	Water, pipeline and transport services

Source: Treasury from GTEM and MMRF.

Electricity generation sector

MMRF is linked with the electricity bottom-up modelling from SKM MMA and ROAM through a series of iterations. The demand for electricity is modelled in MMRF, with the SKM MMA and ROAM modelling providing the supply-side detail. MMRF electricity demand was provided to SKM MMA and ROAM, together with the carbon price. SKM MMA and ROAM then each projected the response of the electricity sector to meet that demand. This was integrated into MMRF by calibrating the technology shares, fuel efficiency, emission intensity of fuel use, wholesale price and retail price by industry. MMRF was re-run to generate new demand levels (one based on ROAM data and the other on SKM MMA) which were then re-supplied to the consultants. The iteration process continued until demand and supply broadly converged.

Road transport sector

The road transport sector of MMRF is linked with the bottom-up modelling from CSIRO. The demand for road transport is determined in MMRF, taking into account population growth, the projected output of industries and changes in the cost structure of road transport. With demand for road transport activities from MMRF as an input, demand for individual fuels and vehicle types is determined using the ESM model. The outputs from ESM are then used as an input back into MMRF. The iteration process continued until demand and supply broadly converge.

Table A4: Inputs and outputs of the Energy Sector Model (ESM)

Inputs	Outputs
Carbon price	ESM provides projections of distance travelled (billion km), fuel used (PJ), and greenhouse gas emissions (Mt CO_2-e).
Transport demand (from MMRF)	ESM results are presented by state across the following categories:
Private transport	**Engine technologies**
Road passenger	Internal combustion engine
Road freight	Hybrid
	Plug-in hybrid
Fuel prices	
Treasury's oil, coal and gas price assumptions	Full electric
Electricity prices (from SKM MMA and ROAM)	Hydrogen fuel cell
Other exogenous assumptions	**Transport modes**
Fuel efficiency assumptions	Private passenger vehicles
Technology cost assumptions	Buses
Emission factors	Light commercial vehicles
Fuel and other vehicle operating costs	Articulated trucks and rigid trucks
Government transport policy settings	**Fuel types**
	Petrol
	Diesel
	Liquefied petroleum gas
	Biofuels (including biodiesel and ethanol blends)
	Electricity
	Natural gas and hydrogen
	Synthetic fuels (coal-to-liquid, gas-to-liquid)

Agriculture and forestry sectors

The agriculture and forestry sectors of MMRF are linked with the bottom-up modelling from ABARES. Agricultural output prices and land prices were obtained from MMRF and provided to ABARES, which then provided estimates for establishment rates of forestry plantations and associated changes in forestry sequestration. These estimates are incorporated into MMRF as exogenous inputs. GTEM incorporates GCOMAP calculations of the net change in emission stocks associated with land use change and forestry (Sathaye et. Al. 2006, 2008).

DCCEE modelled the abatement from livestock, crops, savannah fire management, avoided deforestation and managed regrowth, and legacy waste under the Carbon Farming Initiative (CFI). This abatement from the CFI was incorporated into MMRF by adjusting the emission factors of the appropriate industries and accounting for permit income flows.

Appendix B: Treasury climate change mitigation modelling — assumptions

Introduction

As the costs and impacts of climate change occur over long timeframes, the modelling requires assumptions for a wide range of economic, social and environmental variables over a long horizon. The future path of variables is uncertain, but their values are required for the modelling analysis, so assumptions must be made. Treasury considers the assumptions reflect plausible central estimates within the range of possible values.

The modelling framework and input assumptions draw on research, previous global and Australian studies, input from government, domestic and international experts, and previous consultations with other stakeholders.

Where possible, the assumptions across the suite of models used in the analysis have been harmonised to ensure projections have a common basis. In some instances the assumptions needed to operate one model have been taken from the outputs of another model run for this exercise. Appendix A describes the way the models link together.

Policy and design features

Global carbon price

A Hotelling rule is used to construct a global emissions pathway for each scenario within the global model (GTEM). The starting carbon price for each scenario is set so global emissions give the desired path for concentrations of the modelled greenhouse gases using the MAGICC model. The real carbon 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. This rate of return embodies the commercial risks of holding permits and investing in emissions-related activities. It is calibrated as a risk-free real rate of 2 per cent and a risk premium in markets for permits of 2 per cent. A similar method has been applied in other recent modelling exercises (EMF, 2011).

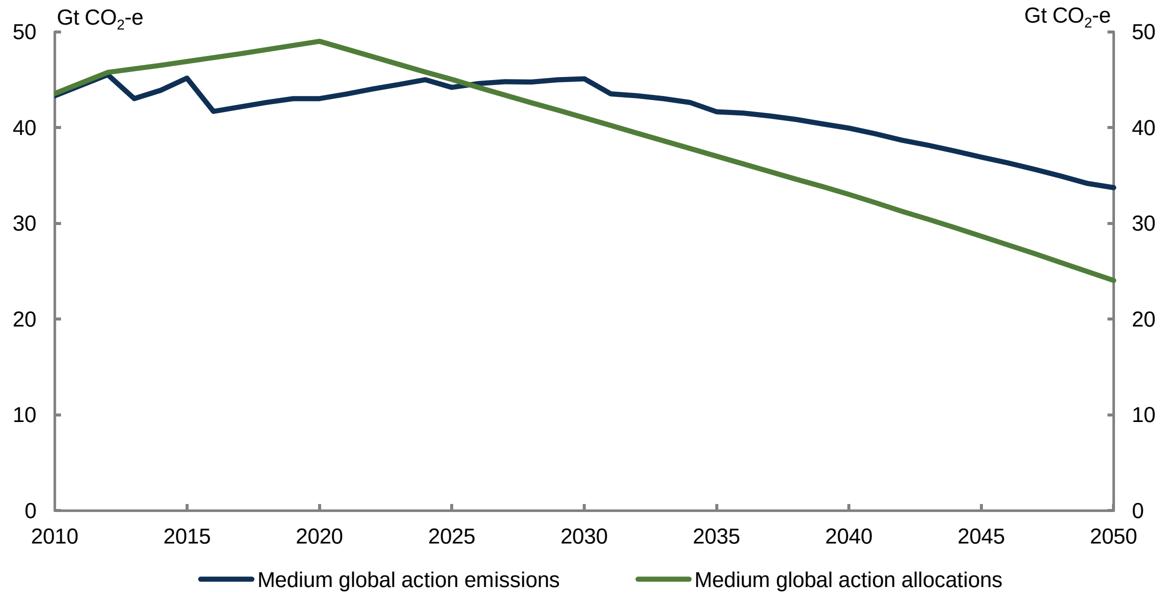
This approach to determining the global carbon price mimics global market that allows abatement to be traded through time, and draws on similarities between mitigation policy and the management of finite resources. Irrespective of the initial allocation of abatement rights, market participants would form views regarding the future carbon price in light of the environmental objective, overall carbon budget, and expected future social, economic and technological conditions.

If market participants expect the carbon price to rise faster than the value of other comparable financial assets, they would bank abatement for use later (to capture a higher return) and the current carbon price would rise. Conversely, if market participants expect the carbon price to rise more slowly than other comparable assets, they would sell abatement rights (or borrow future rights if required) for use now, and the current carbon price would fall.

Permit banking is important in the global carbon price scenarios. National emission allocations gradually move towards long-term emission reduction targets. However, introducing a carbon price causes actual emissions to fall initially, at the level determined by the Hotelling rule. As a result, some allocated permits are banked for future use. The gap between allocations and actual emissions represents banked or borrowed permits. Starting around 2025,[1] actual emissions move higher than allocations, reflecting the use of previously banked permits, or borrowing permits if banked permits are drawn down to zero.

Chart B1: Allocations and emissions

Medium global action scenario



Note: All years in this publication are Australian financial years, ending 30 June of the year quoted.
Source: Treasury estimates from GTEM.

Table B1: Global allocations, emissions and banked permits

	Allocation Gt CO_2-e	Emissions Gt CO_2-e	Banked permits Gt CO_2-e	Net permits in the bank Gt CO_2-e
2020				
Medium global action	49	43	6	28
Ambitious global action	44	37	7	37
2050				
Medium global action	24	34	-10	-107
Ambitious global action	12	18	-6	-41

Source: Treasury estimates from GTEM.

1 All years in this publication, unless otherwise indicated, are Australian financial years, ending 30 June of the year quoted.

Australian assumptions

Summary of domestic policy assumptions

The Australian policy scenarios considered assume Australia introduces a domestic carbon price with a fixed price scheme from 1 July 2012. The price rising each year, before the Government establishes a flexible price cap and trade scheme in 2015-16.

Table B2: Key carbon price design features

	Core scenario	High price scenario
Nominal domestic price in 2012-13	$20, $23 for household impact modelling	$30
Nominal world price in 2015-16, A$	Projected to commence at $29	Projected to commence at $61
World stabilisation target	550 ppm	450 ppm
Australian emission reduction target	5 per cent below 2000 levels by 2020; 80 per cent below 2000 levels by 2050	25 per cent below 2000 levels by 2020; 80 per cent below 2000 levels by 2050

Table B3: Implementation of policy scenario assumptions

Issue	Policy setting	Implementation in MMRF
Australia's emission trajectory	Set as a straight line from the end of the Kyoto commitment period (2008-2012) to 2020 and again as a straight line from 2020 to 2050.	
Coverage	All emission sources covered, except: * activity emissions from agriculture and forestry ; * forestry (in terms of mandatory liability for emissions); * decommissioned mines; * land-use change; * legacy waste; and * existing synthetic gases.	Agriculture comprises sheep and cattle, dairy, other animal and grains.
Emission-intensive trade-exposed activities (EITE)	EITE activities are shielded from the carbon price for direct emissions and for upstream emissions from electricity use. Assistance is based on allocative baselines reflecting historical industry average levels of carbon pollution per unit of production. Definitions of EITE activities and rates of assistance by activity (either 94.5 or 66 per cent) are consistent with the CPRS package as at 24 November 2009. The rate of assistance — the number of permits per unit of output — is reduced by 1.3 per cent per year, before being assumed to phased out in five annual steps starting in 2022.	EITE activities are allocated to MMRF industries. Calculations use 2007-08 data provided by the Department of Climate Change and Energy Efficiency.
International linkage	No international linking during the fixed carbon price period and only quality restrictions from 2015-16.	

Table B3: Implementation of policy scenario assumptions (continued)

Treatment of transport fuels	In the core policy scenario, an effective carbon price is applied to: businesses' combustion of liquid fuels from 2012-13 (except light vehicles, agriculture, forestry and fishing) and heavy on-road vehicles from 2014-15, through the fuel tax credit system; and aviation fuel from 2012-13 through the domestic aviation excise system. Off-road transport use and non-transport use of gaseous fuels face an effective carbon price through reductions in fuel tax credits or automatic excise remission. On-road transport use of gaseous fuels does not face a fuel tax credit reduction due to imposing the Road User Charge. In the high price scenario, all fuel combustion is subject to a carbon price. However, this effect is offset by permanent fuel excise reductions in the first three years for households and light on-road vehicles. Fuel credits offset the effect of the carbon price for the first year for heavy on-road vehicles, and for the first three years for agriculture, forestry and fishing.	In the core policy scenario, liquid fuel combustion is subject to a carbon price except: combustion by the road freight industry for the first 2 years; and combustion by service industries (except transport, but including road passenger transport), households and agriculture, forestry and fishing permanently. In the high price scenario, liquid fuel combustion is subject to a carbon price except: combustion by the road freight industry for the first year; combustion by agriculture, forestry and fishing for the first three years; combustion by service industries (except transport, but including road passenger transport) and households is subject to the incremental increase in the carbon price beyond its level in 2014-15.
Use of permit revenue	Assistance will be provided through increases in Family Tax Benefit, pensions and allowances as well as tax cuts.	Net revenue from the scheme is allocated to households as lump sum payments.
PRISMOD assumptions	Assistance to EITE activities is allocated to the 109 industries in PRISMOD. Transport fuels are treated as described for the core policy scenario. Synthetic gases are assumed to be subject to a levy on importation into Australia. All data are adjusted, where necessary, to be consistent with the 2005-06 input-output tables. No adjustment is made for redistribution of net permit revenue as household assistance payments.	

Existing Australian policy measures in different sectors

Modelling of the global action scenarios includes a number of pre-existing Australian policy measures across a number of sectors.

Electricity policy measures

The global action scenarios assume pre-existing policy measures remain in place, including the Large-scale Renewable Energy Target (LRET), the Small-scale Renewable Energy Scheme (SRES), the NSW and ACT Greenhouse Gas Abatement Scheme (GGAS), the voluntary market program Green Power and the Queensland Gas Scheme. The LRET and SRES targets are in line with those published on the Office of the Renewable Energy Regulators website. The modelling assumes that the Cleaner Power Stations Initiative requires new power stations to have emissions below 0.86 t CO_2-e/MWh, in line with announced government policy.

In the policy scenarios, the GGAS scheme is removed with the introduction of a carbon price, in line with announced NSW Government policy. All other policy measures are assumed to remain in place.

Transport policy measures

The global action scenario assumes existing emission reductions and tax policies continue. The modelling does not include the Government's election commitment to introduce emissions standards for all new light vehicles.

NSW Biofuels Act

The NSW Biofuels Act requires all regular grade unleaded petrol to be E10 from 1 July 2011. The Act establishes a volumetric biodiesel mandate of 2 per cent, increasing the mandate to 5 per cent from 1 January 2012.

Fuel Excise

Methanol and the gaseous fuels, including liquefied petroleum gas (LPG), liquefied natural gas (LNG) and compressed natural gas (CNG), are currently outside the fuel tax system and thus excise free.

Excise tax for ethanol is phased in from 2010 to 2020. Domestic ethanol producers receive targeted assistance over ten years to manage the transition. The phase down in imported ethanol in excise-equivalent customs duty occurs over five years.

LPG Vehicle Scheme

The LPG vehicle scheme offers up to $2,000 in grants to either convert a private motor vehicle to LPG or purchase a new LPG vehicle. The scheme operates from 1 July 2009 to 30 June 2014.

Other policy measures

Both the global action and policy scenarios assume the Carbon Farming Initiative (CFI), which provides an incentive for additional permanent abatement from livestock, crops, avoided deforestation and managed regrowth, savannah fire management, legacy waste and carbon plantations, remains in place.

The CFI enables the sectors listed to generate abatement credits to sell internationally. It is assumed CFI credits are sold at the prevailing world carbon price and this price determines the level of abatement.

World economic assumptions

World gross domestic product

Gross world product (GWP) projections remain broadly similar to the previous climate change mitigation modelling (Australian Government, 2008). However, the balance of economic power is shifting towards developing economies. This is a result of the continued process of developing economies catching up to the per person income levels of developed economies. The recent downgrade to developed economy projections and upgrade to developing economy projections leaves overall GWP growth similar to previous estimates, at an average annual growth rate of 3.5 per cent to 2050, compared to the 3.9 per cent average over the past 50 years.

Chart B2: Real gross world product growth

Source: IMF, 2011 and Treasury.

Table B4: World real GDP growth
Average annual growth (per cent)

	2010-2020	2020-2050
United States	2.5	1.9
European Union (25)	1.8	1.3
China	8.8	3.4
Former Soviet Union	4.3	2.7
Japan	1.2	0.4
India	8.1	6.2
Canada	2.2	1.9
Indonesia	6.8	5.1
South Africa	4.3	3.9
Other south and east Asia	4.4	3.4
OPEC	4.9	3.8
Rest of world	4.5	4.1

Source: Treasury, IMF, OECD and Consensus.

World population and participation

World population projections to 2050 are based on United Nations (UN) data (2011). The projections are interpolated to produce annual projections of population by country (both total and adult). These country projections are then aggregated into the country groups used in GTEM. The UN population projections have been revised up recently, although growth in some of the Asian countries is now lower.

Table B5: World population levels and growth
GTEM regions (per cent)

	Population level (millions)			Average growth rate	
	2010	2020	2050	2010-2020	2020-2050
United States	313	340	406	0.8	0.6
European Union (25)	472	483	488	0.2	0.0
China	1358	1406	1314	0.3	-0.2
Former Soviet Union	284	287	277	0.1	-0.1
Japan	128	126	110	-0.1	-0.5
India	1188	1346	1642	1.3	0.7
Canada	34	37	44	0.9	0.5
Indonesia	236	258	288	0.9	0.4
South Africa	56	59	65	0.6	0.3
Other south and east Asia	429	473	547	1.0	0.5
OPEC	248	296	418	1.8	1.1
Rest of world	2124	2516	3677	1.7	1.3

Source: Treasury and United Nations, 2011.

World productivity and technological development

Aggregate productivity

Estimates of country-by-country growth in productivity (either output per worker or output per hour worked) use a conditional convergence framework. If a country's productivity level is below its 'potential' then, in the process of catching up, it gradually asymptotes to its potential. Baumol (1986) and Barro and Sala-i-Martin (1992) detail the economic framework for convergence. Convergence (sometimes called 'catch-up') is commonly assumed in long-term international growth projections, such as the *Special Report on Emission Scenarios* (IPCC, 2000), the OECD environmental outlook and IMF reports.

Productivity for OECD countries is based on per hour purchasing power parity (PPP) productivity from the Total Economy Database (The Conference Board/Gronningen) 2009 update. Non-OECD productivity is based on per working age population. GDP per person (in PPP terms) is from the World Bank International Comparison Project (ICP) (December 2007 update), and adjusted to a per working age population basis using the population assumptions. Where GDP data are unavailable from the ICP update, the most recent Maddison international PPP update (August 2007) is used. This is done for 50 countries, which collectively represent around 2 per cent of GWP.

US productivity growth is assumed to adjust gradually towards a long-term annual rate of 1.6 per cent. The long-term growth rate assumption is based on historical trends of productivity growth by industry and expected changes in the industry structure of the United States. Official projections of long-term productivity growth are somewhat higher at around 1.7 per cent (OASDI Trustees, 2011; and Congressional Budget Office, 2011), but do not take into account the likely shift towards industries with lower average rates of productivity growth.

Each country's potential productivity is modelled as a percentage of the productivity level of the technological leader, assumed to be the United States.

- High-income OECD countries with 70 per cent or more of US productivity levels converge to a productivity level relative to the US (equal of the average level of the last five years, to abstract from cyclical effects). This generally causes the country to grow at the same rate as the United States.

- High-income non-OECD countries converge to a productivity level relative to the US equal to their starting point. This generally has the causes the country to grow at the same rate as the United States.
- Non-OECD countries with a productivity level of less than 70 per cent of the US level are assumed to converge to a maximum of 70 per cent of the US productivity level, taking into account such things as their recent growth experience and measures of their current level of human development and governance.
  - For most countries, a common rate of convergence of 2 per cent per year is assumed (Sala-i-Martin, 1996). Many studies using climate change models assume this rate (Bagnoli et al, 1996; McKibbin et al, 2004; and more recent OECD work).
- Productivity growth is also smoothed, so that each country takes some time to go from its recent rate of growth to its long-term convergence path.

Convergence and GDP calculations are performed at a country, not regional level. OPEC, in particular, shows seemingly less convergence than other regions as a result. OPEC is a mix of countries with high productivity (such as Qatar) that do not converge, mid income countries (such as Saudi Arabia) that converge more slowly, and low income countries (such as Yemen).

Table B6: Productivity level relative to the United States by GTEM region
Level

	Productivity level		
	2010	2020	2050
United States	100	100	100
European Union (25)	67	67	69
China	13	25	53
Former Soviet Union	20	26	41
Japan	76	77	71
India	7	10	31
Canada	81	79	82
Indonesia	8	12	32
South Africa	20	23	40
Other south and east Asia	16	18	29
OPEC	26	28	39
Rest of world	14	15	20

Note: GDP per adult population, US=100.
Source: Treasury, OECD and United Nations.

Sectoral labour productivity

The productivity and population assumptions indicate the total change in output for the economy. To implement these in GTEM, Treasury assumes this increase in productivity (or efficiency) is distributed across industries. Capital stock accumulates endogenously and the model indicates the supply of other primary factors. It then calculates the value of a productivity variable, so that it is consistent with the exogenous trajectory of regional outputs.

The distribution of labour productivity across industries in each country is based on historical performance. Sectoral productivity growth rates are based on historical averages from the

Groningen Growth and Development Centre database and the OECD. Different sectors have different relative growth rates in the GTEM model.

Table B7: Relative sectoral labour productivity growth rates
Base year values

	USA	EU(25)	China	FSU	Japan	India
Coal mining	1.00	1.00	1.30	0.50	0.50	1.50
Oil mining	1.00	1.00	1.00	0.50	0.50	1.00
Gas mining	1.00	1.00	1.00	0.50	0.50	1.00
Petroleum and coal	1.00	1.00	1.00	0.50	0.50	1.00
Electricity	1.25	1.00	1.00	0.50	0.50	0.50
Mining and chemicals	1.25	1.00	1.00	1.00	1.50	1.00
Manufacturing	1.25	1.50	1.00	1.00	1.50	1.00
Road transport	1.50	2.00	2.00	1.00	2.00	2.00
Water and air transport	0.75	1.00	1.00	0.50	1.00	0.50
Crops	0.75	1.50	1.00	1.00	0.50	0.50
Livestock	0.75	1.50	1.00	1.00	0.50	0.50
Fishing and forestry	0.75	1.50	1.00	1.00	0.50	0.50
Food	1.40	1.50	1.00	1.00	1.00	1.00
Services	1.00	1.00	1.00	0.75	1.00	0.75

	Canada	Indonesia	Sth Africa	Other Asia	OPEC	ROW
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	1.00	0.75	1.00	0.75	1.00	1.00
Petroleum and coal	1.00	0.75	1.00	0.75	1.00	1.00
Electricity	1.25	0.75	1.00	0.75	1.00	1.00
Mining and chemicals	1.25	1.00	1.00	1.00	1.00	1.00
Manufacturing	1.25	1.00	1.00	1.00	1.00	1.00
Road transport	1.50	2.00	2.00	2.00	2.00	2.00
Water and air transport	0.75	0.50	1.00	0.50	1.00	1.00
Crops	0.75	0.75	1.00	0.50	1.00	1.00
Livestock	0.75	0.50	1.00	0.50	1.00	1.00
Fishing and forestry	0.75	0.50	1.00	0.50	1.00	1.00
Food	1.40	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.

The data indicate that, for instance, road transport labour productivity in China will grow twice as quickly as labour productivity in the coal sector. These numbers do not directly compare sector productivity across regions. For example, mining and chemicals productivity growth in China and India are not equal because growth rates are relative to the individual country or regions' aggregate labour productivity growth.

Intermediate input assumptions

The assumption in GTEM is that industries' efficiency in using intermediate inputs changes over time. Rates of improvement differ between regions and sectors.

Table B8: Improvement in intermediate input efficiency in GTEM
Average annual rate of improvement (per cent, 2001 to 2050)

	Annual average
United States	0.3
European Union (25)	0.2
China	0.4
Former Soviet Union	0.7
Japan	0.2
India	1.0
Canada	0.2
Indonesia	0.5
South Africa	0.7
Other south and east Asia	0.3
OPEC	0.5
Rest of world	0.5

Source: Treasury.

Economy-wide energy efficiency

Energy efficiency increases when the same amount of output is produced using less energy. This can occur when: energy prices rise relative to other inputs; existing technology is used more efficiently; upgrading existing technology; or when new technology is developed through research and development and learning by doing.

Assumptions about energy efficiency improvements affect the level of energy use and hence emissions. GTEM and MMRF have different treatments of energy efficiency due to the different structures of the models.

In the baseline scenario, GTEM assumes a rate of improvement in energy efficiency of 0.5 per cent per year, except for specific sectors such as transport, iron and steel, non-metallic minerals, non-ferrous metals, chemicals, rubber and plastics.

Sector-specific energy efficiency

Transport

Energy efficiency in the transport sector is assumed to improve over time. Rates of improvement are based on ABARE (Matysek et al, 2006).

Table B9: Improvement in energy efficiency: transport
Average annual rate of improvement (per cent, 2010 to 2050)

	Rail	ICE	Advanced ICE	Hybrid	Non-fossil fuel
United States	0.6	0.2	0.4	0.7	0.7
European Union (25)	0.6	0.2	0.3	0.5	0.5
China	0.6	1.0	1.2	1.8	1.8
Former Soviet Union	0.6	0.5	0.7	0.9	0.9
Japan	0.6	0.2	0.3	0.5	0.5
India	0.6	1.1	1.4	1.7	1.7
Canada	0.6	0.2	0.4	0.7	0.7
Indonesia	0.6	0.2	0.3	0.5	0.5
South Africa	0.6	0.6	0.7	0.9	0.9
Other south and east Asia	0.6	1.0	1.2	1.5	1.5
OPEC	0.6	0.5	0.7	0.9	0.9
Rest of world	0.6	1.0	1.1	1.1	1.1

Note: ICE refers to internal combustion engines. Non-fossil fuel vehicles include electric and hydrogen cars.
Source: ABARES and Treasury.

Other sectors

Energy efficiency improvement projections in other sectors are assumed to be in line with those in previous Treasury modelling. The efficiency improvement for the non-ferrous metal sector is projected to vary significantly across regions. The improvement is mainly due to the increase of the use of scrap aluminium rather than technological advancement (Fisher et al, 2006). Higher scrap availability in a country leads to greater efficiency improvement projections. Composition shifts within the sector also contribute to the overall efficiency.

Table B10: Improvement in energy efficiency: non-ferrous metals
Average annual rate of improvement (per cent)

	2010-2050
United States	1.7
European Union (25)	1.7
China	1.1
Former Soviet Union	0.7
Japan	0.6
India	0.8
Canada	0.7
Indonesia	1.5
South Africa	0.8
Other south and east Asia	0.7
OPEC	0.7
Rest of world	0.8

Source: ABARES and Treasury.

The efficiency improvement projections for the chemical, rubber and plastics sector are assumed to be almost uniform across regions, reflecting the uniform accessibility of the energy-saving processes for the sector.

Table B11: Improvement in energy efficiency: chemical, rubber and plastics
Average annual rate of improvement (per cent)

	2010-2020	2020-2030	2030-2050
United States	0.5	0.5	0.6
European Union (25)	0.5	0.5	0.5
China	0.5	0.5	0.5
Former Soviet Union	0.4	0.4	0.5
Japan	0.5	0.5	0.5
India	0.6	0.5	0.5
Canada	0.5	0.5	0.5
Indonesia	0.4	0.5	0.5
South Africa	0.5	0.5	0.5
Other south and east Asia	0.4	0.5	0.6
OPEC	0.4	0.5	0.5
Rest of world	0.5	0.5	0.6

Source: ABARES and Treasury.

Energy efficiency in the iron and steel industry, and 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. GTEM represents iron and steel as a bundle with two discrete technologies — blast furnace and electric arc furnace (recycled steel from scrap).

Table B12: Improvement in energy efficiency: blast furnace production
Average annual rate of improvement (per cent)

	2010-2020	2020-2030	2030-2050
United States	0.3	0.3	0.8
European Union (25)	0.3	0.3	0.4
China	1.0	1.0	0.7
Former Soviet Union	0.9	0.9	0.7
Japan	0.3	0.3	0.5
India	0.9	0.8	1.0
Canada	0.3	0.3	0.5
Indonesia	0.0	0.0	0.5
South Africa	0.8	0.8	1.2
Other south and east Asia	0.5	0.5	0.4
OPEC	0.3	0.3	0.9
Rest of world	0.8	0.8	0.9

Source: ABARES and Treasury.

Table B13: Improvement in energy efficiency: electric arc production
Average annual rate of improvement (per cent)

	2010-2020	2020-2030	2030-2050
United States	0.7	0.7	0.9
European Union (25)	0.6	0.6	0.7
China	1.3	1.3	1.0
Former Soviet Union	1.3	1.4	0.8
Japan	0.6	0.6	0.8
India	1.3	1.3	1.3
Canada	0.7	0.7	0.6
Indonesia	1.2	1.2	1.4
South Africa	1.3	1.3	1.5
Other south and east Asia	0.7	0.8	1.2
OPEC	0.9	0.9	1.0
Rest of world	1.2	1.3	1.2

Source: ABARES and Treasury.

Electricity technology assumptions

Thermal efficiency

The thermal efficiency of a fossil fuel power plant is the ratio of electricity generated to energy input. Thermal efficiencies are greatest when plants operate at maximum capacity; as plants do not always operate at maximum capacity, the average thermal efficiency is typically lower than shown.

Table B14: Thermal efficiency of new power plants in GTEM

	Coal			Gas		
	2002	2020	2050	2002	2020	2050
United States	36	40	46	40	52	61
European Union (25)	35	37	40	48	51	54
China	32	38	43	46	57	63
Former Soviet Union	31	33	33	38	39	41
Japan	37	39	42	45	51	60
India	28	41	48	42	55	64
Canada	38	39	45	46	53	57
Indonesia	28	41	46	33	51	63
South Africa	38	42	47	39	54	65
Other south and east Asia	34	41	46	37	51	62
OPEC	39	43	48	32	51	63
Rest of world	33	40	47	41	53	61

Source: ABARES, ACIL Tasman (2008) and SKM MMA.

Carbon capture and storage

Carbon capture and storage (CCS) technology, combined with coal and gas electricity generation, is assumed to be available on a commercial scale only after 2021. This is later than earlier modelling because of the technology's slower assumed development and deployment. In addition, its commercial scale of uptake is also assumed to depend on the level of the carbon price in place, to allow for gains in cost competitiveness compared to other technologies.[2]

In GTEM, the capture efficiency rate is fixed at 90 per cent of produced emissions, imposed as an increased auxiliary use component (increased consumption of electricity necessary for generation, resulting from the CCS technology).

A sensitivity scenario was also run to test the implications of carbon capture and storage being unavailable (see Chapter 3).

Nuclear

Nuclear is assumed to continue to be available in regions where it is currently deployed, but not elsewhere. No specific constraints are imposed: nuclear resources and emerging technology are assumed to be able to meet demand for nuclear electricity. Japan's recent experience with its nuclear electricity plants may result in uncertainty about the extent of future expansion of the technology. Sensitivity analysis examines the impacts of no new nuclear capacity installed beyond 2020 (see Chapter 3). Nuclear is assumed to remain unavailable in Australia.

Marginal abatement cost curves

Carbon pricing provides an incentive for industries to reduce the emission intensity of their production. A 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.

In the current modelling, MAC curves have the functional form:

2 In GTEM, the threshold carbon price for the uptake is assumed to be $31 for coal CCS and $38.5 for gas CCS technology (all in 2010 US dollars), reflecting the costs of transporting and storing the captured emissions.

$$\Lambda = \begin{cases} e^{-\alpha(\tau+1)^{\gamma}} \text{ if } \Lambda > \min\Lambda, \\ \min\Lambda; \end{cases}$$

where:

Λ is an emissions factor relative to the reference year;

τ is the carbon price;

min Λ is the minimum emissions factor possible; and

α and γ sets the extent of adjustment of emission intensity in response to a carbon price with higher values providing larger changes. α is set to 0.03 unless otherwise noted.

The parameters γ and min Λ are chosen for each industry based on sector-specific information on technology and production possibilities. The MAC curves are non-linear and results can be sensitive to the solution methods used by the models.

The MAC curve parameters used in GTEM were chosen to fit global data from the EMF-21 data set by Weyant and Chesnaye (2006). The MAC curves in GTEM are applied only to fugitive and industrial process emissions; that is, only to emissions that are not the consequence of fuel combustion.

Table B15: GTEM fugitive/industrial process emission MAC curve parameters

	CO_2		CH_4		N_2O		
	α	γ	α	γ	α	γ	min Λ
Coal	-	-	0.03-0.07	0.90	-	-	0.02-0.1
Oil	0.03	0.60	0.03	0.75	-	-	0.01-0.1
Gas	0.03	0.60	0.03	0.80	-	-	0.02-0.1
Petroleum and coal products	0.03	0.60	-	-	-	-	0.02-0.1
Non-ferrous metals	0.05	0.99	-	-	-	-	0.01-0.1
Chemicals, rubber and plastic	-	-	-	-	0.09	0.99	0.02-0.1
Non-metallic minerals	0.03	0.60	-	-	-	-	0.01-0.1
Crops	-	-	0.03	0.50	-	-	0.00-0.1
Livestock	-	-	0.03	0.60	0.03	0.60	0.02-0.1
Fertiliser use	-	-	-	-	0.03	0.40	0.3
Waste(a)	-	-	0.05	0.70	-	-	0.1

(a) Waste MAC curves apply only to USA, EU-25, China and the Former Soviet Union.
Source: Treasury; and Weyant and Chesnaye (2006).

Table B16: Change in non-combustion emission intensity in GTEM

Average annual growth (per cent, 2010 to 2050)

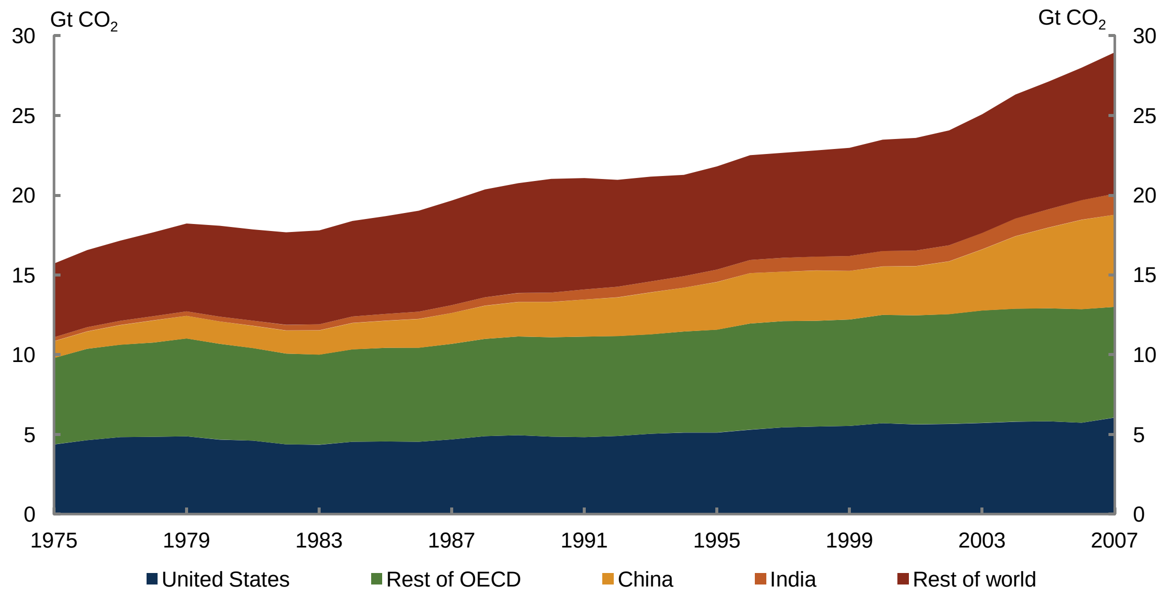
	Coal CH_4	Non-metallic minerals, CO_2	Livestock CH_4/N_2O	Crops N_2O	Gas CH_4	Oil CH_4
United States	-1.4	-0.2	-0.8	-0.8	0.0	0.0
European Union (25)	-1.7	-0.2	-0.8	-0.5	-0.6	0.0
China	-0.7	-0.3	-0.8	-0.3	-1.3	-3.6
Former Soviet Union	-1.0	-0.2	-0.8	-1.2	-2.8	-1.0
Japan	0.0	-0.2	-0.8	-0.5	-1.6	-5.1
India	-3.6	-0.3	-0.8	-0.3	-1.5	-4.6
Canada	0.0	-0.2	-1.1	-2.0	0.0	0.0
Indonesia	-0.7	0.0	-1.1	-1.5	0.0	0.0
South Africa	-3.6	-0.2	-0.8	-0.4	-1.6	-4.8
Other south and east Asia	-1.0	-0.2	-0.8	-0.5	-1.9	-5.1
OPEC	-3.6	-0.2	-0.8	-0.4	-1.7	-4.6
Rest of world	-3.8	-0.2	-0.8	-0.2	-0.2	-3.6

Note: Negative numbers denote improvements in emissions intensity.
Source: Treasury; DCC, 2008a; and Weyant and Chesnaye, 2006.

World emissions

Much of the world's economic activity depends, 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 60 per cent from 1980 to 2008, with most energy coming from fossil fuels (IEA, 2010a).

Chart B3: Fuel combustion emissions



Source: OECD/IEA, 2008; and WRI, 2011.

In the baseline scenario, where the world does not undertake any further abatement action than was in place in 2008, the world economy continues to rely on fossil fuel combustion to power growth, which in turn leads to increased greenhouse gas emissions, despite there being considerable declines in the expected emission intensity of growth.

With the world economy projected to grow strongly this century, annual greenhouse gas emissions more than double between 2010 and 2050. The annual rate of growth of emissions is expected to slow from around 2.5 per cent now to around 1.3 per cent by 2050.

These emissions are mostly carbon dioxide from energy use and deforestation, and methane and nitrous oxide from agriculture. Other gases such as hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) maintain a small share of around 1.5 per cent.

Table B17: Baseline global emissions

Emissions by region

	2010 CO_2-e	2020 CO_2-e	2050 CO_2-e
United States	6.9	6.9	8.2
European Union (25)	4.7	4.5	4.7
China	10.3	17.9	31.0
Former Soviet Union	3.9	4.6	6.2
Japan	1.3	1.2	1.0
India	2.2	3.5	12.6
Canada	0.8	0.8	1.0
Indonesia	0.9	1.0	2.4
South Africa	0.5	0.6	1.2
Other South and East Asia	1.7	1.7	3.1
OPEC	2.1	2.7	5.6
Rest of world	7.8	9.0	16.1
World	43.5	55.0	94.3

Emissions by gas and type

	2010 CO_2-e	2020 CO_2-e	2050 CO_2-e
Carbon dioxide	34.4	43.5	77.1
Combustion	30.6	39.7	70.9
Fugitive/Industrial process	1.5	2.4	5.7
Waste	0.04	0.04	0.04
LUCF	2.2	1.4	0.5
Methane	5.9	7.4	10.6
Combustion	0.5	0.6	0.9
Fugitive/Industrial process	4.1	5.3	7.9
Waste	1.3	1.5	1.8
Nitrous oxide	2.7	3.4	5.3
Combustion	1.6	2.0	3.0
Fugitive/Industrial process	1.0	1.3	2.2
Waste	0.03	0.03	0.04
Other gases	0.5	0.7	1.3
Total	43.5	55.0	94.3

Note: LUCF means land use change and forestry.
Source: Treasury estimates from GTEM.

The emission intensity of the world economy falls by more than 45 per cent by 2050 compared with 2010. The emission intensity of output varies significantly across regions, although these differences are expected to narrow over time. Nevertheless, variations in key factors, such as consumer preferences, geographical location, resource endowments and comparative advantage, cause some differences in emission intensity to remain.

While emissions per unit of output are projected to decline, global emissions per person are projected to almost double between 2010 and 2050 in the baseline. Differences in per person 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 person triple to 2050 and overtake the level of the United States. India's emissions per person remain below the world's average by 2050, despite strong growth. Emissions per person are projected to be relatively stable for developed economies, reflecting continued energy efficiency improvements, technological change and rising consumption of low-emission services.

Emissions per person and emissions intensity of output are both lower than in previous Treasury modelling. This reflects the updated United Nations projections of world population (United Nations, 2011) and higher projected prices of fossil fuel commodities (IEA, 2010a).

Table B18: Baseline emissions by region

Emission intensity of GDP

	2010	2020	2050
	kg CO_2-e per US$		
United States	0.45	0.35	0.23
European Union (25)	0.30	0.24	0.17
Australia	0.66	0.56	0.38
Rest of annex B	0.66	0.58	0.43
China	1.06	0.79	0.50
India	0.58	0.43	0.26
Rest of world	0.62	0.46	0.27
World average	0.58	0.48	0.31

Emissions per person

	2010	2020	2050
	t CO_2-e per person		
United States	22.1	20.2	20.1
European Union (25)	10.1	9.3	9.7
Australia	27.4	27.1	27.4
Rest of annex B	13.3	14.7	19.1
China	7.6	12.7	23.6
India	1.8	2.6	7.7
Rest of world	4.2	4.2	5.7
World average	6.3	7.2	10.1

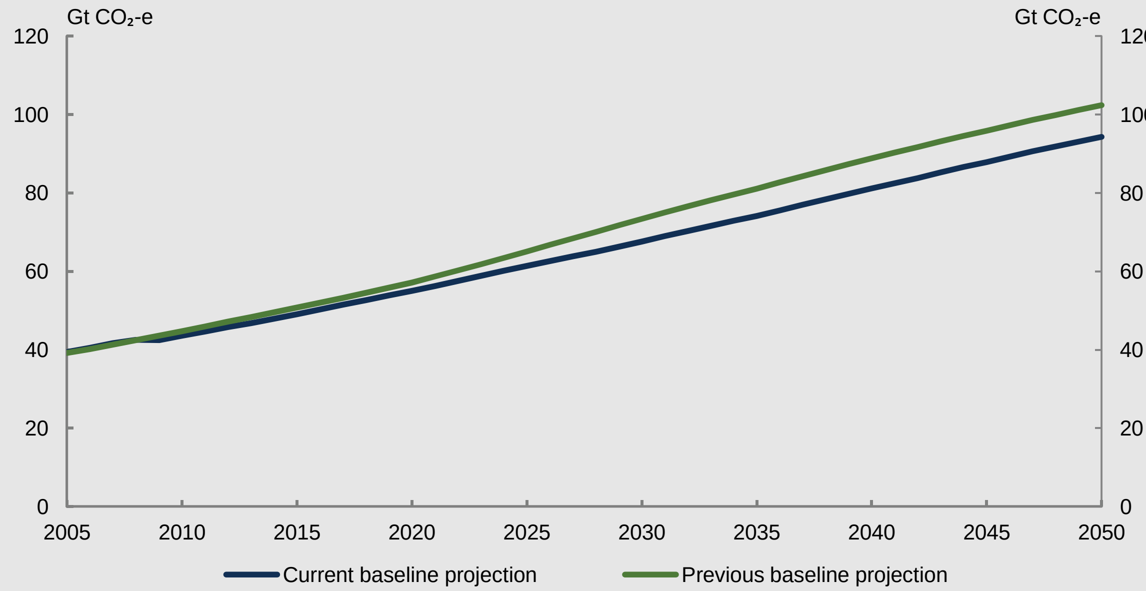
Note: GDP is in US$ 2010 using 2005 PPP weighting.
Source: Treasury estimates from GTEM.

Box B.1: Baseline emissions comparison

The updated baseline scenario projects higher world population growth than previous modelling, but lower global production growth. Additionally, commodity price projections for fossil fuels are higher. Lower incomes and higher commodity prices leads to a decline in the demand for energy and other emission-intensive goods and services declines. Emissions from the two major emission-intensive sectors (electricity generation and transport) are significantly lower, contributing to lower level of world emissions than projected in the previous modelling.

Emissions growth is steady over the projection period, leading to total global emissions of 94 Gt CO_2-e in 2050. This projection is at the high end of the range compared to other studies (IPCC, 2007c; the EMF21 scenarios range from around 50 to 100 Gt CO_2-e in 2050), largely due to higher economic growth projections assumed in the current Treasury modelling. For example, global emissions in the baseline scenario of the current study are higher than those in OECD projections, which are around 70 Gt CO_2-e in 2050 (OECD, 2009). However, the emission intensity of the world economy is comparable, at around 0.29 kg CO_2-e per US dollar in 2050 in the OECD projection (based on calculations from results in OECD, 2009), compared to 0.31 kg CO_2-e per US dollar in 2050 in the current Treasury modelling.

Chart B4: Global greenhouse gas emissions



Source: Treasury estimates from GTEM.

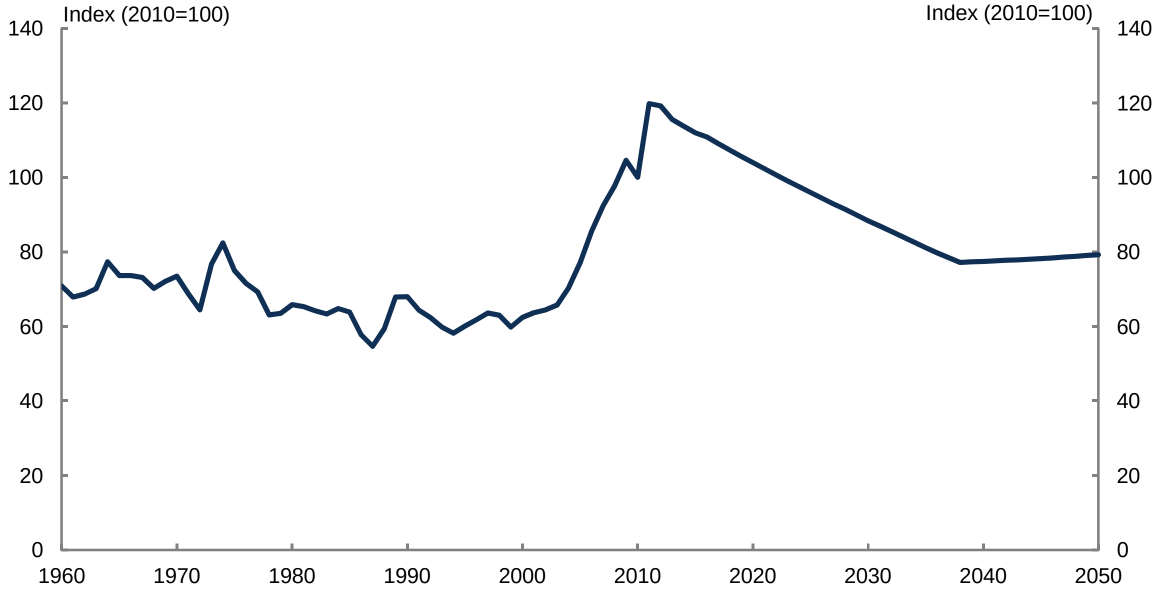
Terms of trade and energy price assumptions

Terms of trade

The modelling uses the same medium-term path for the terms of trade as the Budget, a projected decline of around 20 per cent over a 15-year period. The terms of trade are then assumed to continue declining until 2037-38, when the level is in line with Treasury international modelling results. In later years, it grows modestly reflecting long-term expectations of world demand and supply of Australia's key exports, as modelled within GTEM.

Chart B5: Australia's terms of trade

Medium global action



Source: ABS and Treasury estimates from MMRF.

Energy commodity prices

Consistent with the previous modelling, assumed prices for oil and gas are based on projections from the International Energy Agency (IEA). Since previous modelling, the IEA has increased the projected growth rate and level of oil and gas prices out to 2030, reflecting rapidly increasing demand and the rising cost of extraction from marginal resources. As a result, prices in the current modelling are higher than in previous modelling. Prices in real terms are constant from around 2035.

Coal prices to 2028 are based on Treasury projections, after which they are held constant in real terms. For thermal coal, prices are based on information from individual companies, private sector forecasters, futures markets, ABARES and other industry sources, in addition to Treasury's analysis of bulk commodity prices.

In Australian dollar terms, coal, gas and oil prices in the ambitious global action scenario are the same as in the medium global action scenario until 2012. From 2012 to 2050, oil prices differ modestly between the two scenarios, with prices in the ambitious global action scenario, on average, higher by 0.3 per cent. Over the same period, coal and gas prices are both slightly lower in Australian dollar terms in the ambitious global action scenario: by 4.8 per cent and 3.7 per cent for coal and gas respectively, on average.

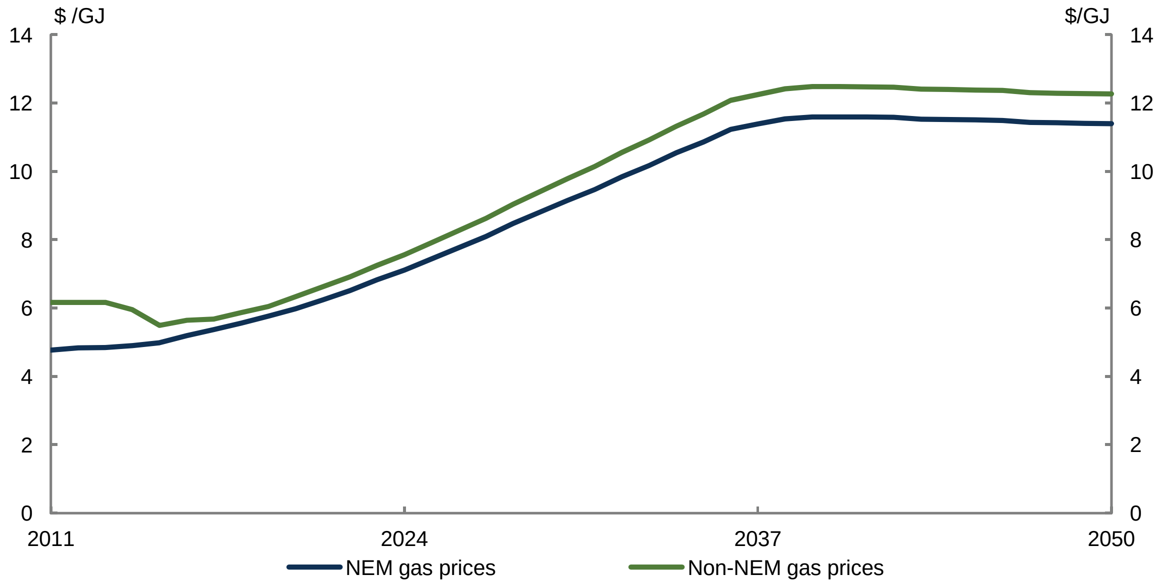
Fuel costs for Australian electricity generation

The detailed modelling by SKM MMA and ROAM employs similar assumptions about the fuel costs generators face.

- Once existing contracts expire for black coal (non-mine mouth), world prices influence new contracts. Brown coal and mine mouth black coal prices are not affected by world energy price movements.
- The modellers were provided with assumptions about the path of world gas prices. These prices are used by the modellers to inform assumptions about the domestic prices for gas.
  - Western Australian gas prices are assumed to be at a domestic equivalent of the international price of gas, excluding export costs (such as for compression).
  - The significant investment plans in production and LNG export facilities in Queensland is assumed to result in the domestic gas price in the east coast being linked to changes in world gas prices by around 2020.

Chart B6: Domestic Australian gas prices

Medium global action scenario



Source: SKM MMA and ROAM.

Australian economic assumptions

Australian gross domestic product

Table B19: Australia's employment, productivity and GDP

Average annual growth (per cent)

Decade	Employment	Labour productivity	Real GDP
2010s	1.6	1.4	3.0
2020s	1.1	1.6	2.6
2030s	1.0	1.6	2.6
2040s	0.9	1.6	2.5

Note: Results from the medium global action scenario.
Source: Treasury and ABS.

Gross state product

Gross state product is a function of assumptions about the distribution of population and industry across states.

Table B20: Gross state product

Average annual growth (per cent)

Decade	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
2010s	2.5	2.7	3.6	2.1	4.3	2.0	3.8	2.3
2020s	2.5	2.5	2.9	1.6	3.0	1.9	2.8	2.4
2030s	2.7	2.5	2.8	1.9	2.6	2.1	2.8	2.6
2040s	2.4	2.3	2.6	1.8	2.4	1.9	2.9	2.4

Source: Treasury and ABS.

Table B21: State population growth

Average annual growth (per cent)

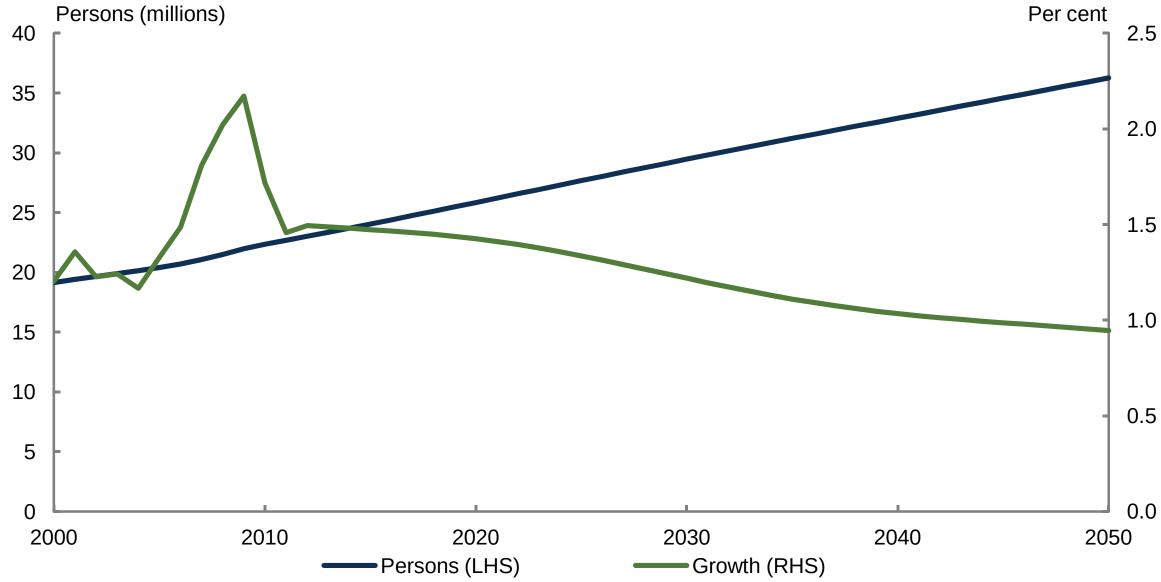
Decade	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
2010s	1.1	1.4	2.1	1.0	2.0	0.7	1.5	1.2
2020s	1.0	1.3	1.8	0.9	1.7	0.5	1.4	1.0
2030s	0.9	1.0	1.5	0.7	1.4	0.3	1.3	0.9
2040s	0.8	0.9	1.3	0.6	1.3	0.2	1.3	0.8

Source: Treasury and ABS.

Australian population and participation

Australian national population is based on Treasury projections updated since the 2010 Intergenerational Report (Australian Government, 2010). State population projections used in MMRF disaggregate the national population into the states by applying state population shares projected by the ABS.

Chart B7: Australia's population growth



Source: 2010 Intergenerational Report and Treasury projections.

Australian productivity and technological development

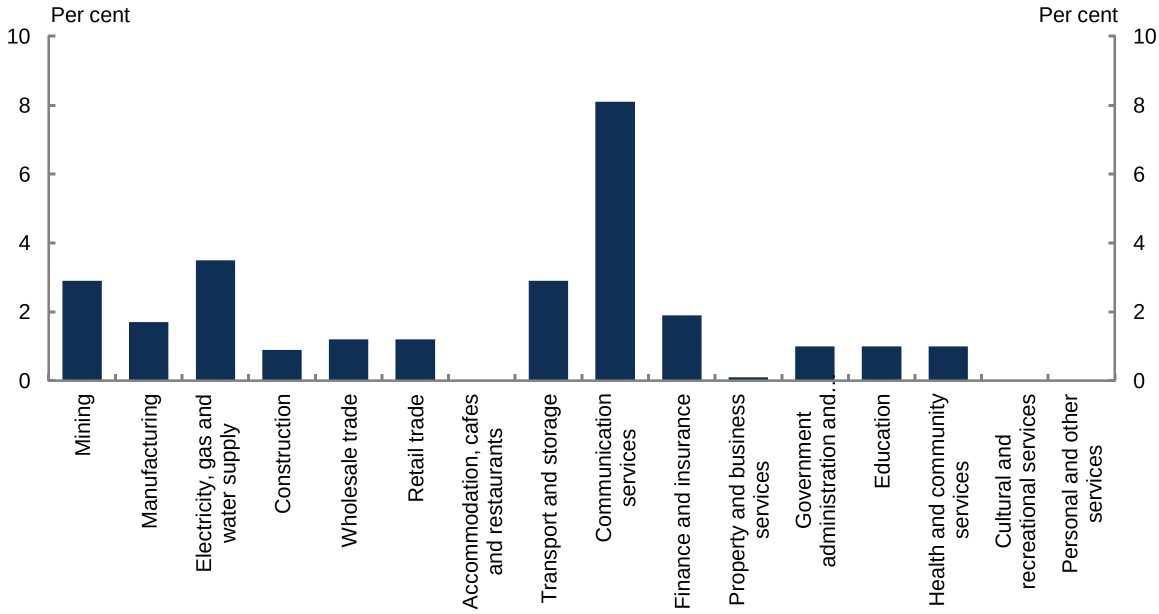
Labour productivity

The modelling uses Treasury forecasts and budget projections for aggregate labour productivity growth to 2014-15. Sector-specific labour productivity then gradually transitions to the assumed aggregate rate of 1.6 per cent per year. Australia's aggregate long-term labour productivity growth of 1.6 per cent is consistent with the US long-term labour productivity growth assumption.

MMRF uses an aggregate labour productivity assumption by adjusting its labour-augmenting technical change variable at an industry level, thereby dispersing technical change across industries, based on historical estimates.

The growth rates of labour-augmenting technical change across industries are not the same. The growth rates are estimated from the ABS National Accounts. They remove the effect of capital deepening on output by adjusting multifactor productivity estimates by industry-level labour income shares.

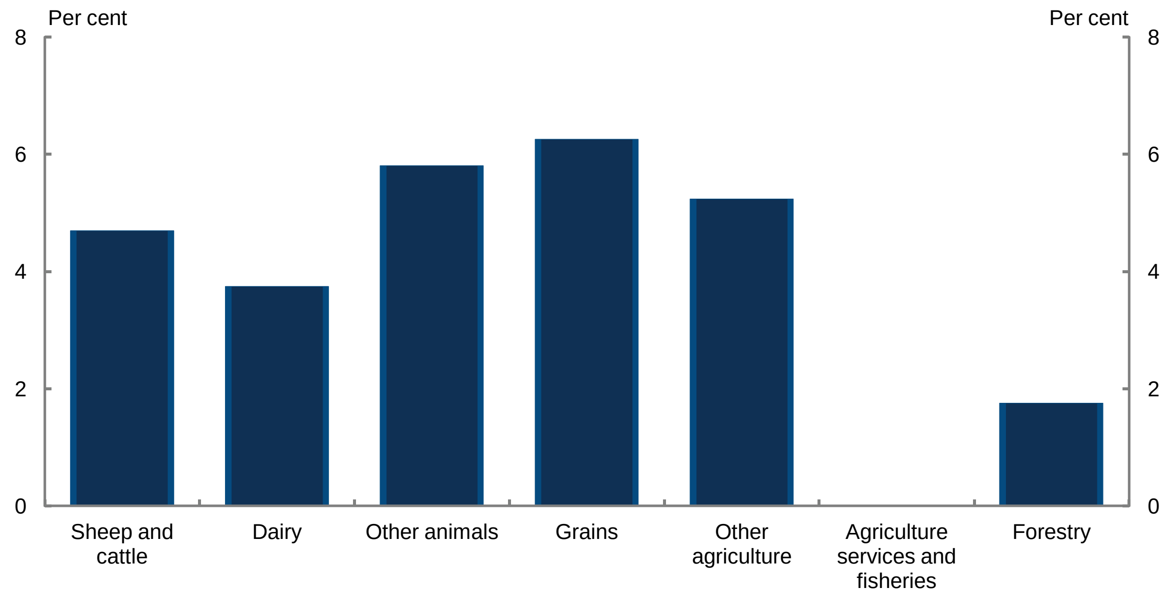
Chart B8: Industry labour-augmenting technical change
Average annual growth from 1976 to 2007



Source: Treasury and ABS.

The modelling uses a more detailed set of assumptions for the agricultural sector than the previous modelling. Technical change for each disaggregated sector is based on Centre for International Economics (2010) and ABARES (2011).

Chart B9: Agriculture, forestry and fishing labour-augmenting technical change
Annual growth



Source: Treasury, Centre for International Economics and ABARES.

Intermediate input assumptions

The assumed changes in MMRF are based on a historical decomposition analysis by Giesecke (2004). Treasury validates intermediate input usage estimates in MMRF using a data set from the Centre for Integrated Sustainability Analysis at University of Sydney. Reflecting uncertainty about the persistence of historical trends over long timeframes, the intermediate input changes are assumed to decline linearly to zero between 2020 and 2050. MMRF implements the change in the intermediate input usage in a cost-neutral way, so total factor productivity remains unchanged.

Table B22: Intermediate input usage in MMRF

Average annual growth

Commodities	2010 to 2020	2020 to 2030	2030 to 2040	2040 to 2050
Sheep and cattle	-0.2	-0.2	-0.1	0.0
Dairy cattle	-0.2	-0.2	-0.1	0.0
Other animals	-0.2	-0.2	-0.1	0.0
Forestry	-0.5	-0.4	-0.3	-0.1
Coal mining	-0.5	-0.5	-0.5	-0.5
Gas mining	-0.5	-0.5	-0.5	-0.5
Other mining	-1.5	-1.2	-0.8	-0.3
Meat products	0.5	0.4	0.2	0.1
Textiles, clothing and footwear	-2.0	-1.6	-1.0	-0.4
Wood products	-0.2	-0.2	-0.1	0.0
Paper products	-0.2	-0.2	-0.1	0.0
Printing	-0.4	-0.3	-0.2	-0.1
Gasoline	-0.5	-0.5	-0.5	-0.5
Diesel	-0.5	-0.5	-0.5	-0.5
LPG	-0.5	-0.5	-0.5	-0.5
Air fuel	-1.0	-1.0	-1.0	-1.0
Other fuel	-0.5	-0.5	-0.5	-0.5
Chemicals	-0.7	-0.6	-0.4	-0.1
Rubber & plastic products	0.5	0.4	0.2	0.1
Non-metal construction products	-0.5	-0.4	-0.3	-0.1
Cement	-0.3	-0.2	-0.2	-0.1
Iron and steel	-1.0	-0.8	-0.5	-0.2
Aluminium	-1.0	-0.8	-0.5	-0.2
Other metals manufacturing	-0.1	-0.1	-0.1	0.0
Metal products	-0.1	-0.1	-0.1	0.0
Other manufacturing	-0.5	-0.4	-0.3	-0.1
Electricity supply	-0.8	-0.6	-0.5	-0.5
Water supply	-1.0	-0.8	-0.5	-0.2
Construction	0.5	0.4	0.2	0.1
Trade	0.5	0.4	0.2	0.1
Accomodation and hotels	-1.5	-1.2	-0.8	-0.3
Road transport: passenger	0.7	0.6	0.3	0.1
Road transport: freight	0.7	0.6	0.3	0.1
Rail transport: passenger	0.4	0.3	0.2	0.1
Rail transport: freight	0.4	0.3	0.2	0.1
Air transport	0.5	0.4	0.2	0.1
Communication services	1.0	0.8	0.5	0.2
Financial services	0.5	0.4	0.2	0.1
Business services	1.5	1.2	0.7	0.3

Note: Annual rate of change of use of the commodity identified per unit of output of all industries. Energy commodities have economy-wide energy efficiency term applied.Excluded commodities have no intermediate input efficiency shocks applied.
Source: Treasury.

Household taste shifts

Additional changes in consumption, apart from changes in incomes and prices, are due to shifts in household tastes. The assumptions are based on a historical decomposition analysis by the Centre of Policy Studies (Adams et al, 1994; Dixon and Rimmer, 2002; and Giesecke, 2004). In addition, Treasury uses the National Accounts consumption categories in its decomposition analysis in the MMRF model.

The projected household taste shifts imply long-term trends continue towards services and away from basic commodities. The assumption reflects uncertainty about how persistent household trends are over long timeframes, with taste shifts declining to zero between 2020 and 2050.

Table B23: Household taste shocks in MMRF

Average annual growth, per cent

Commodities	2010 to 2020	2020 to 2030	2030 to 2040	2040 to 2050
Biofuels	1.0	0.8	0.5	0.2
Forestry	-1.5	-1.2	-0.8	-0.3
Coal mining	-0.6	-0.5	-0.3	-0.1
Paper Products	-1.0	-0.8	-0.5	-0.2
Printing	-1.0	-0.8	-0.5	-0.2
Chemicals	0.8	0.7	0.4	0.1
Water supply	-0.5	-0.4	-0.3	-0.1
Trade	0.5	0.4	0.2	0.1
Accomodation and hotels	0.5	0.4	0.2	0.1
Air transport	1.5	1.2	0.8	0.3
Communication services	3.0	2.5	1.5	0.5
Financial services	0.5	0.4	0.2	0.1
Business services	1.0	0.8	0.5	0.2
Public services	2.3	1.9	1.1	0.4
Other services	1.0	0.8	0.5	0.2
Private transport	-0.2	0.0	0.0	0.0
Private electricity	0.5	0.4	0.2	0.1

Note: Excluded commodities have no taste shocks applied.
Source: Treasury and Centre of Policy Studies.

Economy-wide energy efficiency

CGE models can internally capture price-induced improvements in energy efficiency through consumption and production substitution choices. When the models cannot capture fully these substitution opportunities, a simple autonomous energy efficiency improvement (AEEI) parameter incorporates underlying energy efficiency improvements. The AEEI parameter specifies the rate of annual energy efficiency improvement, not the source of it.

Calibrating the AEEI is difficult, given the uncertainty about energy efficiency over very long timeframes. While history provides a guide, available data often are aggregated, obscuring trends in energy efficiency with other factors such as structural changes in the economy.

In MMRF, the AEEI parameter incorporates the range of policies, of both the Australian Government and the States that drive improvements in energy efficiency. The parameter is higher in the near term, averaging 0.8 per cent per year to 2025, before declining to 0.5 per cent per year for the remainder of the period.

Elasticity of Australian electricity demand

The MMRF model allows for substitution between production and consumption inputs at both the firm and household levels. The aggregate response of electricity demand to electricity prices depends on several factors, including: the assumed constant partial elasticities; and the induced changes in the industrial and consumption structure of the economy.

The constant partial equilibrium elasticities (expenditure and implied own-price elasticities) reflect only part of the response to electricity prices. They indicate the expected change in demand for electricity, given a change in price or expenditure, assuming nothing else in the economy changes. They are deliberately not presented here to avoid any misinterpretation.

As MMRF is a general equilibrium model, important second round effects to electricity demand should be included in any estimate of the total price elasticity of demand. Higher costs reduce profitability and return on capital in electricity and emission-intensive industries. This reduces resources flowing to these sectors and reduces the overall demand for electricity in the economy at industry and household levels.

The modelled outcomes also change depending on the size of the price shift and the impact of electricity and other prices in the economy.

Analysis of the scenarios contained in this modelling suggests a total price elasticity of demand of around -0.3. That is, a 10 per cent increase in wholesale electricity prices leads to a 3 per cent decrease in electricity demand across the economy, in the medium term.

A recent review of domestic and international literature concluded a 10 per cent increase in prices leads to a fall in demand of between 2 and 4 per cent in the short term and 5 and 7 per cent in the long term.[3]

Sector-specific assumptions

Electricity technology assumptions

Electricity generation sector assumptions are particularly important as the sector is a significant source of Australia's emissions. In developing the assumptions, the views of the Department of Resources, Energy and Tourism Stakeholder Reference Group on the cost and performance of Australian electricity generation technologies were considered.

The bottom-up modelling focuses on the main inputs into technology development in the electricity sector: thermal efficiency, capital costs and learning rates. SKM MMA provided the assumptions on thermal efficiency improvements for Australia.

3 See Fan and Hyndman, 2010; and Productivity Commission, 2011.

Table B24: SKM MMA technology cost and performance assumptions

	Capital cost	Capital cost de-escalator		Thermal efficiency	
	2010 $/kWh sent out	2010-20(a) % pa	2021-30(a) % pa	2010 %(b)	Efficiency improvement % pa
Black coal options					
Supercritical coal (dry-cooling)	2,357	0.5	0.5	40	0.5
Ultra-supercritical coal (wet cooled)	2,235	0.5	0.5	41	0.5
IGCC	3,643	1.0	1.0	46	1.2
IGCC with CCS	5,418	1.0	1.0	36	1.3
Ultra-supercritical with CC and oxy-firing	5,676	1.0	1.0	30	0.6
USC with post- combustion capture (wet cooled)	3,828	1.0	1.0	31	0.6
Brown coal options					
Supercritical coal with drying	2,900	0.5	0.5	31	0.5
Supercritical coal	2,900	0.5	0.5	29	0.5
Ultra supercritical coal with drying	3,000	1.0	0.5	32	0.5
IGCC with drying	6,601	1.0	1.0	35	1.2
IGCC with CCS	9,816	1.0	1.0	26	1.3
Natural gas options					
CCGT - small	1,850	0.5	0.5	43	0.6
CCGT - medium	1,400	0.5	0.5	46	0.6
CCGT - large	1,300	0.5	0.5	51	0.6
Cogeneration (large)	1,900	0.5	0.5	69	0.6
CCGT with CCS (wet cooled)	2,755	1.0	0.5	45	0.7
Renewable options					
Wind	2,400	1.0	0.5		0.2
Biomass - Steam (woodwaste used)	6,382	0.5	0.5	25	0.1
Biomass - Gasification (woodwaste used)	5,361	1.5	1.0	25	0.1
Concentrated Solar thermal plant - without storage	6,500	2.5	1.5		0.2
Concentrated Solar thermal plant - with storage	9,500	2.5	1.5		0.2
Geothermal - HSA	6,500	1.0	1.0	28	0.1
Geothermal - Hot Rocks	7,000	1.5	0.5	26	0.1
Concentrating PV	6,175	2.5	1.5		0.1
Hydro	3,500	1.0	0.5		0.1

(a) The de-escalater assumptions reflect factors such as learning-by-doing and efficiency improvements in the production of capital. They are largely influenced by global supply and demand factors. As such, these de-escalater rates will be influenced by global climate change mitigation action. These assumptions reflect global mitigation action to achieve stabilisation of greenhouse gas concentration levels at around 550 ppm CO_2-e around 2100.
(b) GJ of output (electricity) over GJ of input (fuel).

Australian capital costs decline over time, informed by in-house expertise and GTEM global learning rates. The main factors driving capital costs over time in SKM MMA modelling are technological progress, metal prices and movements in the exchange rate. SKM MMA assumptions about the proportion of capital costs reflect commodity price forecasts from the MMRF model.

Table B25: ROAM technology cost and performance assumptions

	Capital cost	Capital cost de escalator		Thermal efficiency	
	2010 $/kWh sent out	2010-20(a) % pa	2021-30(a) % pa	2010 %(b)	Efficiency improvement % pa
Black coal options					
IGCC - black coal	4,768	0.8	1.7	47	0.8
IGCC - black coal with CCS	6,396	0.7	1.6	38	1.2
Supercritical PC - black coal	2,774	0.3	0.7	42	1.3
Supercritical PC - black coal with CCS	5,476	0.5	1.0	37	1.8
Supercritical PC - black coal oxy-combustion CCS	5,877	0.5	1.1	44	1.5
Brown coal options					
IGCC - brown coal	6,191	1.4	3.3	38	1.9
IGCC - brown coal with CCS	8,365	1.2	2.7	29	2.5
Supercritical PC - brown coal	3,722	0.3	0.7	39	1.7
Supercritical PC - brown coal with CCS	6,880	0.4	0.9	33	2.6
Natural gas options					
CCGT - without CCS	1,317	0.5	1.0	51	0.8
CCGT - with CCS	2,607	0.6	1.4	48	1.0
OCGT - without CCS	931	0.4	0.8	33	1.1
Small CCGT - without CCS (non NEM)	1,449	0.5	1.0	51	0.8
Small CCGT - with CCS (non NEM)	2,867	0.6	1.4	48	1.0
Renewable options					
Solar thermal - parabolic trough w 6hrs storage	8,182	1.0	2.3		0.0
Solar thermal - parabolic trough w/out storage	5,308	1.2	2.7		0.0
Solar thermal - central receiver w 6hrs storage	6,054	1.2	2.7		0.0
Solar thermal - central receiver w/out storage	4,262	1.3	3.2		0.0
Photovoltaic - PV fixed flat plate	4,348	1.0	2.3		0.0
Photovoltaic - PV single axis tracking	4,769	1.0	2.3		0.0
Photovoltaic - PV two axis tracking	5,283	1.0	2.3		0.0
Wind	2,699	0.7	1.4		0.0
Geothermal - EGS	7,586	0.2	0.5		0.0
Geothermal - HSA	7,260	0.3	0.7		0.0
Biomass	4,675	0.0	0.0	30	0.0

(a) The de-escalator assumptions reflect factors such as learning-by-doing and efficiency improvements in the production of capital. They are largely influenced by global supply and demand factors. As such, these de-escalator rates will be influenced by global climate change mitigation action. These assumptions reflect global mitigation action to achieve stabilisation of greenhouse gas concentration levels at around 550 ppm CO_2-e around 2100. ROAM only apply de-escalator rates after 2015.
(b) GJ of output (electricity) over GJ of input (fuel).

Capital costs in ROAM are based on Electric Power Research Institute (EPRI) as reviewed by ACIL Tasman (2010). These estimates were based on an exchange rate around US 81c = AU 1. Given the current level of the exchange rate, the DRET estimates were adjusted to remove the currency cost factors previously used by EPRI. ROAM's deescalators were also informed by GTEM global learning rates.

Technology constraints

Exogenous assumptions and constraints in the SKM MMA and ROAM include:

- constraints on new power plant entry in the near term, especially where planning has not started, to allow sufficient time for planning and construction
- limits on the rate of growth in deploying and totally developing renewable energy capacity, reflecting resource availability, and engineering and technical constraints.

Carbon capture and storage

SKM MMA's, ROAM's and GTEM's approach to modelling CCS differ, reflecting the level of detail in the models and the inherent uncertainty surrounding the technology. The timing of CCS technology deployment depends on current and expected future electricity demand, carbon prices, capital costs, the running costs of CCS technologies and that of competing low emission technologies. ROAM and MMA have assumed CO_2 storage and transport costs of between \$7/t CO_2 and \$38 /t CO_2 depending on the plant location.

Australian transport

CSIRO provided detailed modelling of the effects of a carbon price on the road transport sector. This bottom-up modelling was an input into MMRF. The assumption in CSIRO modelling is that, from 2006 to 2050, vehicles equipped with petrol engines will become 25 per cent more efficient and diesel engines 14 per cent more efficient. This will occur independently of changes to fuel type and hybrid drivetrain.

Table B26: CSIRO fuel efficiency improvements from 2010 to 2050
Average annual rate of improvement (per cent)

	2010-20	2020-30	2030-40	2040-50
Medium global action	0.8	1.3	1.0	0.4
Ambitious global action	0.8	1.3	1.0	0.4
Core policy	0.7	1.5	1.4	0.5
High price	0.8	2.4	2.5	6.3

Source: CSIRO.

Marginal abatement cost curves

Carbon pricing provides an incentive for industries to reduce the emission intensity of their production. A common way to represent and model this reduction, especially in models that allow only limited substitution between intermediate inputs of production, is with marginal abatement cost (MAC) curves.

In the current modelling, MAC curves have the functional form:

$$\Lambda = \begin{cases} e^{-\alpha(\tau+1)^{\gamma}} & \text{if } \Lambda > \min \Lambda, \\ \min \Lambda; & \end{cases}$$

where:

Λ is an emissions factor relative to the reference year;

τ is the carbon price;

min Λ is the minimum emissions factor possible; and

α and γ sets the extent of adjustment of emission intensity in response to a carbon price with higher values providing larger changes. α is set to 0.03 unless otherwise noted.

The parameters γ and min Λ are chosen for each industry based on sector-specific information on technology and production possibilities. The MAC curves are non-linear and results can be sensitive to the solution methods used by the models.

In MMRF, marginal abatement cost curves represent opportunities, in the long-term, for cost-effective abatement, but take up of these opportunities takes time. There is a gradual dynamic adjustment of emissions factor towards the potential MAC curve. This gradual adjustment mechanism accounts for the time required for a firm to transform its production process towards less emission-intensive technologies. In MMRF this is represented by:

$$\Lambda_t^* = (1-\beta)\Lambda_{t-1}^* + \beta\Lambda_t$$

where:

Λ_t^* is the actual emissions factor in year t;

Λ_{t-1}^* is the actual emissions factor in the previous year;

Λ_t is the potential emissions factor given the carbon price in year t which is defined by the earlier MAC curve equation; and

β is the speed of adjustment parameter.

A higher β parameter represents a faster speed of adjustment towards the potential emissions factor. The speed of adjustment parameter β is set to 0.3 in most years. This means that the emissions factor changes each year to close 30 per cent of the gap with the potential emissions factor. This parameter is lower in the earlier years of carbon pricing, reflecting an assumption of slower adjustment during this initial period.

The take up of new abatement opportunities involves a cost to industries. These costs offset some of the savings in carbon costs.

Fugitive and industrial process emission 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 information provided by industry stakeholders. This process yielded a set of MAC curves tailored to Australian industries.

Table B27: MMRF fugitive/industrial process emission MAC curve parameters

Sector	γ	minΛ
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	0.70	0.1
Aluminium	0.70	0.1
Other manufacturing	0.70	0.1
Gas supply	0.64	0.1
Trade	0.99	0.1
Accomodation 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; Weyant and Chesnaye (2006); MMA SKM; and information provided by industry.

Table B28: Change in non-combustion emission intensity in MMRF

Average annual growth

Sectors	2010 to 2020 Per cent	2020 to 2050 Per cent
High enteric livestock	-0.3	-0.5
Other animals	0.0	-0.4
Grains	-0.9	-0.1
Other agriculture	-0.3	-0.4
Agriculture services and fishing	-0.8	-0.6
Forestry	-10.9	-1.6
Coal mining	0.2	0.2
Gas mining	0.8	0.3
Iron ore mining	-1.1	-0.8
Non-Ferrous ore mining	-0.6	-0.5
Other mining	-1.3	-1.0
Textiles, clothing, footwear and leather	-0.9	-0.6
Refinery	-0.5	-0.5
Chemicals	-0.1	-0.4
Non-metal construction products	-0.5	-0.3
Cement	-0.1	-0.1
Iron and steel	-0.9	-0.5
Alumina	-1.2	-0.7
Aluminium	0.0	0.0
Gas supply	-0.7	-0.1
Trade services	0.0	-1.6
Other services	-3.1	-1.1

Note: Negative numbers denote improvements in emission intensity.
Source: Treasury and DCCEE, 2011c.

Combustion MAC curves

The MMRF model does not currently capture the potential for fuel switching, that is, substitution between say coal and gas within each sector. In the MMRF model, MAC curves were applied to combustion emissions in the industrial (non-transport) sectors, allowing industrial combustion emissions to decline in response to carbon pricing.

The MAC curve for each fuel type is calibrated to reflect possible use of CCS technology (as in the electricity generation sector) or decarbonisation of the transport sector through the electrification of transport.

Table B29: MMRF combustion emission MAC curve parameters

Fuel	α	γ	minΛ
Coal	0.000001	2.55	0.1
Gas	0.000001	2.35	0.1
Gasoline	0.000015	2.20	0.1
Diesel	0.000015	2.30	0.1
LPG	0.000015	2.20	0.1
Air fuels	0.000015	2.20	0.1
Other fuels	0.000015	2.20	0.1

Source: Treasury.

Resource constraints

The MMRF model incorporates assumptions about energy resource supply constraints, drawing on Geoscience Australia and ABARE (2010). It is assumed that oil production in Australia ceases around 2030; and gas production ceases in South Australia around 2020 and in Victoria around 2030. No constraints on coal production are imposed: Geoscience Australia and ABARE report Australia has about 90 years of black coal reserves and around 490 years of brown coal reserves, at current production rates.

Land use, land use change and forestry assumptions

Forestry

Detailed modelling of the forestry sector can be problematic within CGE models. Due to the importance of this sector ABARES provided more detailed bottom-up modelling of the forestry sector.

The Australian estimates are based on the Kyoto Protocol Article 3.3 emissions accounting framework but are less consistent with the United Nations Framework Convention on Climate Change (UNFCCC) than the global estimates. The differences largely reflect the availability of data. The main differences between the carbon accounting in the international forestry modelling and the reporting adopted for Australia are:

- including all identified managed native forests and plantations (even if cleared after 1990)
- reporting all carbon including harvested wood products
- not including short rotation harvests.

For Australia, the supply of land available for use in the agricultural and forestry sectors is assumed to be fixed. ABARES models this land using a spatial modelling framework.

ABARES modelling examines the reforestation component of the CFI in Australian. The ABARES modelling incorporates assumptions on water inception and pricing, implications of native vegetations laws, timber processing capacity, reforestation establishment costs, carbon sequestration rates and others. These assumptions are provided in Burns et. al. (2011).

The assumed percentage changes each year to the returns to agriculture and timber are based on MMRF global action 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 are 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.

ABARES modelling is supplemented by estimates of net carbon sequestration for plantations planted between 1990 and 2009 provided by the DCCEE, and adjustments to account for site quality.

Land use and land use change

There is no long-term economic modelling of emissions from Australian land use and land use change. Emissions from this sector are exogenously imposed in the models. Land use emissions for Australia are from clearing regrowth as part of agricultural management, as well as clearing new land. In the global action scenario in the absence of the CFI, emissions from land clearing are assumed to remain at 49 Mt CO_2-e per year throughout the modelling period, based on a simple extrapolation consistent with DCCEE projections in the most recent national emission projections (DCCEE, 2011c).

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.
Allocative efficiency	Reference to the efficiency with which markets allocate resources. When the input mix of an economy is consistent with cost minimisation and where no externalities in production exist, the economy's allocative efficiency is maximised. A market is allocatively efficient if it produces the right goods for the right people at the right price.
Annex B countries	Annex B of the Kyoto Protocol lists countries that have a quantified greenhouse gas emission limit or reduction commitment in the period 2008–12.
Anthropogenic greenhouse gases	Greenhouse gases released due to human activities.
Australia's Low Pollution Future (ALPF) report	Australian Government report on the economics of climate change mitigation, released by the Treasurer and the Minister of Climate Change and Water on 30 October 2008.
Banking	The ability to hold permits for use in the future.
Base-load demand	The minimum amount of power that a utility or distribution company must make available to its customers, or the amount of power required to meet minimum demands based on reasonable expectations of customer requirements.
Biofuel	A fuel composed of or produced from biological raw materials.
Biomass	Biological material from living, or recently living organisms, such as wood, waste and (hydrogen) gas.
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.

Cap-and-trade scheme	A limit (or cap) on certain types of emissions or pollutions is set, and firms can sell (or trade) the unused portion of their limits to other firms that are struggling to comply.
Carbon capture and storage (CCS)	Technology to capture and store greenhouse gas emissions from energy production or industrial processes. Captured greenhouse gases can be stored in various 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 Farming Initiative (CFI)	The Australian Government's Carbon Farming Initiative is a carbon offset scheme to establish a carbon crediting mechanism; fast-tracked development of methodologies for offset projects; and information and tools to help farmers and landholders benefit from carbon markets.
Carbon leakage	An increase in global emissions, arising from the relocation of emission-intensive production activity in response to the introduction of a carbon price.
Carbon price	The cost of releasing greenhouse gases into the atmosphere See emission price.
Carbon Pollution Reduction Scheme (CPRS)	The Carbon Pollution Reduction Scheme (CPRS) was a cap-and-trade emissions trading scheme (ETS) developed by the Australian Government to reduce Australia's greenhouse gas emissions.
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	A change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and 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.
Coverage	The scope of an emissions trading scheme. Covered sectors are liable for their emissions under the scheme.
Deforestation	The conversion of forested land to an alternative, non-forest use.
Dry cooling	Cooling towers used to transfer process waste heat to the atmosphere.
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 emissions per unit of sectoral output (such as the emission-intensity of electricity generation) and the emissions per unit of economy-wide output (which usually refers to GDP). Also called carbon intensity.
Emission-intensive, trade exposed (EITE) industries	Industries that either export or compete against imports (trade exposed) and produce significant emissions in their production of goods.
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.
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.
Endogenous	A variable which is generated within the model.
Energy Sector Model (ESM)	A partial equilibrium model developed by CSIRO to model the Australian energy sector, with detailed transport sector representation. The model has an economic decision-making framework, based around the cost of alternative fuels and technologies.
Exogenous	A variable which is generated outside the model.
Externality	When the production or consumption of goods and services imposes costs or benefits on others not reflected in the prices charged.

Factor cost	The cost of a good or a service in terms of the various factors that have played a part in its production or availability, and exclusive of tax costs.
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 released in the course of oil and gas extraction and processing, through leaks from gas pipelines, and as waste methane from black coal mining.
GCOMAP model	A model used by the Lawrence Berkeley National Laboratory to model the forestry sector overseas. GCOMAP simulates how forest land users respond to changes in prices in forest land and products to emission prices.
General Equilibrium Modelling Package (GEMPACK)	A suite of economic modelling software, suitable for computable general equilibrium models. GEMPACK is the software platform on which GTEM and MMRF are implemented.
Geothermal energy	Thermal energy generated and stored in the Earth.
Gigatonne (Gt)	One billion (10^9) tonnes.
Gigawatt hour (GWh)	A unit of energy equal to one billion watt hours.
Global Trade and Environment Model (GTEM)	Developed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and extended by Treasury, GTEM is a global model which provides insights into Australia's key international trading partners. The version of GTEM used disaggregates the world into 13 geographic regions and 19 industrial sectors (see Modelling Framework for more details).
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).
Greenhouse Gas Reduction Scheme (GGAS)	New South Wale's mandatory greenhouse gas emissions trading scheme started on 1 January 2003. GGAS aims to reduce greenhouse gas emissions associated with the production and use of electricity by using project-based activities to offset the production of emissions.

Groningen Growth and Development Centre	Research centre within the Economics Department of the University of Groningen. The research is largely based on a range of comprehensive databases on indicators of growth and development.
Gross domestic product (GDP)	The total market value of all final goods and services produced in an economy.
Gross domestic product (GDP) deflator	An economic metric that accounts for inflation by converting output measured at current prices into constant-dollar GDP. The GDP deflator shows how much a change in the base year's GDP relies on changes in the price level.
Gross national income (GNI)	This reflects changes in GDP, the terms of trade and international income transfers. It is measured as GDP less net taxes on production and imports, less compensation of employees and property income payable to the rest of the world, plus the corresponding items receivable from the rest of the world.
Gross output	The value of an industry's output is 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 state product (GSP)	The total market value of all goods and services produced in a particular state or territory.
Gross value added (GVA)	GVA measures the returns accruing to 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 world product (GWP)	Aggregate market value of all final goods and services produced worldwide in a given year.
Harberger triangles	Measures the net welfare loss, or deadweight loss, due to a market distortion or policy.
Hotelling rule	Derived from resource economics, the Hotelling rule explains the growth in the price of finite resources. The emission price follows a Hotelling rule, whereby it grows at the real interest rate from a specified starting level.
Hot rocks	Rocks beneath the Earth's surface with a high temperature. Hot rocks can be used to create geothermal energy by pumping cold water and making use of the rising hot water which the rocks have heated.
Hybrid vehicles	Vehicles that use two or more distinct power sources. The term most commonly refers to hybrid electric vehicles, which combine an internal combustion engine and one or more electric motors.

Intergovernmental Panel on Climate Change (IPCC)	Established in 1988, the IPCC surveys worldwide scientific and technical literature and publishes assessment reports widely recognised as the most credible existing sources of information on climate change.
Kyoto Protocol	An international treaty that sets binding targets to limit greenhouse gas emissions by individual developed countries to be met within the first commitment period, 2008–12.
Land use, land use change and forestry (LULUF)	A reporting category comprising agriculture emissions (land use), and emissions from deforestation (land use change) and carbon sequestered through reforestation (forestry).
Large scale renewable energy target (LRET)	A scheme implemented through the Renewable Energy (Electricity) Act 2000 and the accompanying Renewable Energy (Electricity) Regulations 2001 to create a financial incentive to establish and grow renewable energy power stations, such as wind and solar farms, or hydro-electric power stations.
Learning by doing	Reductions in technology costs due to greater use of a technology, such as through incremental innovation.
Legacy waste	Waste deposited in landfill before 1 July 2012.
Marginal cost of mitigation	The cost of reducing emissions by one additional unit.
Marginal product	The output produced by one more unit of a given input.
Market exchange rate (MER)	The rate of exchange between currencies in foreign exchange markets. See purchasing power parity exchange rate.
Market failure	A situation where the market is unable 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.

Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC)	A model used to estimate the atmospheric concentrations of emission trajectories from the international reference scenarios derived in GTEM.
Monash Multi-Regional Forecasting (MMRF) model	MMRF, developed by the Centre of Policy Studies at Monash University, models the Australian economy. It has 58 industrial sectors, and provides results for all eight states and territories.
Multi-stage approach	An approach to international allocation where the number of economies participating in global mitigation gradually expands.
National Energy Modelling Systems (NEMS)	A computer-based, energy-economy modelling system of the United States energy market, created by the US Energy Information Administration.
Nominal emission price	The emission price in current dollars (that is, including the effects of inflation).
ORANI	An applied general equilibrium model developed at Monash University.
Photovoltaics	Materials and devices that convert sunlight into electrical energy.
Policy scenario	A projection of the future path of the global and Australian economy if policies to reduce emissions are introduced.
Price Revenue Incidence Simulation Model (PRISMOD.IO)	A large-scale highly disaggregated model of the Australian economy developed by Treasury that captures the flows of goods between industries and final consumers. PRISMOD.IO models the impact of a carbon price on households and the consumer price index.
Price Revenue Incidence Simulation Model and Distribution Model (PRISMOD.DIST)	A static micro simulation model developed by Treasury that examines the distributional effects of government policies on spending by different households.
Productivity	A measure of output from a production process per unit of input. For example, labour productivity is typically measured as output per worker or output per hour worked.
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.
Quintile	The set of four variate values which divide the total frequency into five equal parts.

Real emission price	The emission or carbon price in constant dollars (that is, without the effects of inflation).
Reference scenarios	The two international reference scenarios incorporate world action to stabilise greenhouse gas concentration levels at around either 550 or 450 parts per million by around 2100. They provide a credible and realistic backdrop to examine the introduction of a domestic carbon price.
Renewable energy	A source of energy that is not depleted by use. Renewable technology includes hydro, biomass, solar, wind and geothermal sources.
ROAM Consulting model	A highly detailed model that provides analysis of the Australian electricity generation sector, with projections for levels of generation, total capacity, emissions, energy use (fuel use), wholesale and retail electricity prices and the profit streams of generators.
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 analysis	A technique for systematically changing variables in a model to determine the effects of those changes.
Sequestration	The removal of atmospheric carbon dioxide, either through biological processes (such as photosynthesis in plants), or geological processes (such as storage of carbon dioxide in underground reservoirs).
Sinclair Knight Merz – McLennan Magasnik Associates(SKM-MMA) model	A highly detailed model that provides analysis of the Australian electricity generation sector, with projections for levels of generation, total capacity, emissions, energy use, wholesale and retail electricity prices and the profit streams of generators.
Small-scale Renewable Energy Scheme (SRES)	A scheme implemented through the *Renewable Energy (Electricity) Act 2000* and accompanying *Renewable Energy (Electricity) Regulations 2001* to create a financial incentive for owners to install eligible small-scale installations such as solar water heaters, heat pumps, solar panel systems, or small-scale wind systems.
Social Accounting Matrix (SAM)	A framework for organising information about income, expenditure and financial flows in the economy at a point in time.
Solar thermal energy	Technology for harnessing solar energy to generate electricity.
Solow-Swan type growth model	A neoclassical growth model.

Stabilisation	Reference 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.
Static Incomes Model (STINMOD)	The National Centre for Social and Economic Modelling's (NATSEM) static microsimulation model of Australia's income tax and transfer system.
Stationary energy	Stationary energy is the largest contributor to energy sector emissions. Stationary energy includes emissions from fuel consumption for electricity generation, fuels consumed in the manufacturing, construction and commercial sectors, and other sources like domestic heating and direct combustion of fuels.
Technical efficiency	The effectiveness with which a given set of inputs are used to produce an output (that is, productivity). A production process that achieves the maximum possible output, given a fixed set of inputs and technology, is fully technically efficient.
Terawatt hour (TWh)	A unit of energy equal to one trillion (10^{12}) watt hours.
Terms of trade	The ratio of the price of an economy's exports to the price of its imports. If the ratio rises, the terms of trade improve.
Thermal efficiency	The ratio of electricity generated to energy input.
Top-down model	A top-down model breaks down a system to gain insight into its compositional sub-systems. This report uses GTEM as the top-down model for the global economy and MMRF as the top-down model of the Australian economy.
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.

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Charts and tables list

Charts

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