Climate Change Mitigation Scenarios

Modelling report provided to the Climate Change Authority in support of its Caps and Targets Review

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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
B20	A blend of 20 per cent biodiesel with 80 per cent conventional diesel
BITRE	Bureau of Infrastructure, Transport and Regional Economics
CCA	Climate Change Authority
CCS	Carbon capture and storage
CER	Certified Emission Reductions
CFI	Carbon Farming Initiative
CGE	Computable general equilibrium (model/s)
CNG	Compressed natural gas
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CoPS	Centre of Policy Studies (Monash University)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DIICCSRTE	Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education
EMF	Energy Modelling Forum
ESM	Energy Sector Model
ETS	Emission Trading Scheme
EU25	European Union — 25 countries
GCOMAP	Generalised Comprehensive Mitigation Assessment Process
GDP	Gross domestic product
GGAS	Greenhouse Gas Reduction Scheme (New South Wales)
GNI	Gross national income
GSP	Gross state product
Gt	Gigatonne
GTAP	Global Trade Analysis Project
GTEM	Global Trade and Environment Model

GWh	Gigawatt hour
GWP	Gross world product
HGWP	High global warming potential
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
Kg	Kilogram
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LRET	Large-scale Renewable Energy Target
LULUCF	Land use, land use change and forestry
MAC	Marginal Abatement Cost
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MMA	McLennan Magasanik and Associates
MMRF	Monash Multi-Regional Forecasting (model)
Mt	Megatonne
MWh	Megawatt hour
NEM	National Electricity Market
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PAGE	Policy Analysis of the Greenhouse Effect
ppm	Parts per million
PPP	Purchasing power parity
PV	Photovoltaic
SRES	Small-scale Renewable Energy Scheme
t	Tonne
TWh	Terawatt hour
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

Key points

The Climate Change Authority (CCA) requested modelling support and emissions analysis from the Treasury and the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE) as an input to their Caps and Targets Review.

This report provides updated emissions projections and economic analysis for various climate change mitigation scenarios for the CCA, but the results in this report do not constitute official Australian Government estimates.

The key findings reinforce previous analysis contained in Australia's 2012 annual emissions projections (Australian Government 2012) and modelling of the economics of climate change mitigation (Australian Government 2008, 2011).

Emissions reductions consistent with meeting targets between 5 and 25 per cent below 2000 levels in 2020 are achievable with continued economic growth. Central projections of the abatement task and the effective carbon price faced by Australian firms during the flexible price period are lower than in previous assessments. This results in lower estimates of the economic impacts of achieving these targets through a combination of carbon pricing and the Carbon Farming Initiative (CFI).

The abatement task and domestic emissions levels are lower than previous assessments due to a range of factors including: updates to data on historical emissions, including from electricity generation; lower rates of underlying growth in certain emissions-intensive industries; and lower technology cost estimates in the electricity sector, especially for wind and solar technologies.

This report also analyses the economic implications of varying scheme caps. While the level of the carbon price determines the extent of transformation of the industry structure of the domestic economy and the emissions-intensity of production within industries, under each of the emissions caps modelled, firms source additional abatement overseas through the purchase of international carbon permits.

The effect on gross national income (GNI) of the purchase of each international permit may be expected to be larger than the permit price because the increase in foreign income outflows tends to lower Australia's terms of trade. Lower caps also create a need to replace forgone carbon revenue with revenue from other sources. Taking all effects together, the effect on GNI of reducing the level of the scheme cap by 1 tonne of carbon dioxide equivalent and replacing the forgone revenue with other taxes is estimated to be around 1.55 times the international permit price.

The modelling considers only the economic effects of action to reduce emissions and these effects should be considered in the context of the broader social benefits associated with averting climate change.

Context for the report

This modelling report was prepared in response to a request from the Climate Change Authority (CCA) for assistance in its Caps and Targets Review. The results provide input into the CCA's recommendations on the level of greenhouse gas emissions caps for the carbon pricing mechanism; indicative national emissions trajectory; national carbon budget; and its assessment of Australia's progress towards its medium and long-term emissions reduction targets. The CCA is due to provide these recommendations to the Australian Government by 28 February 2014.

The modelling in the report is the outcome of collaboration between the Treasury and the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE). The updated projections build on analysis previously undertaken as part of Australia's annual emissions projections (Australian Government 2012) and modelling of the economics of climate change mitigation (Australian Government 2008, 2011). The scenarios and sensitivities were agreed by the CCA and DIICCSRTE to provide analytical inputs to both the Caps and Targets Review and emissions analysis within Government. The results in this report do not constitute official Australian Government estimates.

Framework for analysis

The report uses economic models to make long-term projections and analyse the effect of emissions reductions on the Australian economy. Emissions projections are produced from the modelling results using updated historical data on emissions and emissions intensities from *Australia's National Greenhouse Gas Inventory* and other sources. They are compiled against an outlook for the Australian economy broadly consistent with the macroeconomic projections in the 2013-14 Budget—given the long lead times involved in commissioning detailed sectoral modelling, these were the most up-to-date projections available. Detailed outlooks have been drawn from a range of experts for the agriculture, mining and manufacturing sub-sectors, and updated to incorporate some of the more recent movements in commodity price projections.

The modelling results draw on a suite of models that includes two top-down, computable general equilibrium (CGE) models developed in Australia: the Global Trade and Environment Model (GTEM) created by the Australian Bureau of Agricultural and Resource Economics and Sciences and the Monash Multi-Regional Forecasting (MMRF) model created by the Monash University Centre of Policy Studies; as well as a series of sector-specific modelling for electricity generation, transport, agriculture and forestry.

The CGE models are economy-wide and capture the interactions between different sectors, as well as among producers and consumers. Sectoral modelling complements the CGE models and provides richer detail for those activities that produce the majority of emissions in Australia. This suite of models provides the most comprehensive approach to examining the effects of carbon pricing and national emissions trajectories on the Australian economy at the global, national, state, industry and detailed sectoral levels.

It should be noted that the modelling in this report does not represent a complete assessment of the economic, social and environmental costs and benefits of climate change policies. It does not consider the risks and impacts of climate change itself nor the benefits associated with averting climate change impacts.

Scenarios

Ninety-nine countries, including all major emitters, covering over 80 per cent of global emissions have pledged mitigation action to 2020 through the Copenhagen Accord and Cancun agreements. Countries are also negotiating a new climate agreement to be agreed by 2015 and to apply to all countries from 2020. The aim of the new agreement is to bring all of the world's major greenhouse gas emitters into a common international framework.

Modelling of the global economy and the outlook for global emissions provides projections of carbon prices and the environment in which Australian industries compete. The extent and pace of international action over time remains uncertain. For this reason, two long-term global action scenarios are modelled as backdrops for four different scenarios for Australia's emissions outlook.

The international scenarios both assume that from 2013 to 2020 regions act to meet their pledges under the Cancun Agreement to reduce or limit emissions.[1] The medium global action scenario incorporates a world taking action based on the low end of pledges initially and stabilising atmospheric concentrations of greenhouse gases at 550 parts per million carbon dioxide equivalent (ppm CO_2-e) in the long term. The ambitious global action scenario assumes a collective will to cut emissions deeper and sooner. It is based on the high end of 2020 pledges and, from 2021, moving to limit the probability of global average temperatures rising more than 2 degrees Celsius above pre-industrial levels to 50 per cent. This is consistent with returning atmospheric concentrations to 450ppm in the long term. From 2021, each scenario assumes a common international price which is chosen to achieve the specified environmental outcomes.

The domestic scenarios include three different price paths for Australian carbon prices, including abatement from the Carbon Farming Initiative (CFI); and one scenario in which there is no carbon price and no CFI, which provides a benchmark against which to measure abatement. These scenarios present a central policy projection within an illustrative range of alternative possibilities.

The domestic central policy scenario assumes that, after a two-year fixed carbon price period beginning on 1 July 2012, the price of Australian carbon units rises linearly from a European Union emission allowance (EUA) futures market price for December 2014 through to a price of A$36/t CO_2-e in 2020.

The central policy scenario also assumes an Australian emissions target of 5 per cent below 2000 levels in 2020 with a national trajectory to 2020 that is consistent with Australia's provisional quantified emission limitation or reduction objective (QELRO) for the second commitment period of the Kyoto Protocol. Beyond 2020 it assumes a straight-line trajectory to 80 per cent below 2000 levels in 2050.

The carbon price pathway to 2020 and beyond is subject to uncertainty, and the sensitivity of emissions projections to alternative carbon prices has been assessed by exploring scenarios with higher and lower carbon prices. The domestic low price scenario assumes a carbon price that increases only gradually over the period between 2015 and 2020 to reach a price of around

[1] All years referred to are financial years ending in that year (that is 2011-12 is 2012). Comparisons to current values relate to 2012 levels.

A\$8/t CO_2-e in 2020, before rising linearly to the same carbon price in 2030 as in the central policy scenario.

The domestic high price scenario assumes an Australian emissions target of 25 per cent below 2000 levels in 2020 in a world taking more ambitious action. Beyond 2020, it assumes a straight-line transition to reduce emissions to 80 per cent below 2000 levels in 2050.

International carbon price projections after 2020

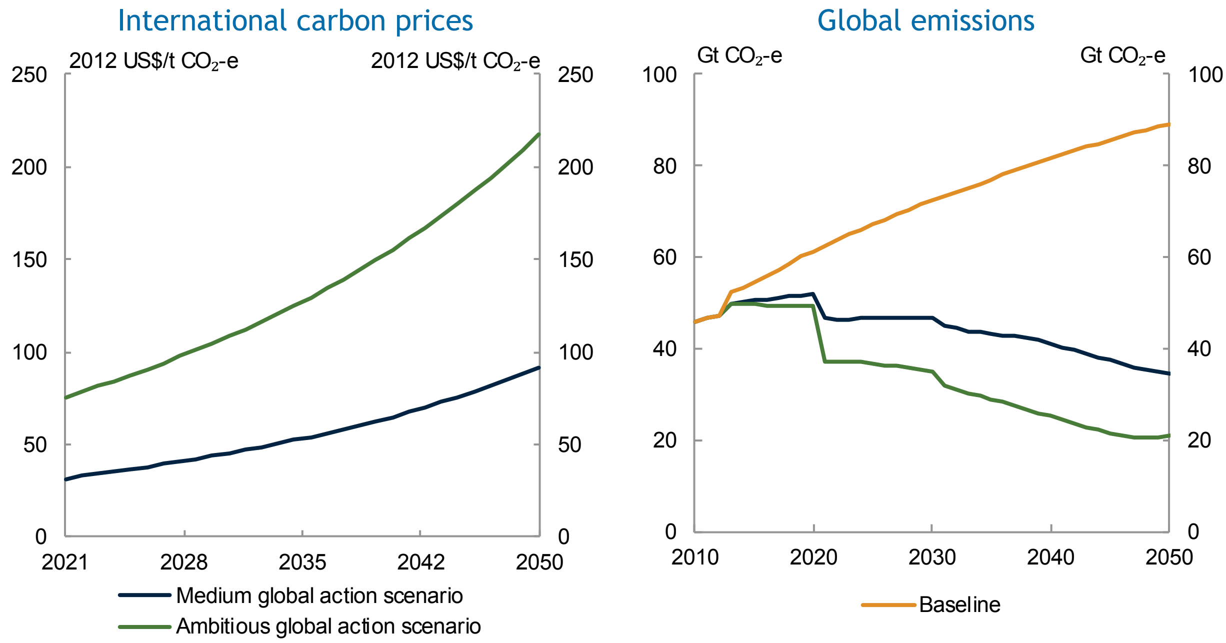
A common international carbon price is modelled from 2021 for each of the international scenarios. Different countries may achieve their carbon reduction trajectories through a range of different policies—regulation, subsidies, carbon taxes and emissions trading schemes. Furthermore, abatement costs differ across countries, reflecting their different economic structures and abatement opportunities. The modelling assumes that, by 2021, individuals or governments can trade abatement such that businesses face the same carbon price equivalent in each country. It estimates the carbon price equivalent that would produce sufficient global abatement to achieve the stated environmental outcomes.

The methodology projects long-term international carbon price paths that can meet the specified environmental outcomes. It assumes that carbon prices increase steadily over time from 2021 at an annual real rate of 4 per cent, which is the assumed rate of return on assets of similar risk. To project the path of future economic growth and emissions, it takes account of long-term international trends in population, employment and productivity. The level of carbon prices projected is similar to that presented in previous modelling (Australian Government 2008, 2011) and is within the range of projections in comparable studies.

International action is projected to reduce the level of global emissions by transforming the structure of economies and driving production towards low-emissions technologies in sectors such as electricity generation, transport and industrial processes. Emissions are reduced compared to baseline trends with a resulting reduction in the rate of growth in world production: the projections are for average annual growth in gross world product per person of 2.0 per cent in the medium global action scenario and 1.9 per cent in the ambitious global action scenario. This compares with 2.1 per cent in the baseline scenario without international action, in which atmospheric concentrations rise above 1200 ppm, leading to an estimated global temperature rise of more than 4 degrees Celsius above pre-industrial levels.[2]

2 The temperature change is determined within the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC v6), which is calibrated against more complex climate models and was used in the Intergovernmental Panel on Climate Change's Fourth Assessment Report.

International action reduces emissions



Note: The step down in emissions in 2021 reflects coordinated world action with a harmonised international carbon price; and the step down in 2031 reflects the expansion of global mitigation policy to agriculture emissions.
Source: Estimates from GTEM.

Global mitigation action sees world demand for emissions-intensive goods fall, compared to a baseline without climate change action. Higher levels of international ambition see faster transformation of economies from the combustion of fossil fuels towards renewable sources of power.

Australia's emissions projections

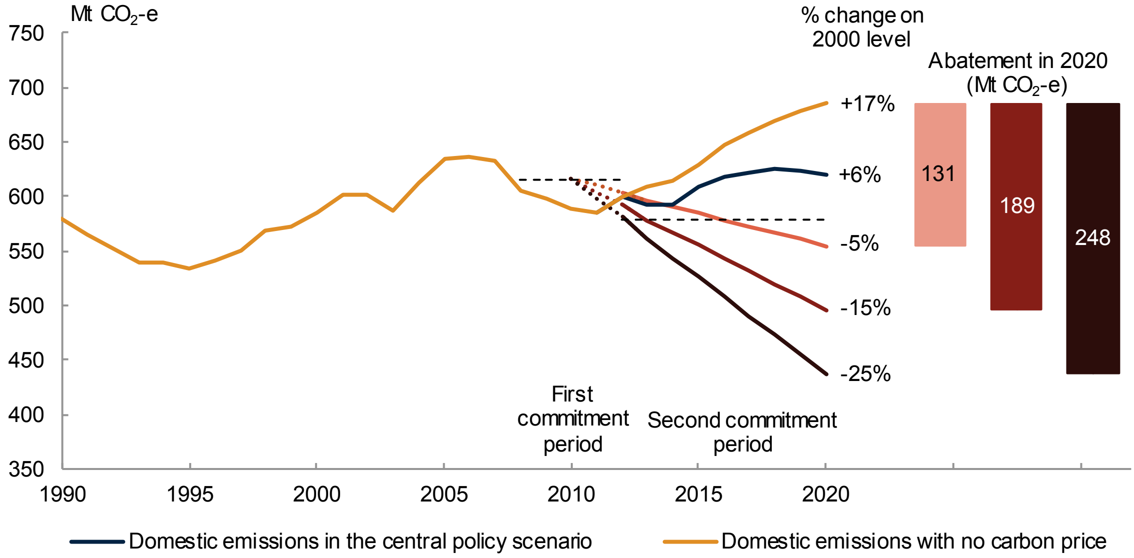
The Australian economy continues to grow in all scenarios. In the central policy scenario, the size of the economy in real GDP terms is projected to grow by around one-third over the decade to 2020 and a further one-third over the decade to 2030. As the population grows and the economy expands, employment increases, by around 1.5 million people over the period to 2020 and a further 1.7 million over the decade to 2030.

This economic outlook presents a substantial abatement task. Without either the carbon pricing mechanism or the CFI, Australia's emissions are projected to rise to 685 Mt CO_2-e in 2020. To achieve a 5 per cent reduction in emissions in 2020 compared to 2000 levels implies an abatement task of 131 Mt CO_2-e.[3]

This abatement task is lower than previous economy-wide assessments. These projections take account of more recent historical emissions levels and a lower rate of underlying growth in key emissions-intensive industries. In addition, there have been a range of changes to the scope and measurement of emissions compared to the *Australia's Emissions Projections 2012* report, as well as changes to reflect emissions accounting in Australia's second commitment period under the Kyoto protocol.

3 These figures include an adjustment for emissions reductions through GreenPower, which the Government committed would be additional to meeting Australia's emissions reduction target.

Domestic emissions are reduced and further abatement is sourced overseas



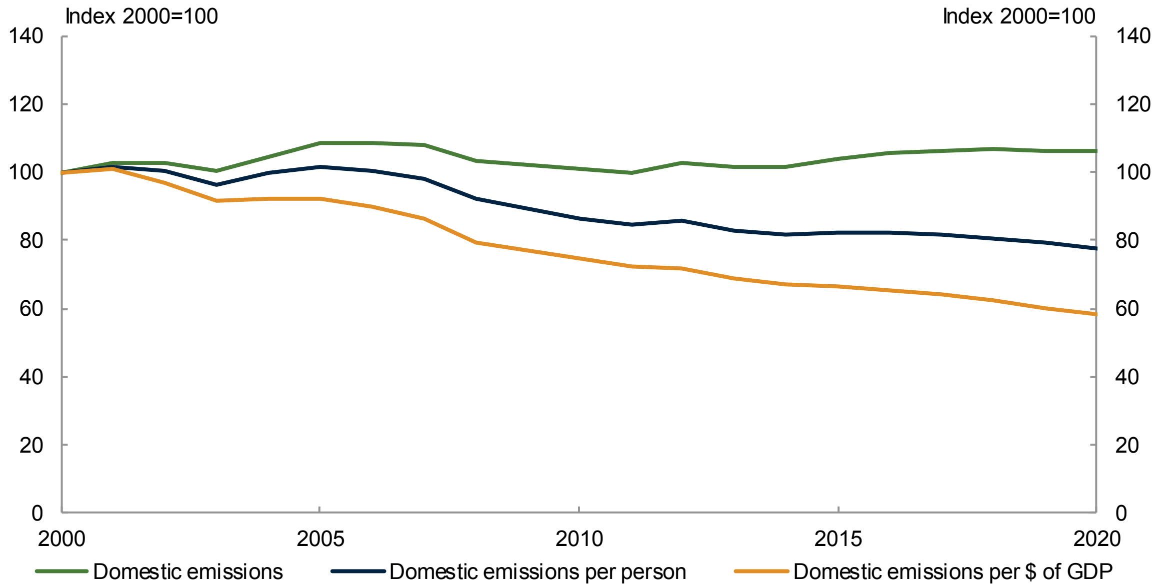
Note: Straight lines indicate alternative national trajectories to emissions reductions targets of 5, 15 and 25 per cent below 2000 levels in 2020, including adjustment for abatement through GreenPower. Dashed lines indicate Australia's annual average assigned amounts for the first commitment period (2008 to 2012) and second commitment period (2013 to 2020) under the Kyoto Protocol.
Source: National Greenhouse Gas Inventory and projections from MMRF.

Under carbon pricing, Australia is projected to meet this abatement task through a combination of domestic abatement, including the CFI, and internationally-sourced abatement from the purchase of international carbon permits. During the flexible price period, the level of Australia's net emissions (domestic emissions plus international abatement) is determined by the cap on emissions in the covered sector and the level of emissions in the uncovered sector. Emissions in the covered sector above the cap and the CFI are offset by purchasing international abatement. The modelling assumes a path for the cap on the covered sector such that Australia's net emissions match the national trajectory for net emissions

Australia's domestic emissions are projected to rise slowly from current levels in the central policy scenario. The main contributors to this rise are direct combustion of fuels and fugitive emissions from energy extraction industries—both of which reflect the very rapid growth projected for gas production and liquefaction—and agricultural activity, which is not covered by the carbon pricing mechanism. Growth in domestic emissions is projected to average 0.4 per cent per year over the period from 2012 to 2030. This is well below the rate of growth projected for the economy or population, so that emissions intensity per unit of production in the economy and per person are projected to fall steadily over the period.

The emissions intensity of the economy falls over time

Central policy scenario



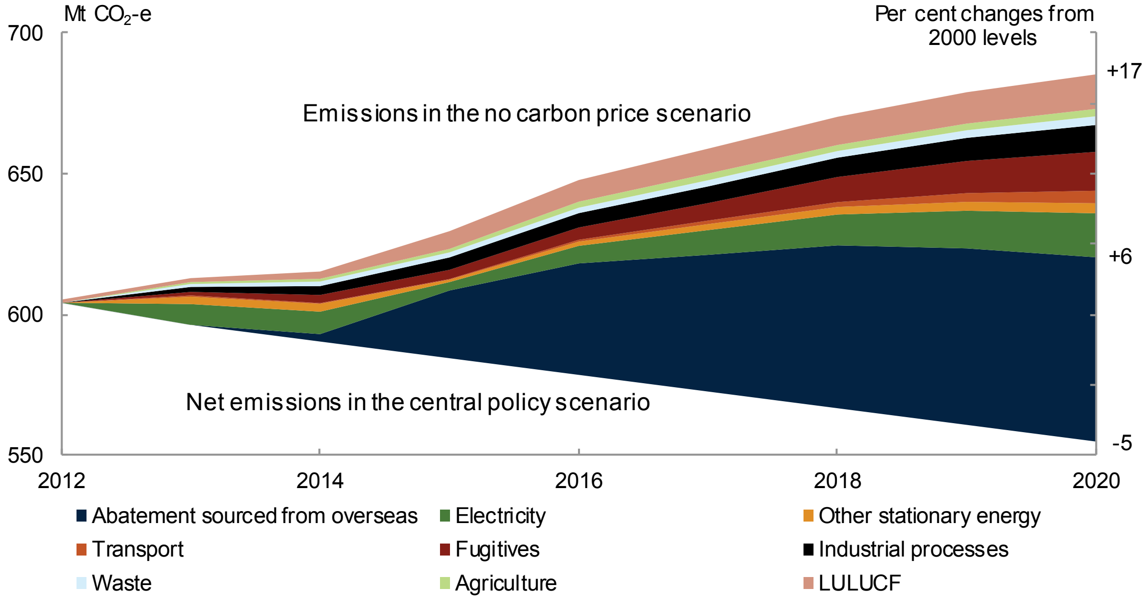
Source: Projections from MMRF.

The carbon pricing mechanism and the CFI are projected to reduce domestic emissions by 65 Mt CO_2-e in 2020 and 156 Mt CO_2-e in 2030 in the central policy scenario compared to the no carbon price scenario. Emissions reductions occur in all covered sectors of the economy by reducing the emissions intensity of production as well as by driving a structural change in the economy towards production of lower emissions-intensive goods and services. Reductions in emissions intensities are greater where mitigation costs are projected to be lower, such as for industrial process emissions, and less where mitigation costs are higher, such as for direct combustion emissions. Overall, changes in emissions intensities within industries contribute around three-quarters of cumulative domestic abatement to 2020 and two-thirds of abatement to 2030, while changes in the structure of the economy deliver the balance.

The electricity generation sector provides the largest source of domestic emissions reductions over time, delivering a quarter of domestic abatement over the period to 2020 in the central policy scenario. The reduction in emissions occurs through a switch towards lower emissions generation, including renewable sources, and slower growth in electricity demand. These changes are in addition to the effects of the Renewable Energy Target, which remains in place in the no carbon price scenario.

The coal, oil and gas fugitive sector is projected to be the second largest source of abatement, achieving around 14 Mt CO_2-e emissions reductions in 2020, while production in this sector continues to grow to meet strong export demand. The industrial processes sector is projected to contribute a proportionally large amount of abatement of around 10 Mt CO_2-e in 2020. Abatement in industrial processes is driven by reduction of synthetic greenhouse gases through gas switching and destruction, as well as the implementation of abatement technologies and process improvements.

Emissions reductions occur across all sectors



Source: Estimates from MMRF.

Direct combustion abatement of 4 Mt CO_2-e is projected in 2020 in the central scenario, growing in the longer term as new investments incorporate low-emissions technologies. The transport sector is projected to deliver about 4 Mt CO2-e of abatement in 2020, primarily from road transport due to changes in the fuel mix. Beyond 2020, abatement is projected to continue with the uptake of hybrids and electric vehicles.

Waste emissions are projected to decline in the central policy scenario, with the carbon price and the CFI together contributing to 3 Mt CO_2-e of abatement in 2020. Methane capture and waste diversion are projected to be the biggest drivers of abatement.

The CFI complements the carbon pricing mechanism by allowing farmers and land managers to earn carbon credits by storing carbon or reducing greenhouse gas emissions on the land using approved methodologies. These credits can then be sold to people and businesses wishing to offset their emissions under the carbon pricing mechanism rather than purchasing units from other sources. The CFI is projected to reduce domestic emissions by 16 Mt CO_2-e in 2020.

In agriculture, the CFI is projected to drive abatement of 3 Mt CO_2-e in 2020 primarily through reduced emissions from livestock and improved savannah fire management practices. For the land use, land-use change and forestry (LULUCF) sector, the CFI is projected to achieve 12 Mt CO_2-e of domestic abatement, with avoided deforestation and forest management practises the largest contributors.

Higher carbon prices drive greater reductions in domestic emissions. The level of the carbon price determines the extent of transformation of the industry structure of the domestic economy and the emissions intensity of production within industries. For a given emissions cap, higher carbon prices will result in a greater transformation of the domestic economy, resulting in firms sourcing less abatement overseas.

Economic effects of alternative caps

The Climate Change Authority also requested advice on the economic implications of varying scheme caps.

Tighter emissions caps drive greater reductions in net emissions, which may see firms source additional abatement overseas. Tighter caps do not lead to higher domestic carbon prices because the carbon pricing mechanism is an internationally-linked scheme.

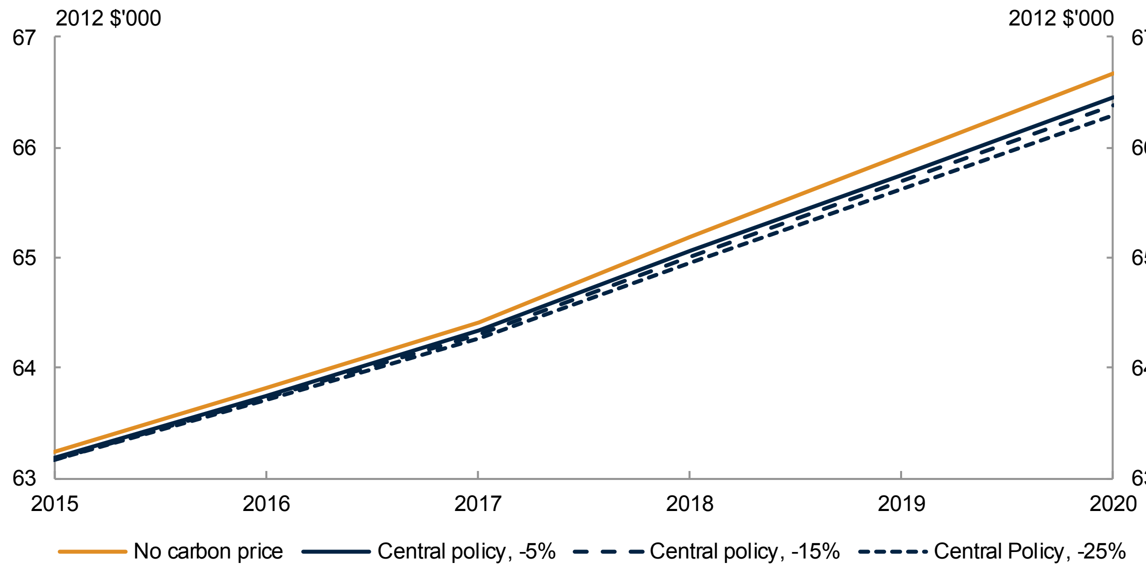
The direct economic effects of reducing the level of the scheme cap by 1 tonne CO_2-e will be to increase foreign income outflows by the carbon price (assuming tighter caps have no material impact on global prices) and reduce Australian Government revenue by the carbon price. The effects on gross national income (GNI) may be expected to be larger than the carbon price because the increase in foreign income outflows tends to lower Australia's terms of trade. Estimates from the MMRF model suggest the effect on gross national income is around 30 per cent greater than the value of the international permits purchased.

Replacing forgone carbon revenue from alternative sources will typically also carry additional welfare costs. While taxes fund public services and transfer payments to improve the wellbeing of the Australian people as a whole, they also tend to change investment, employment and consumption decisions in a way that reduces welfare. These costs have not been modelled, but previous studies suggest that the marginal cost to welfare is typically around 25 per cent of the value of revenue generated.

Taken together, the welfare cost of reducing the level of the scheme cap by 1 tonne CO_2-e and replacing the forgone revenue with other taxes is estimated to be around 1.55 times the carbon price. In all scenarios, average incomes measured by GNI per person grow over time.

Economic effects are different for alternative 2020 targets

GNI per person



Source: Estimates from MMRF.

Chapter 1: Introduction

1.1 Context for the report

This report provides a detailed illustration of the long-term outlook for greenhouse gas emissions. It contains projections for the structure of the Australian and world economies and associated emissions pathways under a range of scenarios at global, national, state, industry and detailed sectoral levels.

The report was prepared in response to a request from the Climate Change Authority (CCA) for assistance in its Caps and Targets Review. The modelling results are intended to provide input into the CCA's recommendations on the level of the greenhouse gas emissions caps for the carbon pricing mechanism, indicative national emissions trajectory, national carbon budget, and its assessment of Australia's progress towards its medium and long-term emissions reduction targets. The CCA is due to provide these recommendations to the Australian Government by 28 February 2014.

The modelling presented in the report is the outcome of collaboration between the Treasury and the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE). The updated projections build on analysis previously undertaken as part of annual emissions projections (Australian Government 2012) and modelling of the economics of climate change mitigation (Australian Government 2008, 2011). The scenarios and sensitivities were agreed by the CCA and DIICCSRTE to provide analytical inputs to both the Caps and Targets Review and emissions analysis within Government. The results in this report do not constitute official Australian Government estimates.

Emissions projections are constructed to be consistent with the accounting rules applicable to Australia during the second commitment period under the Kyoto Protocol. This includes the application of global warming potentials for greenhouse gases that are consistent with the Intergovernmental Panel on Climate Change's Fourth Assessment Report, except where otherwise indicated.

Public comments on a range of key assumptions for the electricity, fugitive, transport and agriculture sectors were invited between April and May 2013. DIICCSRTE held two consultation workshops with sectoral experts and received five public submissions on assumptions.

The report uses economic models to make long-term projections and analyse the effect of emissions reductions on the Australian economy. The emissions projections are compiled against an outlook for the Australian economy broadly consistent with the macroeconomic projections in the 2013-14 Budget—given the long lead times involved in commissioning detailed sectoral modelling, these were the most up-to-date projections available. Detailed outlooks have been drawn from a range of experts for the agriculture, mining and manufacturing sub-sectors, and updated to incorporate some of the more recent movements in commodity price projections.

1.2 Scenario design

Alternative outlooks are presented for different scenarios under which Australia and the world take action that reduces emissions so atmospheric greenhouse gas concentrations are stabilised at levels that limit the effects of climate change. It examines the impact of different carbon prices on Australia's economy in the context of different levels of global ambition.

The modelling investigates the projected economic and emissions outlook for Australia in the context of a range of uncertainties. One of the uncertainties that will affect the economic and emissions outlook is the level of the carbon price. Assumptions about the level of international ambition and the extent of international permit trading are important determinants of the level of Australia's carbon price. These assumptions also affect the prices of the goods Australia imports and exports, which has implications for energy exports in particular.

Two international action scenarios are modelled. The two international action scenarios assume the world takes action to stabilise atmospheric concentrations of greenhouse gases at levels around 550 and 450 parts per million carbon dioxide equivalent (ppm CO_2-e) in the long term.

Against this backdrop, four domestic action scenarios are modelled. Economic activity and emissions projections are presented for three scenarios with carbon pricing in Australia including the Carbon Farming Initiative (CFI), and one scenario in which there is neither carbon pricing nor the CFI.

The scope of the modelling exercise is to consider the effects of mitigation policies on sectoral emissions and the economy. The modelling does not consider the risks and impacts of climate change itself nor the benefits associated with averting climate change impacts. The effects of carbon pricing need to be considered in the context of broader benefits of mitigation action (Stern 2007; Garnaut 2008; Bollen *et al* 2009; Tol 2009; Aldy *et al* 2010; Garnaut 2011b).

1.3 Modelling framework

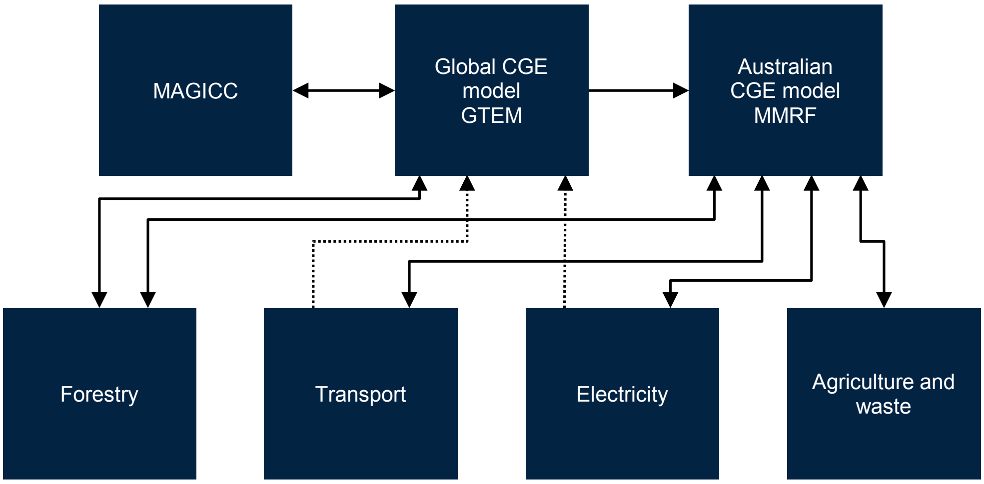
The report uses economic models to make long-term projections and analyse the effect of emissions reductions on the Australian economy. Emissions projections are produced from the modelling results using information on emissions and emissions intensities from Australia's national greenhouse gas accounts and other sources.

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 comprehensively integrate economic and other data with economic theory about how the world responds to changing circumstances.

The report uses a suite of models because no single model adequately captures the global, national, state, industry and detailed sectoral dimensions or focuses on all relevant aspects of mitigation policy in Australia.

The suite 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.

Chart 1.1: How the suite of models fits together



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

The GTEM model, developed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), is used to model the international economy and provides insights into the evolution of Australia's key trading partners (Pant 2007; Australian Government 2008, 2011). The version of GTEM used disaggregates the world into 13 geographic regions and 19 industrial sectors.

The international scenarios are designed to achieve certain long-term atmospheric greenhouse gas concentrations. The Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) is used to map emission trajectories from the international scenarios to estimated atmospheric concentrations (Raper *et al* 1996; Wigley and Raper 1992; Wigley and Raper 2001; Meinshausen *et al* 2009).

The MMRF model, developed by the Centre of Policy Studies at Monash University (Adams *et al* 2010), is used to model the Australian economy. The version of the model used includes 57 industries, as well as state and territory-level detail.

A series of sector-specific models for electricity generation, transport, agriculture, forestry and waste complement these CGE models and enrich the understanding of the economy's likely response to climate change mitigation policy. For example, the electricity sector features long-lived and discrete investment decisions and a wide variation over the course of a year in wholesale prices in response to demand conditions, which are difficult to capture accurately in a recursive CGE model.

ACIL Allen Consulting modelled the electricity generation sector. They applied their PowerMark LT model to represent generation and investment decisions at the generator level or by the unit within each generator, giving insights into the transformation of the electricity generation sector. The model incorporates a range of fuel types, including brown and black coal, natural gas and renewables (including hydro, biomass, solar, wind and geothermal), technology like carbon capture and storage, and differences between natural gas technologies.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) modelled the Australian road, air, water and rail sectors. They used their Energy Sector Model (ESM) to provide a detailed representation of choices between fuels and technologies, taking account of a range of existing policies and the time taken to turn over the transport stock (Graham and Reedman 2011; Graham *et al,* 2008).

The Centre for International Economics (CIE) modelled the agriculture sector. CIE used three models to estimate domestic agricultural production and livestock populations based on a range of domestic and international economic factors: the Global Meat Industries (GMI) CGE model; the Dairy partial equilibrium model; and the Grains partial equilibrium model.

Abatement under the CFI scheme for agriculture, forestry, land-use change and legacy waste sectors was analysed by DIICCSRTE. The abatement estimates are based broadly on a top-down approach using marginal abatement cost curves, constructed to be consistent with previous bottom-up estimates published by DIICCSRTE and combined with detail about short-term abatement. Where appropriate, expert judgement is applied that draws on observed and expected rates of CFI uptake and technical abatement potential.

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 sectoral modelling.

Reports commissioned from external consultants are available on the CCA website http://climatechangeauthority.gov.au.

1.4 Model limitations and uncertainty

Economic models allow examination of complex issues rigorously and consistently across long timeframes. Nevertheless, as approximations of the real world, they have limitations that affect the interpretation of results. These limitations include:

- The models are aggregated to different extents reflecting data and computing power limitations. For industries where firms have differing patterns of inputs and emissions intensities vary widely, this simplification reduces the accuracy of the modelling and results.
- The CGE models provide better estimates of long-term economic adjustments than short-term transition paths. The domestic modelling within MMRF represents short-term transition paths based on assumptions that capital, labour and emissions intensity improvements take time to respond to changes in the economy, and is supplemented with sectoral models and other insights from partial analysis. The international GTEM modelling, by contrast, assumes labour and capital adjust immediately across industries, and it does not capture as many of the transition costs as would be experienced in the real world.
- 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.
- The models do not capture transaction costs in reducing emissions, such as through regulating emission trading schemes.

The modelling relies upon a range of assumptions. As climate change operates over very long timeframes, quantitative analysis of carbon pricing and climate change mitigation must take a long-term view. This report provides international projections to 2050 and domestic projections to 2030. This difficult exercise requires assumptions for a wide range of economic, social and environmental variables, which can change in unpredictable ways. Some forms of uncertainty are explored by undertaking sensitivity analyses. Further details of the suite of models used and the underlying assumptions are presented in Appendix A of the report.

Chapter 2: Global projections

Global projections are presented across a range of alternative scenarios with and without international action to reduce carbon emissions. They provide international context for the domestic modelling and the assessment of detailed impacts on Australia's economy and its emissions pathway in a low-emissions world.

Different countries may achieve their carbon reduction trajectories through a range of different policies—regulation, subsidies, carbon taxes and emissions trading schemes. Furthermore, abatement costs differ across countries, reflecting their different economic structures and abatement opportunities. The modelling estimates the carbon price equivalent that would produce sufficient global abatement to achieve the stated environmental outcomes. It assumes that by 2021 there is coordinated world action with a harmonised international carbon price.

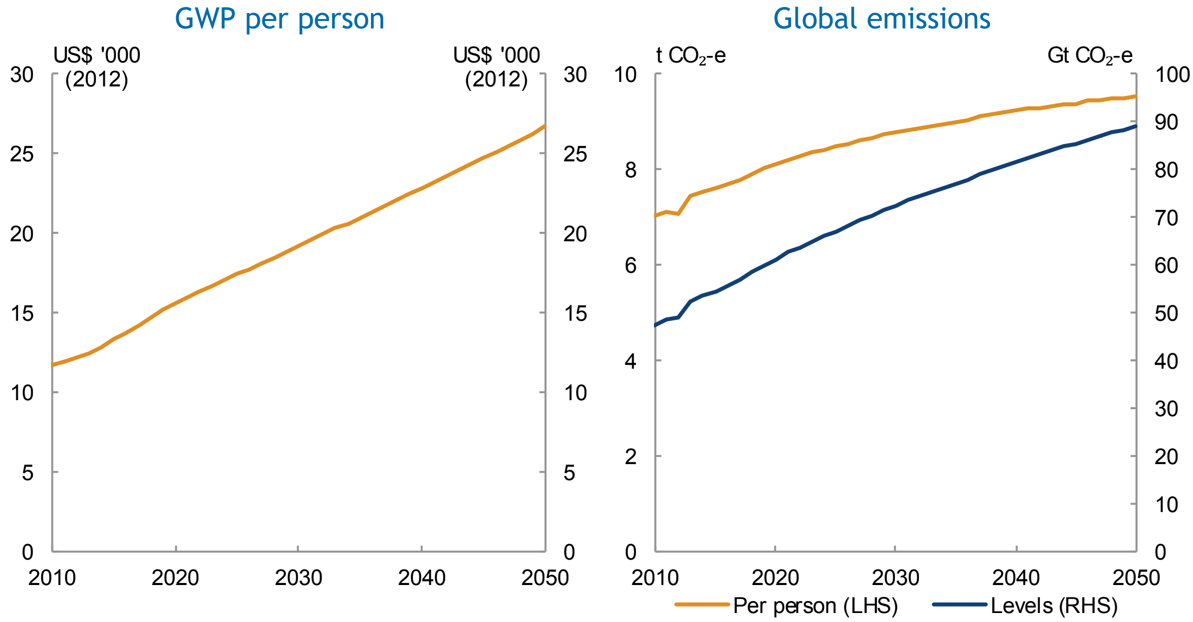
The projections show that, in those scenarios with international action, the global economy continues to grow while at the same time cutting emissions in line with stated environmental outcomes. Stronger environmental outcomes result in higher projections for international carbon prices. This produces larger effects on global economic production relative to baseline, and faster uptake of low-emissions technologies, with implications for international trade in energy commodities.

2.1 Baseline

All global scenarios are built from a baseline without mitigation action. Living standards, measured by gross world product (GWP) per person, are projected to more than double by 2050 compared to current levels in the baseline (Au-Yeung *et al* 2013) and global emissions are projected to be around 81 per cent higher in 2050 than they are now. [1]

1 All values referred to in this chapter are in 2011-12 US dollars unless otherwise stated. Comparisons to current values relate to 2012 levels.

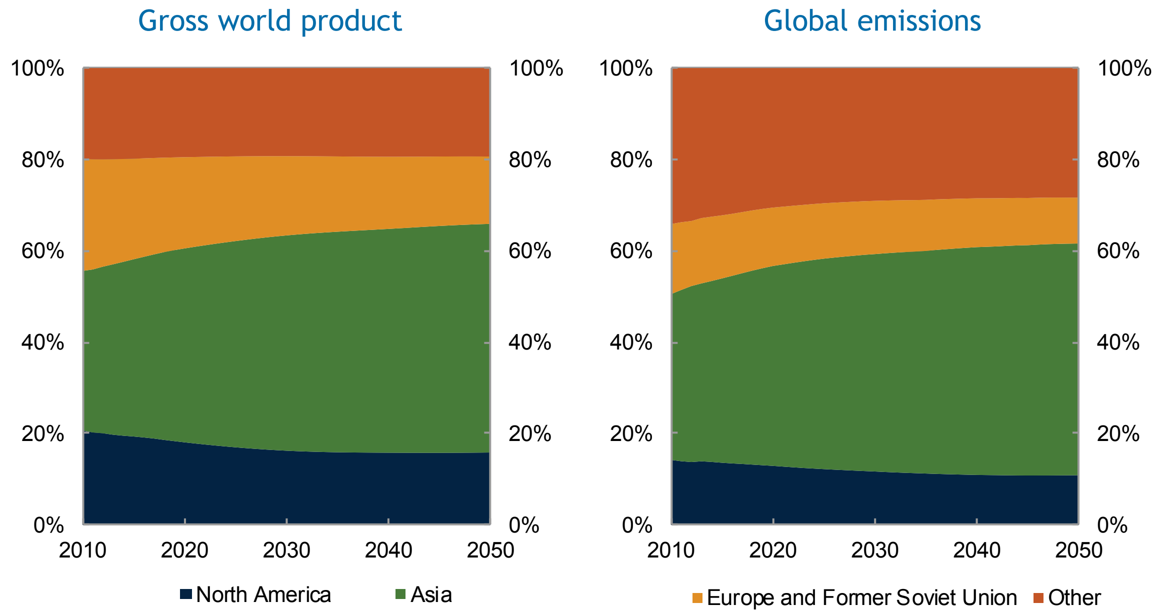
Chart 2.1: Baseline gross world product and global emissions



Note: GWP per person is based on 2005 Purchasing Power Parity (PPP) weights. Both charts show baseline values. The baseline is a scenario in which no mitigation occurs. For more information on the baseline see Appendix A.
Source: Estimates from GTEM.

The geographical structure of the global economy, as measured by regional shares of GWP, is projected to shift from developed regions to developing regions, in particular towards Asia. As a result, the share of emissions from developing regions is projected to grow.

Chart 2.2: Baseline regional shares of gross world product and global emissions

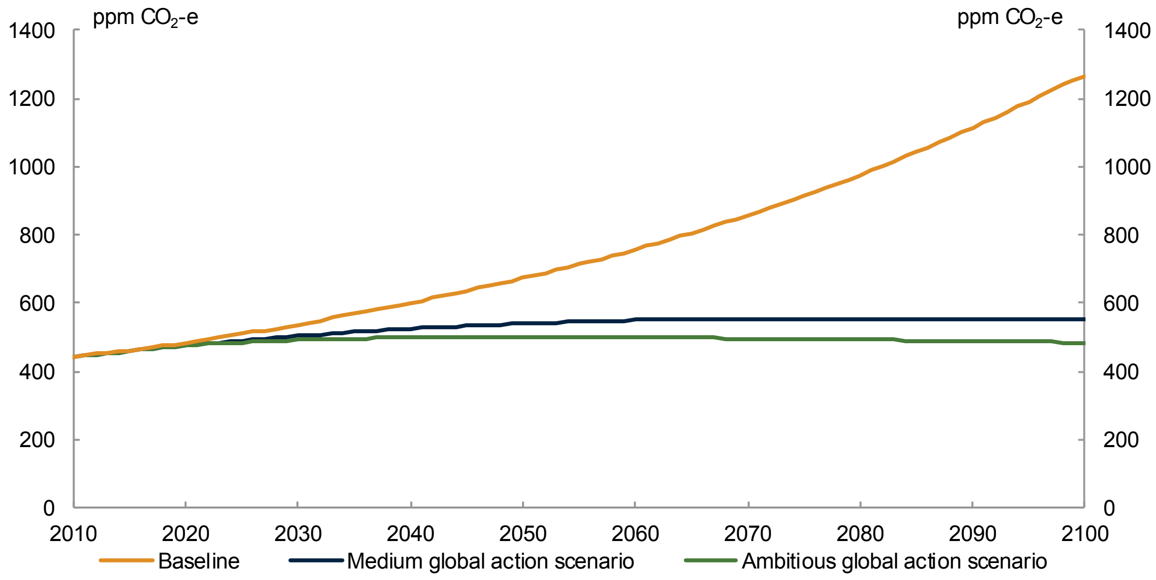


Source: Estimates from GTEM.

2.2 Global action scenarios

Two global action scenarios are modelled. The medium global action scenario projects world action to stabilise greenhouse gas concentration levels at around 550 parts per million carbon dioxide equivalent (ppm CO_2-e) by 2100. The ambitious global action scenario projects world action sufficient to limit the probability of a 2 degree Celsius temperature increase above pre-industrial levels to 50 per cent, consistent with returning concentration levels to 450ppm beyond 2100.

Chart 2.3: Atmospheric concentration pathways



Source: Estimates from GTEM and MAGICC.

International action in both global scenarios from 2013 to 2020 is modelled such that regions act either unilaterally or as a bloc to meet their pledges under the Cancun Agreement to reduce or limit emissions by 2020. During this period, regional impacts differ depending on the cost of abatement to meet these pledges and on modelling assumptions about opportunities for permit trade between regions.

- Australia and the EU meet their 2020 pledges through current announced policy (including emissions trading schemes and limited use of international units, such as Certified Emission Reduction units from the United Nations' Clean Development Mechanism).[2]
- The USA and Canada meet their targets through domestic action alone, as neither country has indicated an intention to meet their pledges through internationally-sourced abatement.
- OPEC is modelled as not acting before 2020 because only one member, which accounts for a small share of this region's total emissions, has a 2020 target.[3]
- All other regions are modelled as achieving their respective national pledges with a common carbon price.[4] Within this group, some developing countries provide permits to developed regions, as well as to the EU and Australia, which acts as a proxy for international permit trade, such as through the Clean Development Mechanism.

2 In the context of GTEM modelling EU refers to EU25: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

3 The OPEC region in GTEM includes: Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Palestine, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates, Venezuela and Yemen. Of these, only Israel has a quantifiable 2020 target.

4 These regions are: China, the former Soviet Union, Japan, India, Indonesia, Southern Africa, other South and East Asia and rest of world.

- Where countries' Cancun pledges span a range (such as Australia's pledge to reduce emissions by between 5 and 25 per cent below 2000 levels by 2020) the low-end pledge is assumed in the medium global action scenario and the high-end pledge is assumed in the ambitious global action scenario.

International action in both global scenarios is modelled for 2021 and beyond with a harmonised international carbon price. The world price follows a Hotelling path—which assumes a steady rate of growth in carbon prices over time. The price grows at 4 per cent real per year, consistent with the rate used in previous modelling (Australian Government 2008, 2011). Agriculture is assumed to be uncovered until after 2030.

Table 2.1: Summary of global action scenario assumptions

Medium global action scenario	Ambitious global action scenario
Consistent with the long-term concentration of greenhouse gases stabilising at around 550 ppm CO_2-e.	Consistent with a 50 per cent chance of limiting temperature increase to 2 degrees Celsius above pre-industrial levels and long-term concentration of greenhouse gases stabilising at around 450 ppm CO_2-e.
Incorporates the low-end pledges for 2020 emissions under the Cancun Agreement, including Australia's unconditional 5 per cent target, until 2020.	Incorporates the high-end pledges under the Cancun Agreement, including Australia's conditional 25 per cent target, until 2020.
For 2021 and beyond, there is a harmonised international carbon price and all regions are assumed to trade on the basis of targets that assume proportional action to Australia's 80 per cent emissions reduction target by 2050.	For 2021 and beyond, all regions face the same carbon price.
Used as an input to the central policy and low price scenarios in the domestic modelling.	Used as an input to the high price scenario in the domestic modelling.

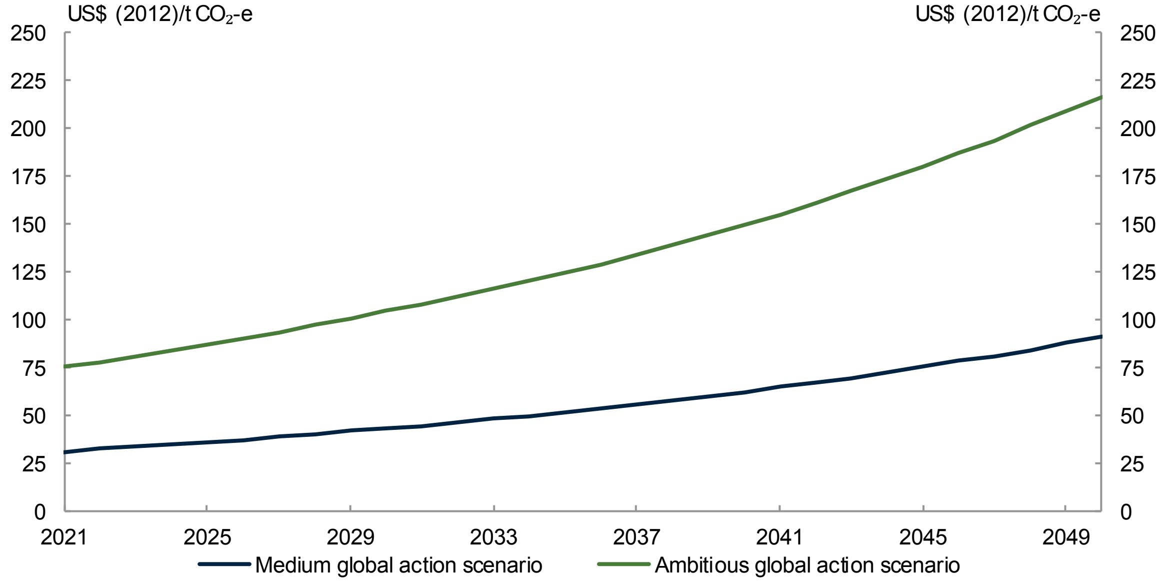
Note: Where a whole region is treated as not having a pledge (such as OPEC), the 2020 allocation is set equal to baseline emissions. Where a region includes a number of countries with 2020 pledges, regional allocations have been estimated, weighted by countries' shares of total regional emissions in 2005, with those countries in the region without pledges receiving allocations equal to baseline emissions. See Appendix A for more detail of regional allocations.

2.3 Global results

2.3.1 Carbon prices

The modelling shows that the harmonised international carbon price in 2021 for the ambitious global action scenario is more than double that of the medium global action scenario, $76 compared to $32 (measured in 2012 US dollars).

Chart 2.4: International carbon prices



Source: Estimates from GTEM.

The 2021 carbon prices are similar to previous modelling (Australian Government 2008, 2011), with the ambitious global action scenario around $2 higher, and the medium global action scenario around $4 lower (measured in 2012 US dollars). Compared to the previous modelling, lower global growth in the baseline scenario has reduced international carbon prices, while some offsetting effects result from revised global warming potentials from certain greenhouse gases. In addition, the projected international carbon prices have been affected by revisions to the scientific calculations translating annual emissions into atmospheric concentrations over time, as well as changes to the GTEM database.

Box 2.1: International carbon price projections

The projected carbon prices in the current modelling are in the range of projections published in comparable international studies, such as those by the Organisation for Economic Cooperation and Development (OECD) and the Energy Modelling Forum (EMF). Direct comparisons are not straightforward due to differences in model structures and input assumptions, such as macroeconomic and model parameter values, database vintages, and other model aggregations.

Table 2.2: Comparison of carbon price projections

	Carbon price at (US$ 2012 / tCO_2-e)		
Source	2020	2030	2050
650ppm scenarios			
IMF	17		
IEA New Policies Scenario	31	41	
550ppm scenarios			
GTEM - Medium global action scenario	30	44	91
IPCC AR4 - 535ppm to 590ppm scenarios		24 to 106	40 to 208
EMF - Full participation, overshoot scenarios	5 to 61		
IMF	34		
450ppm scenarios			
GTEM - Ambitious global action scenario	73	105	217
EMF - Full participation, overshoot scenarios	18 to 312		
OECD - 450 Core Scenario	10		341
IEA	46	98	

Note: IEA prices presented here are assumptions used in the *World Energy Outlook 2012*. GTEM prices at 2020 are 2021 prices deflated by the real rate of 4 per cent.
Source: Estimates from GTEM, de Mooij *et al* (2012), IEA (2012a), IPCC (2007d), Clarke *et al* (2009) and OECD (2012).

2.3.2 Economic growth

Under both global action scenarios, the world economy continues to grow while reducing emissions. In the medium global action scenario, GWP per person is projected to be more than double current levels by 2050, with average annual growth around 2.0 per cent to 2050 compared to 2.1 per cent in the baseline. GWP per person is also projected to be more than double current levels by 2050 in the ambitious global action scenario, with average annual growth around 1.9 per cent to 2050.

Table 2.3: Global headline indicators

	Baseline	Medium global action scenario	Ambitious global action scenario
Current levels - at 2012			
Emissions, Gt CO_2-e	47	47	47
GWP per person, US$'000/person	12.3	12.3	12.3
GHG concentration, parts per million CO_2-e[(a)]	451	450	450
Near term - at 2020			
Emissions, Gt CO_2-e	61	52	49
GWP per person, change from baseline, per cent		-0.6	-0.7
GWP per person, US$'000/person	15.6	15.5	15.5
Emissions-intensity of gross output, kg CO_2-e/US$	0.52	0.44	0.42
GHG concentration, parts per million CO_2-e	484	477	476
Medium term - at 2030			
Emissions, Gt CO_2-e	73	47	35
GWP per person, change from baseline, per cent		-2.1	-4.0
GWP per person, US$'000/person	19.2	18.8	18.5
Emissions-intensity of gross output, kg CO_2-e/US$	0.46	0.30	0.23
World emissions price, real, 2012 US$/t$CO_2$-e		44	105
GHG concentration, parts per million CO_2-e	538	504	493
Long term - at 2050			
Emissions, Gt CO_2-e	89	34	21
GWP per person, change from baseline, per cent		-3.9	-7.5
GWP per person, US$'000/person	26.7	25.6	24.7
Emissions-intensity of gross output, kg CO_2-e/US$	0.36	0.14	0.09
World emissions price, real, 2012 US$/t$CO_2$-e		91	217
GHG concentration, parts per million CO_2-e	674	541	501
GWP per person real annual average growth rate			
2012 to 2050, per cent	2.1	2.0	1.9

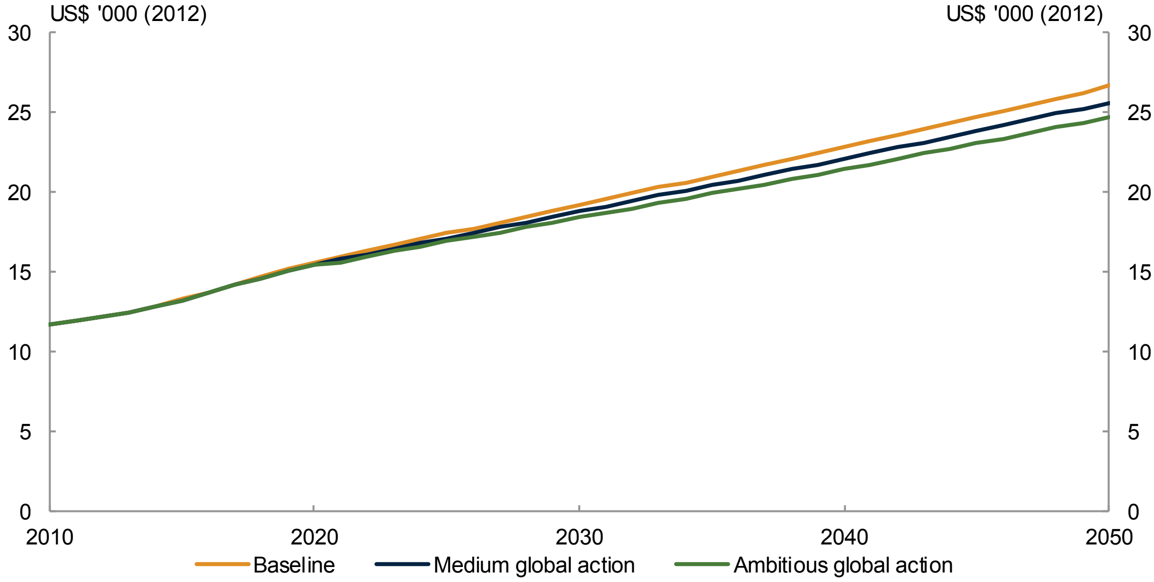
Notes: (a) The baseline concentration in 2012 is different because abatement from existing policies is removed.
GWP is based on 2005 PPP weights.
Source: Estimates from GTEM.

The broad sectoral trends in global economic activity continue while emissions are reduced. The services sector continues to comprise a growing share of the global economy, and agriculture and energy-intensive industries continue to comprise declining shares.

Carbon pricing drives a shift from the production of emissions-intensive goods towards low-emissions goods, combined with a general decline in the emissions intensity of production across all sectors.

These global results do not take into account the economic impacts of climate change itself. As a consequence, the results do not represent the net costs or benefits of action.

Chart 2.5: Gross world product per person



Note: GWP per person is based on 2005 PPP weights.
Source: Estimates from GTEM.

Table 2.4: Shares of global emissions, mitigation, population and gross world product in 2050

Per cent of global total

	Population	GWP [a]	Emissions[b]	Mitigation[c] Medium Global Action	Mitigation[c] Ambitious Global Action
United States	4	15	10	11	12
European Union (25)	5	12	6	6	6
China	15	26	34	39	35
Former Soviet Union	3	3	4	5	6
Japan	1	3	1	1	1
India	17	13	10	10	9
Canada	0	1	1	1	1
Indonesia	3	3	3	3	3
South Africa	1	1	1	1	1
Other South and East Asia	6	5	3	4	4
OPEC	4	3	5	4	5
Rest of world	40	14	21	14	15

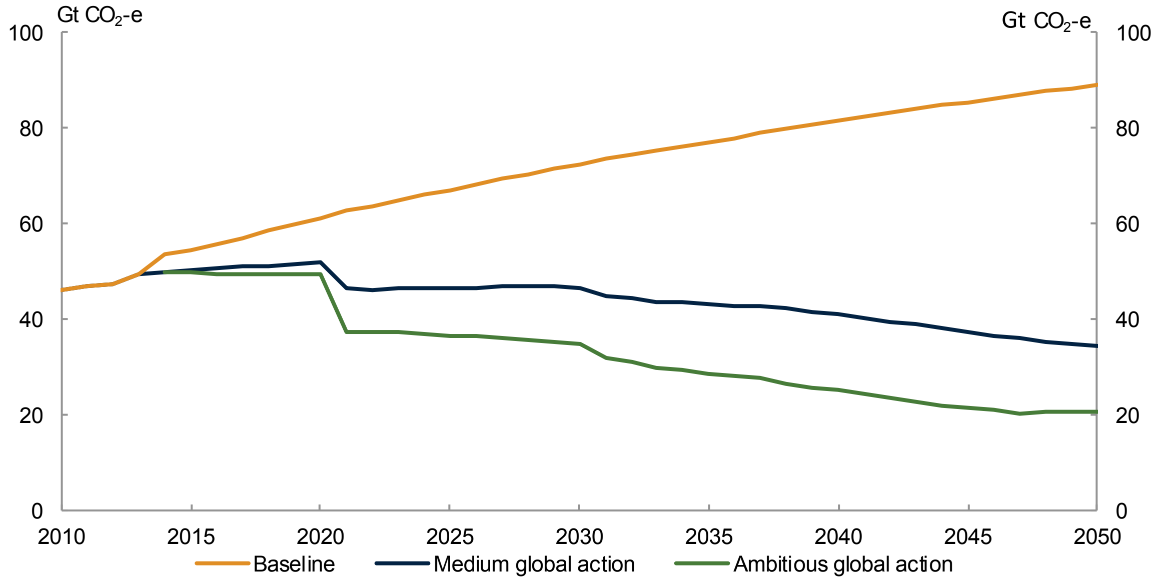
Note: (a) GWP is from the baseline. (b) Emissions are from the baseline. (c) Mitigation shares are calculated based on emissions reduction from the baseline for each region.
Source: Estimates from GTEM.

Each region's projected share of mitigation reflects its share of emissions in the baseline and the availability of low cost abatement opportunities. For example, China has relatively more low cost abatement opportunities than others, but also strong gross domestic product (GDP) growth in the baseline scenario, accompanied by increasing emissions, leading to its large share of global mitigation in both international action scenarios.

2.3.3 Emissions reductions

Various global emissions pathways can achieve a given stabilisation outcome. Alternative pathways achieve different allocations of mitigation effort over time, with implications for economic costs, intergenerational equity and flexibility in managing emissions budgets and stabilisation outcomes in light of future information. The pathways modelled here are consistent with an assumed steady rate of growth in carbon prices over time.

Chart 2.6: Global emissions



Note: The shifts reflect timing of different mitigation actions and coverage of agriculture. The shift at 2021 reflects coordinated world action with a harmonised international carbon price; and the shift in 2031 reflects the expansion of global mitigation policy to agriculture emissions.
Source: Estimates from GTEM.

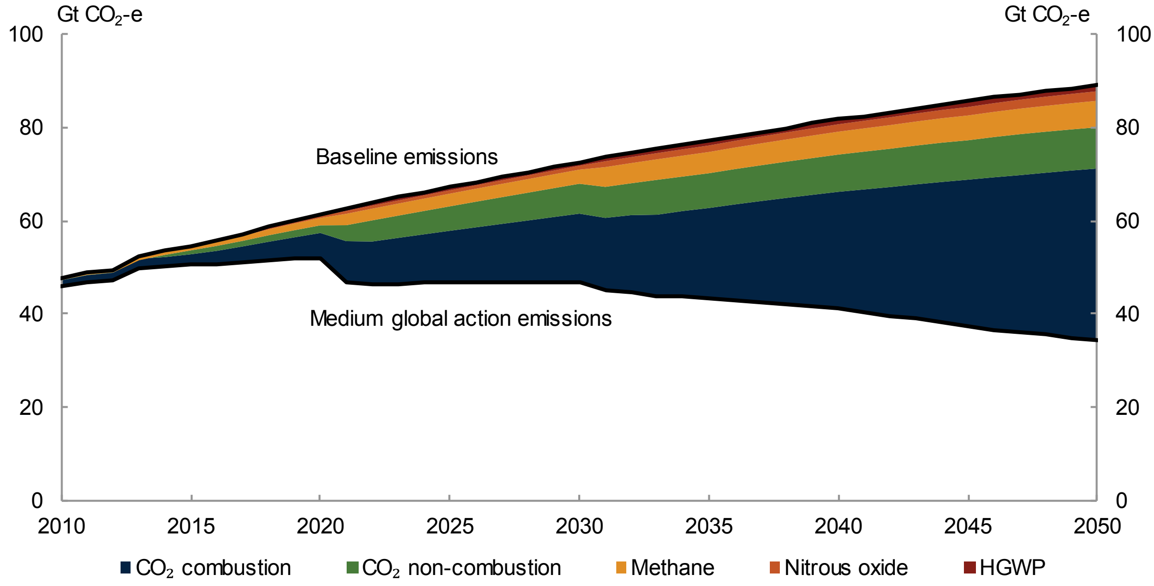
The sharp change in modelled emissions in the first year of harmonised international carbon prices reflects the design of GTEM. The model assumes capital and labour move freely between industries. When carbon is priced, emissions fall immediately as capital and labour move to less emissions-intensive industries. Electricity generators, land transport providers and producers of iron and steel can also switch to other sources of fuel and methods of production. Other firms switch to lower emissions-intensive sources of intermediate inputs. In practice, the pace of change would be more gradual, as new investments are made when capital is retired, and workers are re-trained and find jobs in other sectors. Furthermore, GTEM does not model forward-looking behaviour. Hence mitigation occurs in the model when there is a carbon price in place. In practice, mitigation actions could occur earlier and more smoothly, as forward-looking firms respond to anticipated or announced future policy.

Reducing emissions from fossil fuel combustion accounts for most of the mitigation effort to 2050. Forestry sinks across most regions also provide substantial mitigation through carbon sequestration.

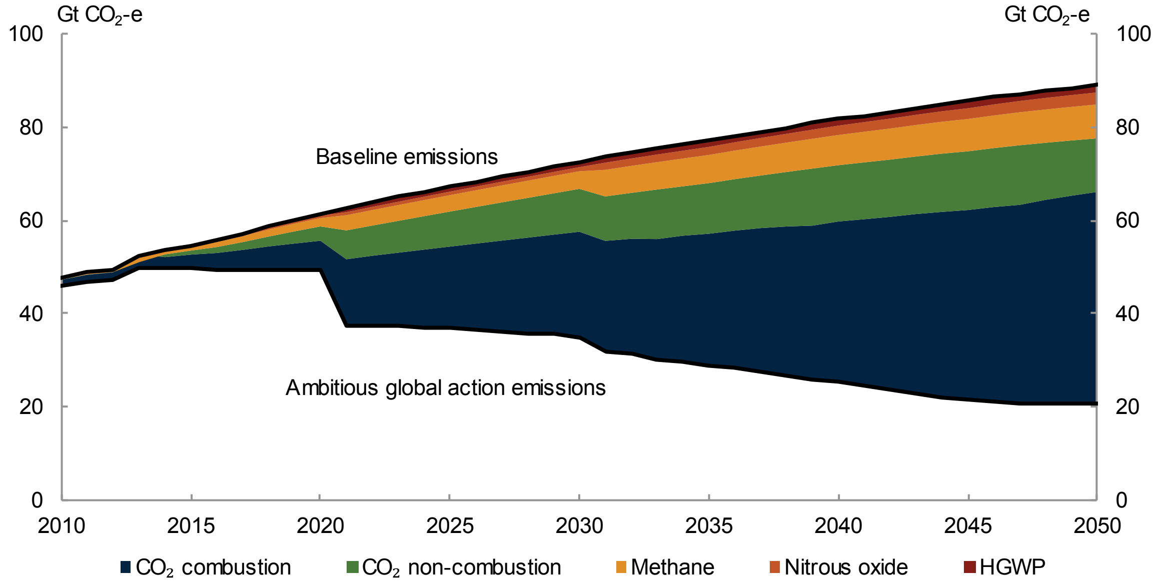
In the long term, reductions in methane and nitrous oxide emissions contribute less to global mitigation than reductions in CO_2 emissions. Agriculture—which is a major source of both methane and nitrous oxide emissions—is assumed to be uncovered until after 2030. As a share of global emissions, methane increases from 16 per cent now to between 19 and 24 per cent in 2050 and nitrous oxide increases from 6 per cent to between 10 and 14 per cent in 2050 in the medium global action and the ambitious global action scenarios, respectively. The higher shares of methane and nitrous oxide in the ambitious global action scenario reflect more cost-effective abatement opportunities for CO_2 emissions resulting from higher carbon prices. Global emissions of the other gases (sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons) are largely eliminated through changes to industrial processes by 2050, and are projected to comprise around one per cent of global emissions in both action scenarios at that time.

Chart 2.7: Global emissions reductions by gas

Medium global action scenario



Ambitious global action scenario



Note: HGWP refers to high global warming potential gases: sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons.
Source: Estimates from GTEM.

2.3.4 Sectoral analysis

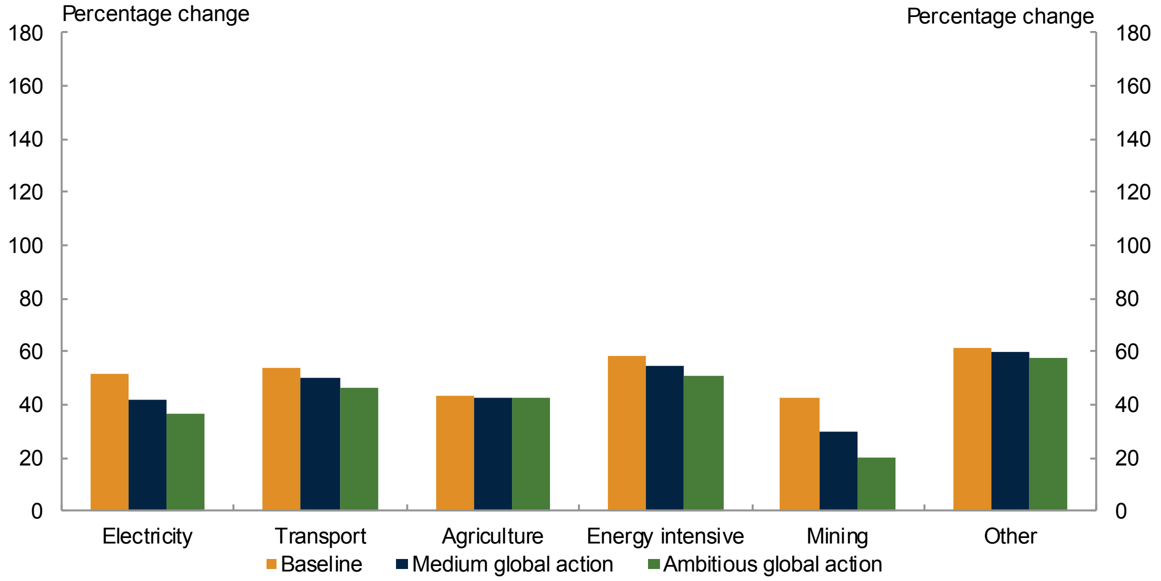
In the global action scenarios, global demand for most commodities and services continues to grow. While growth in the output of some sectors slows, most emissions reductions come from changes in production processes and adoption of low-emissions technologies.

Between the two scenarios, time profiles of growth for some emissions-intensive sectors can be very different due to the assumptions about technological options. Higher carbon prices in the ambitious global action scenario drive faster switching to low-emissions technologies in electricity and land transport, and improvements in production processes reduce activity emissions in agriculture and manufacturing. With switching to low-emissions technologies, the electricity sector grows more in the ambitious global action scenario than in the medium global action scenario to 2050. As the carbon price rises and the electricity sector reduces its emissions, it becomes cost-effective for sectors like transport and industrial processes to connect to the electricity grid rather than directly consume gas, oil and other fuels.

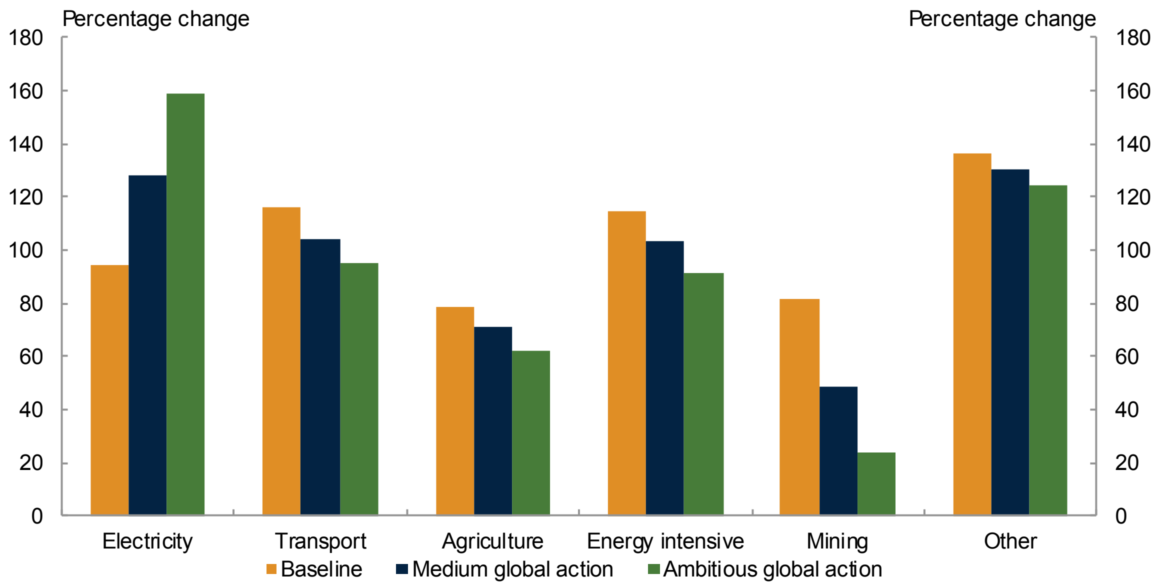
For those sectors where no technological switching options are assumed, abatement results only from the flow through of higher carbon prices to production costs, thus reducing output more in the ambitious global action scenario than in the medium global action scenario.

Chart 2.8: Changes in sectoral output from current levels

2030



2050



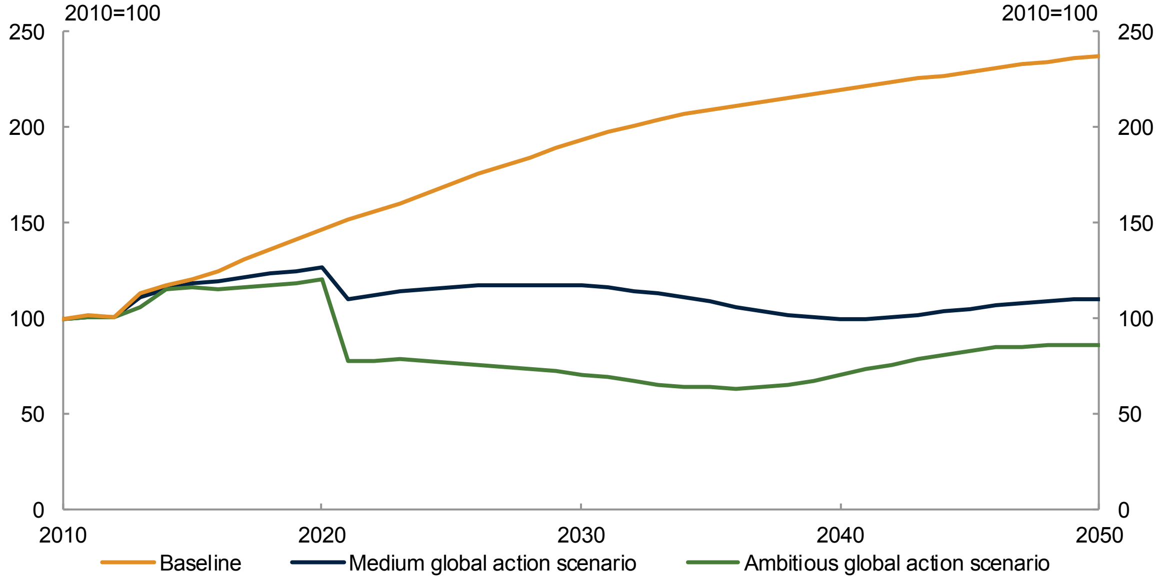
Source: Estimates from GTEM

Global demand for coal

While all broad sectors—electricity, transport, agriculture, energy intensive, mining and other—continue to grow from current levels, the effects on individual industries within these sectors vary. For coal and gas, within the broad mining sector, global production is significantly lower in the international action scenarios than in the baseline. Higher carbon prices reduce the demand for these emissions-intensive goods as consumers substitute towards lower emissions-intensive sources of energy.

The production of coal is affected more than gas, as coal is more emissions-intensive. However, as the uptake of carbon capture and storage (CCS) technology increases towards 2050, coal production stabilises. As CCS becomes available, global coal output is projected to return by 2050 to above the current level in the medium global action scenario, and to around 15 per cent below the current level in the ambitious global action scenario.

Chart 2.9: Global coal output



Source: Estimates from GTEM.

Australia's competitiveness in global trade

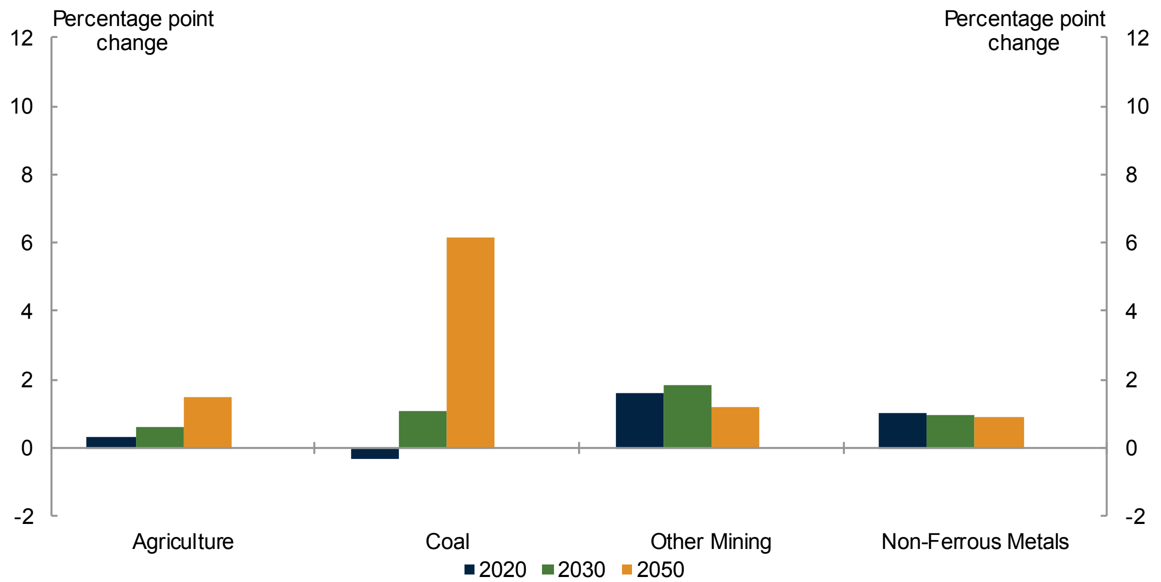
Mitigation action increases the cost of producing emissions-intensive goods throughout the world compared to the baseline. If production in a certain sector is relatively less emissions-intensive in one country than in others, its global competiveness improves which, in turn, results in a higher share of world trade.

Under global carbon pricing in 2021 and beyond, Australia's share of global trade in coal increases due to the relatively lower emissions intensity in this sector. This partially offsets the lower global demand for coal, compared to the baseline, across the board. Australia's share of global exports of all commodities in value terms increases over the simulation period.

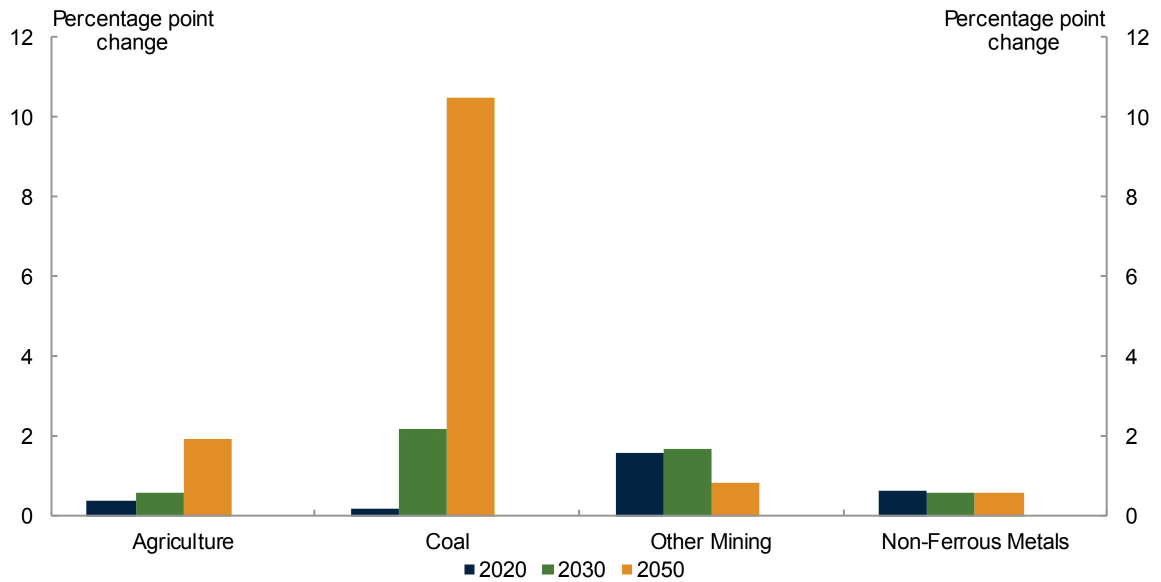
Sensitivity analysis of these results to changes in certain assumptions is included at the end of this chapter.

Chart 2.10: Australia's share of global trade for selected exports

Medium global action scenario



Ambitious global action scenario



Note: Bars show the percentage point increase from current levels in Australia's share of the global export market for each sector. The small decrease in Australia's coal export share in 2020 from its current levels in the medium global action scenario reflects relative regional impacts prior to the transition to a harmonised international carbon price in 2021. Other mining does not include oil and gas.
Source: Estimates from GTEM.

Sectoral emissions

In most economies, the majority of emissions come from energy consumption and production. Energy emissions are reduced through a range of adjustments. Consumers and producers can change their consumption and production decisions to lower the energy intensity of production in the economy. Energy production itself can transition to low-emissions sources. Technology options like drying of coal or CCS reduce emissions from fossil fuels.

In developing economies, emissions from agriculture, and land use, land-use change and forestry (LULUCF) play a relatively larger role. Low-emissions options in agriculture are less extensive than in the energy sector, but include fertiliser application methods, animal management practices and animal diets. As the agriculture sector is assumed not to be subject to emissions pricing until after 2030, there is less incentive to implement these changes, so they play a less important role in reducing emissions. Reducing deforestation and increasing reafforestation play a large role in lowering LULUCF emissions.

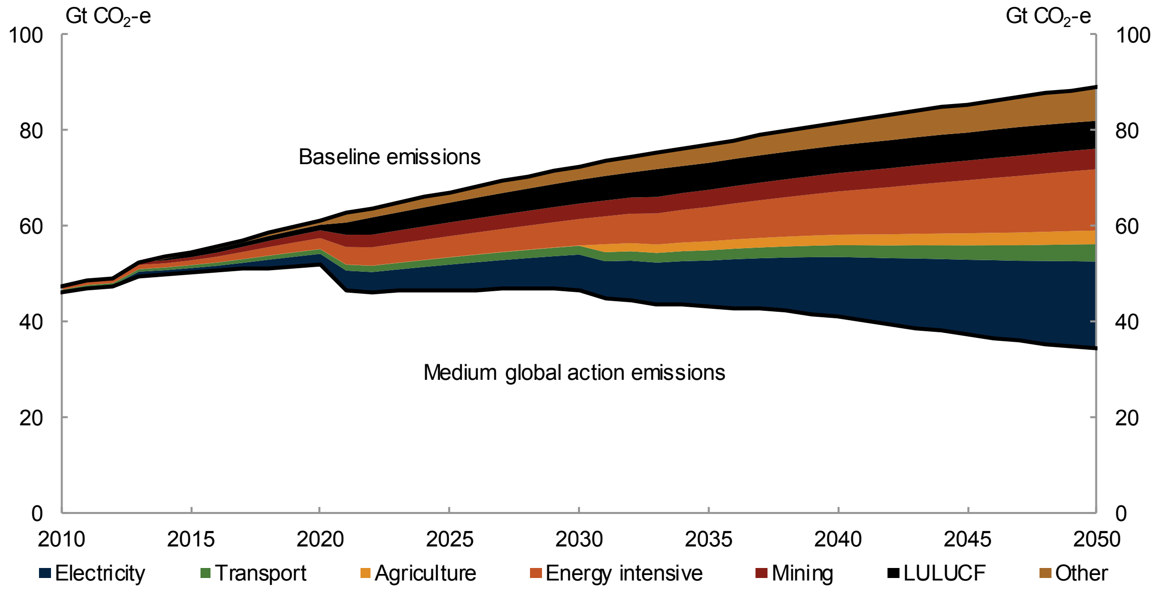
Table 2.5: Global emissions by sector
Change from baseline

	Baseline Gt CO_2-e	Medium global action scenario Per cent	Ambitious global action scenario Per cent
2020			
Electricity	16	-13	-17
Transport	6	-15	-16
Agriculture	8	0	0
Energy-intensive[(a)]	14	-16	-18
Mining	5	-31	-35
Land use, land-use change and forestry	4	-33	-71
Other[(b)]	8	-13	-16
Total	61	-15	-19
2030			
Electricity	21	-36	-58
Transport	7	-25	-35
Agriculture	9	-1	-1
Energy-intensive[(a)]	19	-29	-41
Mining	6	-56	-72
Land use, land-use change and forestry	2	-214	-300
Other[(b)]	9	-31	-46
Total	73	-35	-52
2050			
Electricity	26	-71	-86
Transport	9	-40	-59
Agriculture	10	-28	-43
Energy-intensive[(a)]	25	-52	-64
Mining	6	-73	-84
Land use, land-use change and forestry	2	-308	-380
Other[(b)]	12	-59	-72
Total	89	-61	-77

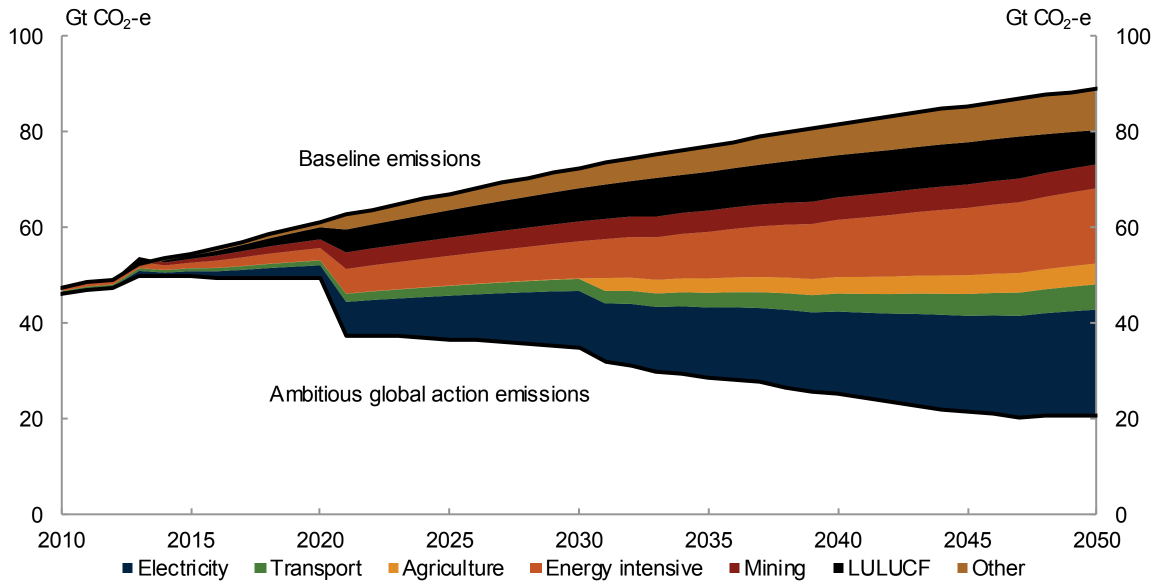
Notes: (a) Energy-intensive manufacturing includes petroleum and coal; iron and steel; non-ferrous metals; chemicals, rubbers and plastics; and non-metallic minerals. (b) Includes all other GTEM industries, excluding emissions resulting from private consumption of petroleum and coal products, which are included in the transport sector emissions.
Source: Estimates from GTEM.

Chart 2.11: Global emissions reductions by sector

Medium global action scenario



Ambitious global action scenario



Source: Estimates from GTEM.

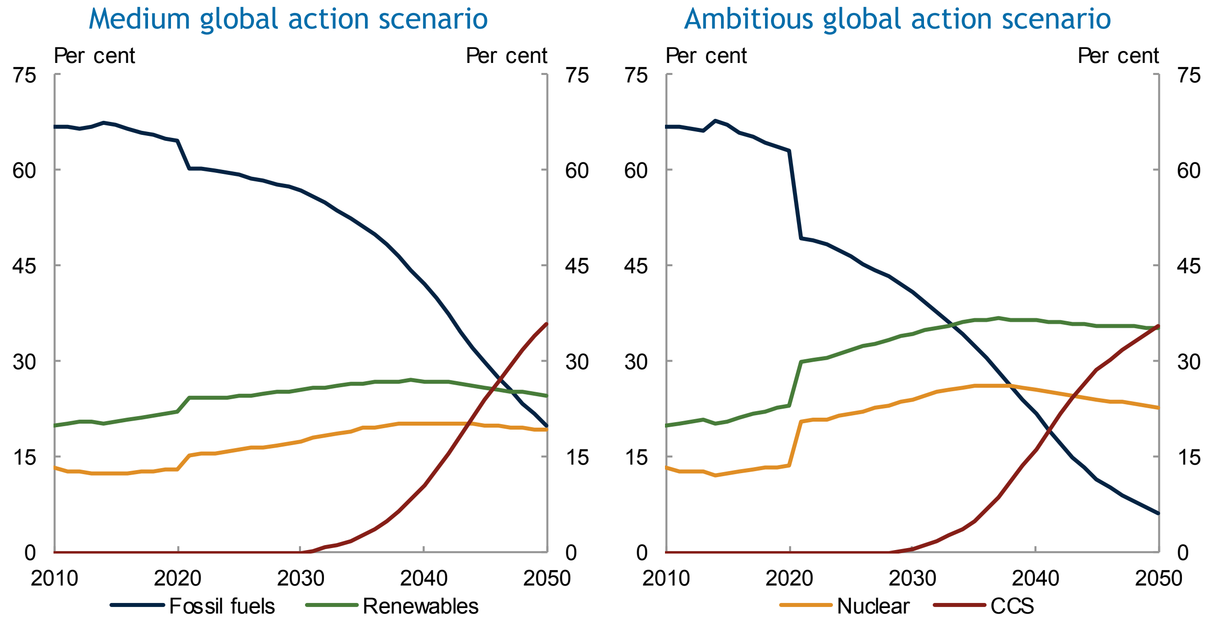
Electricity

The electricity generation sector is a major source of global emissions and it provides the largest source of abatement. At present, around 25 per cent of emissions come from electricity generation and around 62 per cent of electricity generation comes from coal and gas. Initially, pricing carbon leads to a decrease in the demand for electricity. However, as electricity decarbonises, users substitute towards electricity from other energy sources in the transport and direct combustion sectors. As a result, by 2050, electricity demand is higher than in the baseline—15 per cent higher in the medium global action scenario and 32 per cent higher in the ambitious global action scenario.

In all scenarios, fossil fuels' share of electricity generation falls consistently, with the fall more pronounced under the ambitious action scenario because of higher carbon prices. The reduction in fossil fuels is initially taken up by renewables (particularly wind, solar and nuclear power), from which there are no direct emissions.

Renewable technologies are projected to make up between 25 and 35 per cent of the global electricity sector in 2050 in the medium global action and the ambitious global action scenario, respectively, compared to only 15 per cent in the baseline. Within renewables, there is also a change in composition of the technology mix over time as the capacity limits of hydro and wind technologies are reached.

Chart 2.12: Global electricity sector technology shares



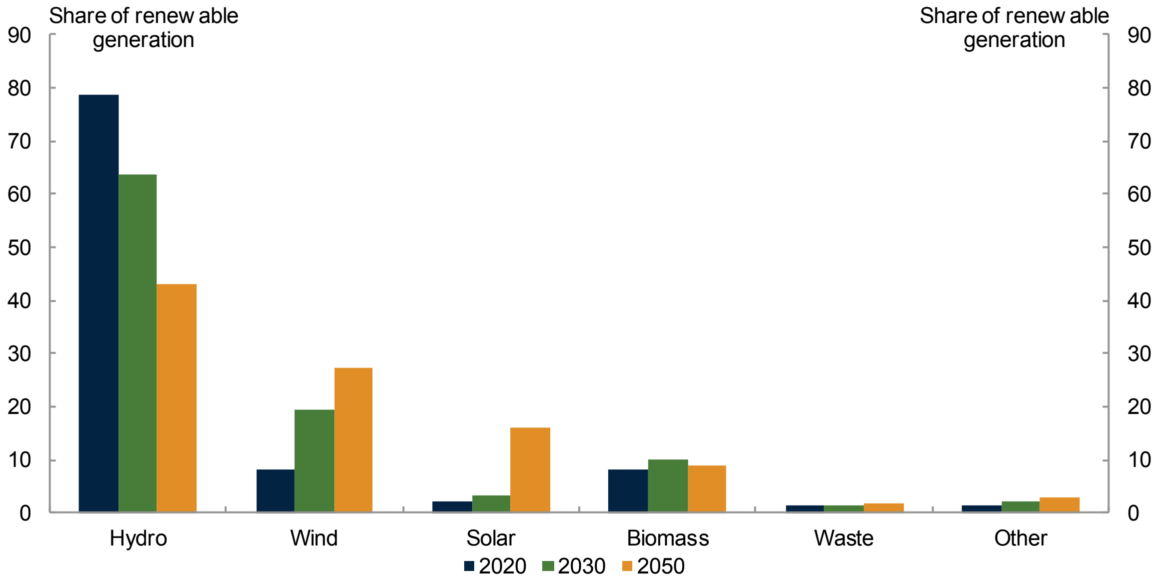
Source: Estimates from GTEM.

Renewables account for a larger share of electricity generation in the ambitious global action scenario as the abatement task is greater and higher carbon prices drive a further switch from fossil fuels.

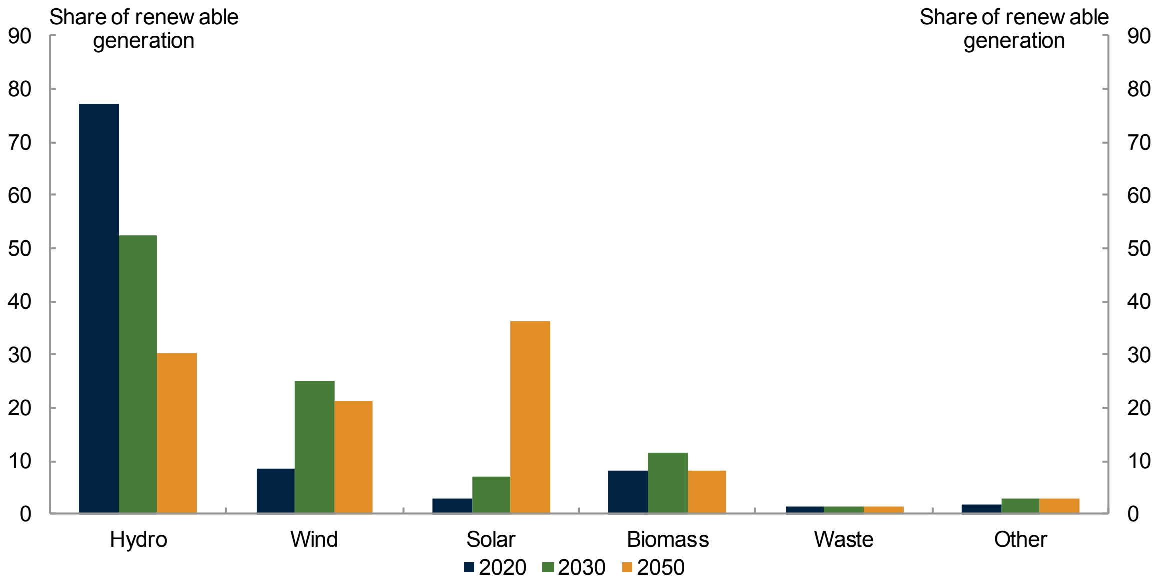
Later in the period, CCS technologies for coal and gas play a role. From 2030, the technology is deployed rapidly and makes up around 35 per cent of electricity generation in 2050 in both global action scenarios. In GTEM, CCS is assumed to provide an emissions-reduction potential from coal and gas generated electricity of up to 90 per cent. Sensitivity analysis at the end of this chapter explores the effects were CCS to prove commercially unviable.

Chart 2.13: Global renewable electricity generation shares

Medium global action scenario



Ambitious global action scenario



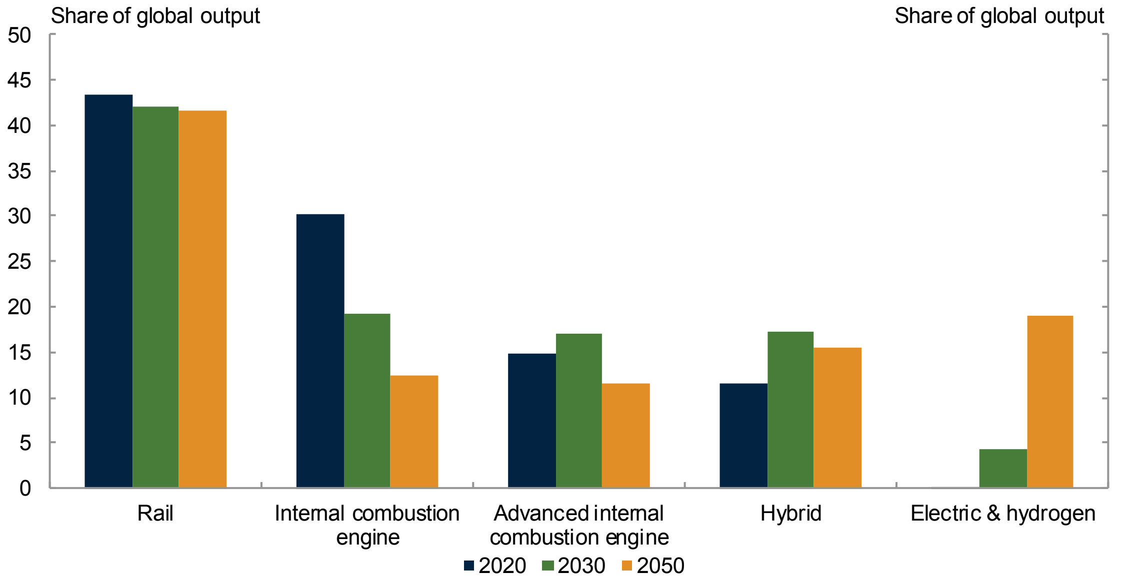
Source: Estimates from GTEM.

Transport

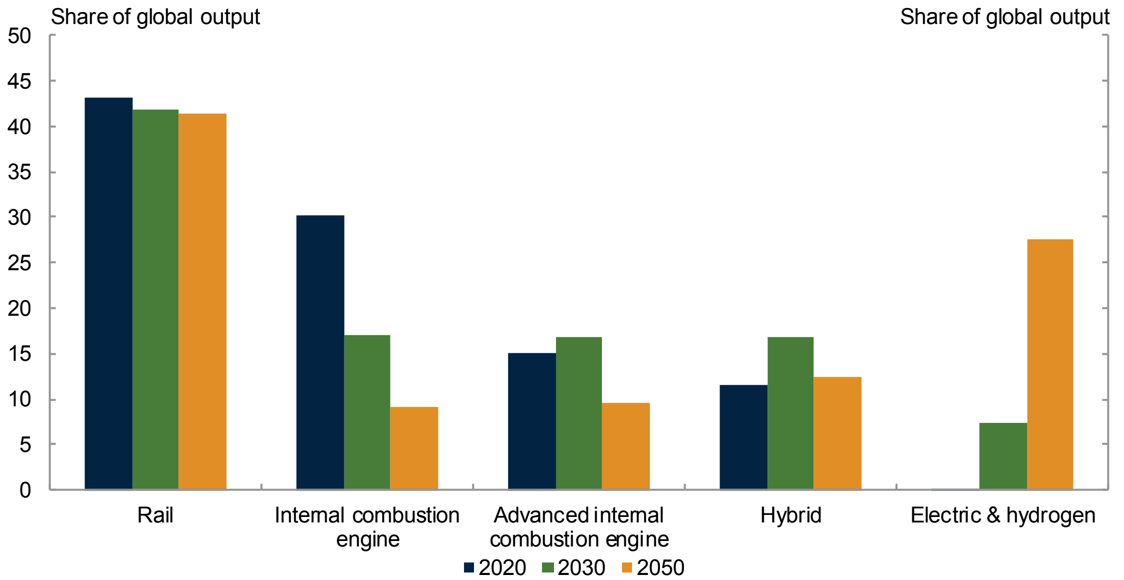
Within transport, the greatest reduction in emissions intensity is achieved in road, rail and pipeline transport. In these sectors, abatement is driven by substitution of production technologies, such as through the uptake of hybrids and electric/hydrogen vehicles. The modelling assumes there is not similar technology switching available for the water and air transport sectors and, as such, these sectors have very limited mitigation options. Consequently, the emissions from water and air transport increase over time in both action scenarios. Transport emissions as a whole decline as abatement in the land transport sectors outweighs increased emissions from the air and water transport sectors.

Chart 2.14: Global transport technology shares

Medium global action scenario



Ambitious global action scenario



Source: Estimates from GTEM.

Land use, land-use change and forestry (LULUCF)

Pricing carbon reduces deforestation rates in the action scenarios, and stimulates large-scale reafforestation. Land use, land-use change and forestry provide a cumulative net global sink of between 56 and 127 Gt CO_2-e from 2012 to 2050 in the two global action scenarios respectively, which is subtracted from the total emissions from other sectors. 'Other South and East Asia' and the USA contribute the largest forest sinks in both global action scenarios.

Other

Agriculture is assumed not to be covered by global carbon prices until after 2030 and its emissions continue to grow until that time. The emissions intensity of production improves over time, but output grows strongly as living standards in developing economies rise, and consumers shift towards emissions-intensive livestock products.

In both the resource processing and other emissions-intensive manufacturing sectors, emissions decline by around 15 per cent relative to the baseline in 2020, and by between 50 and 70 per cent in 2050 in both global action scenarios.

Sensitivity analysis

Sensitivity analysis explores the impacts of limiting access to particular technologies for electricity generation, alternative assumptions about the pace of technological change and greater ambition to limit temperature increases.

If CCS proved commercially unviable or construction of additional nuclear capacity were halted, carbon prices would need to be higher to achieve the same environmental outcome, resulting in larger reductions in GWP compared to baseline levels. The lack of one particular technological option for generation would result in greater uptake of other renewables, albeit at higher overall production cost, resulting in higher electricity prices and a lower overall level of electricity generation.

On the other hand, faster rates of 'learning-by-doing'—improvements in the productivity of labour and capital as global cumulative production grows—in the electricity and transport sectors would allow environmental outcomes to be achieved with lower carbon prices and smaller reductions in GWP compared to baseline levels. Total output of electricity and transport would increase, compared to both the medium and ambitious global action scenarios.

Table 2.6: Sensitivity analysis: gross world product in 2050

	Carbon price US$ (2012)	GWP per cent change from baseline	Major changes in electricity generation
Medium global action scenario	91	-3.9	
High learning-by-doing	82	-2.7	+21pp solar, -8pp nuclear
No new nuclear	100	-4.5	+5pp coal CCS, +3pp solar
No CCS	113	-5.5	+14pp renewables, +9pp coal, +9pp nuclear
Ambitious global action scenario	217	-7.5	
High learning-by-doing	196	-5.6	+29pp solar, -13pp nuclear
No new nuclear	233	-8.5	+7pp solar, +3pp coal CCS
No CCS	247	-9.4	+20pp renewables, +8pp nuclear

Note: All sensitivities are from simulations without trade in permits. Carbon prices are presented in 2012 US dollars. pp refers to percentage point difference. The high learning-by-doing scenario is implemented by doubling the learning-by-doing parameter.
Source: Estimates from GTEM.

Table 2.7: Sensitivity analysis: Australia's share of world exports in 2050
Change from 2012

	Coal % pt change	Other mining % pt change	Non-ferrous metals % pt change	Total exports % pt change
Medium global action scenario	5.0	1.1	0.8	0.1
High learning-by-doing	7.4	1.2	2.0	0.1
No new nuclear	4.9	1.1	0.8	0.1
No CCS	4.5	1.1	0.4	0.1
Ambitious global action scenario	10.5	0.9	0.6	0.1
High learning-by-doing	14.3	0.8	2.0	0.1
No new nuclear	11.0	0.8	0.7	0.1
No CCS	6.7	0.7	0.3	0.1

Note: All sensitivities are from simulations without trade in permits. Other mining does not include oil and gas.
Source: Estimates from GTEM.

Australia's share of global trade is affected by a mix of factors across the sensitivity scenarios. Faster rates of learning-by-doing increase Australia's export shares in mining commodities, as the world economy grows faster which, in turn, requires more material inputs to production. If CCS were not available, this would decrease Australia's export shares in mining commodities, particularly coal and non-ferrous metals, as the world economy needs to employ more expensive technologies and consequently grows slower, leading to lower demand for material inputs.

Box 2.2: Defining ambitious global action

In previous modelling, the environmental target for the ambitious global action scenario was defined as stabilising concentrations of greenhouse gases at 450ppm CO_2-e just beyond 2100 (Australian Government 2011). At that time, targeting concentrations at 450ppm just beyond 2100 using the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) provided a proxy for limiting the probability of temperature increase to less than 2 degrees Celsius above pre-industrial levels to 50 per cent.

The latest version of MAGICC (version 6) draws on updated science, and features other improvements that have allowed us to model an updated global emissions budget for the ambitious global action scenario consistent with meeting the 2 degree objective with a probability of 50 per cent. However, a scenario that increased this probability to 67 per cent, with a tighter concentration hitting 450ppm by 2100, would require a starting carbon price of around $116 in 2021, compared to $76 in the ambitious global action scenario (measured in 2012 US dollars).

This higher price would result in larger changes in the world economy. Global output of electricity would increase in the longer term, reflecting greater decarbonisation in generation. Global electricity output would be served by a higher share of renewables at the expense of fossil fuel-based generation. With standard assumptions around the availability of CCS, the higher carbon prices in this scenario mean coal-based CCS would be much lower in the later part of the simulation, while gas-based CCS would be much higher, reflecting lower emissions-intensity in gas than coal.

Compared to the ambitious global action scenario, global output of transport would decrease under the more stringent target. The global transport fleet would contain more electric and hydrogen vehicles and fewer petroleum-based ones.

Chapter 3: Australian projections

This chapter presents projections for Australian emissions and the structure of the Australian economy for a range of alternative carbon policy scenarios.[1] The emissions projections are developed and presented at a sectoral level, encompassing domestic emissions from stationary energy (including electricity generation and direct combustion), transport, fugitive emissions from fuel production, industrial processes, agriculture, waste and deforestation and reforestation. Australia's domestic emissions are defined as all emissions from within Australia, less all removals within Australia, measured and defined in accordance with the Kyoto Protocol. The choice of scenarios is designed to present a central projection and illustrate a range of alternative projections around it.

The projections present point estimates of emissions and economic outcomes under each scenario. They rely upon judgments about growth in the global and domestic economy, the implementation of policy actions, technological innovation and behavioural responses. The future course of the Australian economy in aggregate and at a sectoral level is subject to uncertainty and will be influenced by events that cannot be anticipated. These uncertainties increase over time so that emissions projections for 2030 have greater potential variation than those for 2020.

3.1 Description of scenarios

Projections are presented for three scenarios with carbon pricing in Australia, including the Carbon Farming Initiative (CFI). The policy scenarios have been developed on the basis of policies at the time of writing including: the Clean Energy Future plan announced in 2011; linking arrangements with the European Union emissions trading scheme and sub-limits on the use of Certified Emissions Reductions (CERs); and the 16 July 2013 announcement to bring forward the timing of the move to a flexible price scheme. Each policy scenario commences with a fixed nominal carbon price of $23 in 2012-13, rising to $24.15 in 2013-14 before transitioning to a flexible price cap-and-trade scheme from 1 July 2014. A summary of the scenario design is presented in Table 3.1.

The three policy scenarios are:

- Central policy scenario — Assumes a world with medium global action as described in chapter 2 and an Australian emissions target of a 5 per cent reduction on 2000 levels by 2020 and an 80 per cent reduction by 2050. After the fixed price period, the price of Australian carbon units is assumed to follow a linear transition from December 2014 EUA futures market prices through to a price of A$36/t CO_2-e in 2020 (equivalent to

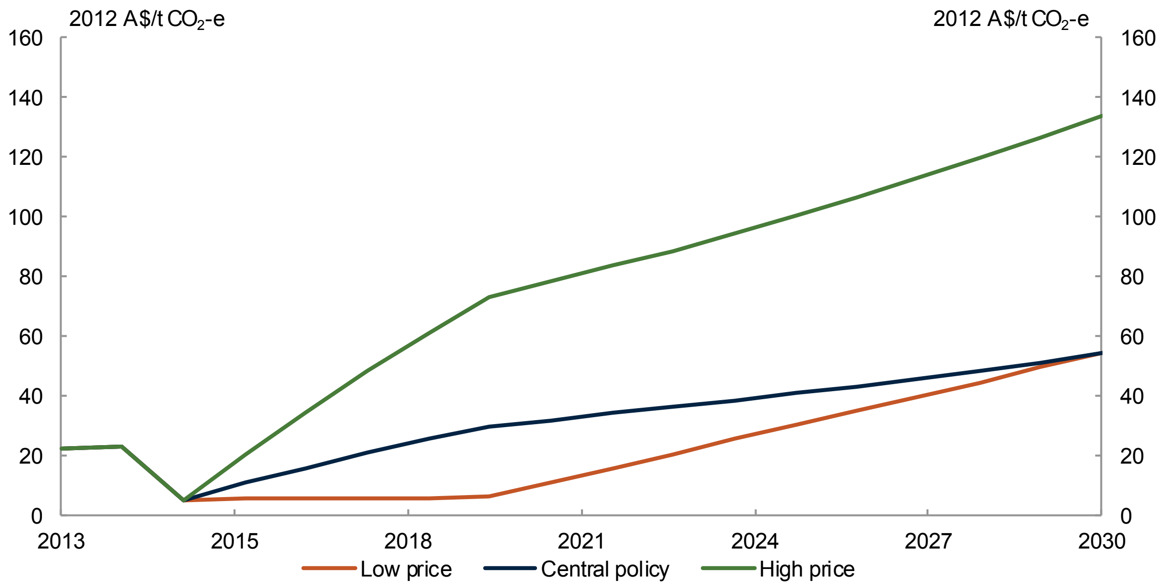
1 All years referred to in this chapter are financial years ending in that year (that is 2011-12 is 2012) and values are in 2011-12 Australian dollars unless otherwise stated. Comparisons to current values relate to 2012 levels.

2012 A$30) which is consistent with a transition to the modelled international price from 2021.

- Low price scenario — Assumes a world with medium global action and an Australian emissions target of a 5 per cent reduction on 2000 levels by 2020 and an 80 per cent reduction by 2050. After the fixed price period, the price of Australian carbon units is assumed to grow from December 2014 EUA futures market prices at a rate of 4 per cent per year plus inflation to reach A$8/t CO_2-e in 2020 (2012 A$6), before following a linear transition to the modelled international price in 2030.

- High price scenario — Assumes a world with more ambitious global action as described in chapter 2 and an Australian emissions target of a 25 per cent reduction on 2000 levels by 2020 and an 80 per cent reduction by 2050. After the fixed price period, the price of Australian carbon units is assumed to follow a linear transition from December 2014 EUA futures market prices through to a price of A$89/t CO_2-e in 2020 (2012 A$73) which is consistent with a transition to the modelled international price (described in chapter 2) from 2021.

Chart 3.1: Projected Australian carbon unit prices



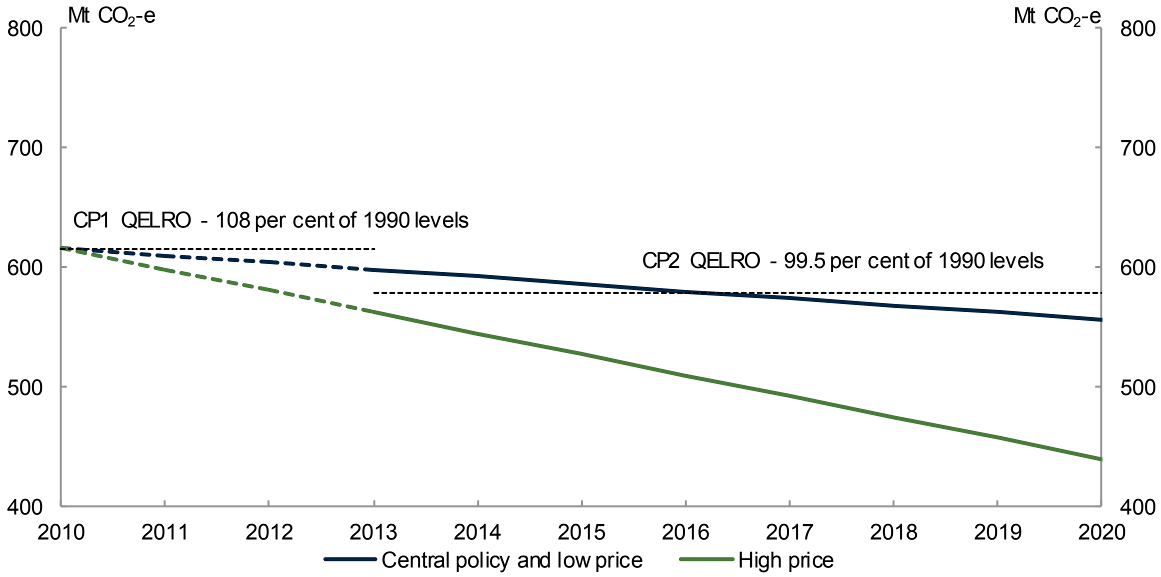
Source: Estimates from MMRF and GTEM.

From 1 July 2014, when the carbon price mechanism transitions to the flexible price period, the cap on carbon pollution in sectors covered by the carbon price (the 'scheme cap') will reduce Australia's net emissions. In the sectors covered by the carbon price, if domestic abatement falls short of the level required to meet the scheme cap, it is projected that liable entities would purchase eligible international abatement permits. This may include a combination of European Union Allowances (EUAs) and CERs validated by the United Nations Framework Convention on Climate Change (UNFCCC). While the scheme cap is yet to be determined for that period, the total number of international permits purchased by Australian entities is assumed to make up any difference between the level of domestic emissions and Australia's net emissions trajectory.

The central policy scenario assumes a national trajectory to 2020 consistent with Australia's provisional quantified emissions limitation or reduction objective (QELRO) and unconditional -5 per cent 2020 target. Australia has nominated a provisional QELRO of 99.5 per cent of 1990 levels over the eight years to 2020, equivalent to an average of 578 Mt CO_2-e per year. The trajectory is determined as a straight line from Australia's first Kyoto commitment period assigned amount of 616 Mt CO_2-e in 2010 (expressed using Fourth Assessment Report global warming potentials) to achieve the unconditional commitment of a reduction in emissions of 5 per cent below 2000 levels in 2020. The Government has committed that abatement through voluntary GreenPower purchases will be in addition to these reductions, as discussed in Appendix B. Beyond 2020, it assumes a straight-line transition to a reduction in emissions of 80 per cent on 2000 levels by 2050. The low price scenario assumes the same national trajectory as the central policy scenario.

In the high price scenario, the national trajectory assumes a straight-line pathway from Australia's first commitment period assigned amount in 2010 to a reduction in emissions of 25 per cent below 2000 levels in 2020. Beyond 2020, it assumes a straight-line transition to a reduction in emissions of 80 per cent on 2000 levels by 2050.

Chart 3.2: National emissions trajectory



Note: GreenPower abatement is not included in these trajectories.
Source: National Greenhouse Gas Inventory; UNFCCC (2009).

During the flexible price period, it is assumed that the Australian carbon unit price moves with the EUA price until 2020. Limits apply to the use of international permits within the Australian carbon pricing mechanism during this period. Liable entities may use international units to meet up to 50 per cent of carbon pricing mechanism liabilities, although the emissions profiles presented in these projections would not see this overall limit bind. Within the overall limit, usage of CER units is restricted to 6.25 per cent of liabilities in 2014-15 and 12.5 per cent of liabilities thereafter. CER units are assumed to trade at a lower price than EUAs throughout the period to 2020, based on the relative market prices in recent months. As these limits scale with liable entities' emissions, the effective marginal carbon price faced by domestic firms is taken to be a weighted average of the Australian carbon unit price and the CER unit price over the period to 2020, with weights reflecting the CER sub-limit.

The scenario design ignores the potential to carry over a bank of units across years. The modelling does not assume that Australia's surplus from the first commitment period of the Kyoto protocol is available for use during the flexible price period. Internationally-sourced abatement is assumed to be used only to the extent needed to meet Australia's emissions trajectory year by year.

A 'no carbon price' scenario, in which there is neither carbon pricing nor the CFI, is also presented. This scenario includes abatement from pre-existing measures such as energy efficiency measures and the Renewable Energy Target (RET).

Table 3.1: Domestic policy scenario assumptions

	Central and low price scenarios	High price scenario
Global action	Medium global action consistent with long-term stabilisation of atmospheric concentrations of greenhouse gases at 550 ppm CO_2-e.	Ambitious global action consistent with a 50 per cent chance of limiting temperature increase to 2 degrees Celsius above pre-industrial levels and long-term stabilisation of atmospheric concentrations of greenhouse gases at 450 ppm CO_2-e .
Australian emissions 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.
Trajectory	Set as a straight line from the mid-point of Australia's first commitment period QELRO to a target of 5 per cent below 2000 levels in 2020, consistent with Australia's second commitment period QELRO; and from 2020 as a straight line to a 2050 target of 80 per cent below 2000 levels.	Set as a straight line from the mid-point of Australia's first commitment period QELRO to a target of 25 per cent below 2000 levels in 2020; and from 2020 as a straight line to a 2050 target of 80 per cent below 2000 levels.
International linking	No international linking during the fixed price period. Linkage to the EU ETS (initially as a one-way link) from 2015 to 2020 with quantitative restrictions to ensure liable parties meet at least 50 per cent of their annual liability from domestic permits and credits until 2020, and no more than 6.25 per cent through CERs in 2015 and 12.5 per cent in other years. Transition to a common international price from 2021.	
Coverage	All emissions sources are covered directly by the carbon price or indirectly through an equivalent price, except: * activity emissions from agriculture; * combustion emissions from agriculture, forestry and fishing; * on-road combustion of liquid fuels by light vehicles and gaseous fuels; * on-road combustion of liquid fuels by heavy vehicles in 2012-13 and 2013-14; * decommissioned mines; * land use, land-use change and forestry; * legacy waste; * synthetic gases imported prior to the introduction of carbon pricing; and * emissions from facilities below the coverage threshold (generally 25 kt CO_2-e). Emissions reductions in land use, land-use change and forestry, legacy waste and agriculture are eligible for CFI credits.	
Emissions-intensive trade-exposed activities	Assistance to activities starts at 94.5 per cent or 66 per cent of historical emissions intensity baselines, declining at an annual rate of 1.3 per cent per year before being assumed to phase out in five steps beginning in 2022. LNG facilities receive assistance of a minimum 50 per cent of emissions. The steel industry receives a 10 per cent increase in permit allocations from 2016-17.	
Fuel	An equivalent 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.	
Use of permit revenue	Net scheme revenue is allocated to households as lump sum payments.	

3.2 Economic growth in the central policy scenario

A detailed outlook for the composition and volume of production in the Australian economy was modelled as a backdrop to the emissions projections. The economic projections are designed to allow construction of emissions series and the focus of the analysis is on detailed projections by third parties for the emissions-intensive industries within the agriculture, mining, manufacturing, transport and electricity sectors. A snapshot is presented based on the data available while it was being prepared (Box 3.1 discusses recent changes to economic parameters).

Box 3.1: Recent changes in the economic outlook

The projections provide a snapshot consistent with the macroeconomic parameters in the 2013-14 Budget. A number of projection parameters changed between the Budget published in May 2013 and the Pre-Election Economic and Fiscal Outlook published in August 2013. These include a downward revision of real GDP growth forecasts by ¼ percentage point in 2013-14, a downward revision to the terms-of-trade forecasts on the back of weaker Chinese growth to a level around 10 per cent lower in 2014-15 than previously forecast, and an exchange rate assumption of 91 US cents down from 103 US cents at the time of the Budget.

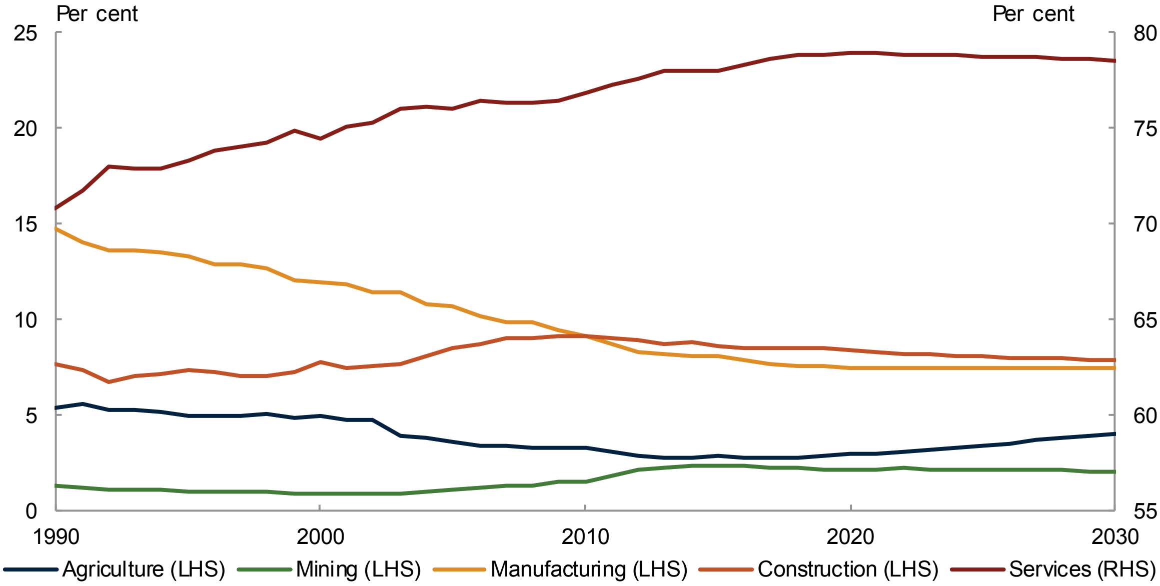
Given the long lead times in commissioning detailed modelling of the electricity generation, transport, agriculture and other sectors, it was necessary to settle on the broad macroeconomic parameters early in the process. Sensitivity analysis suggests that a reduction in the terms of trade of 10 per cent will tend to add 3 to 5 per cent to employment, investment and output levels (relative to baseline) in manufacturing and agriculture sectors as a whole, consistent with previously published analysis (McKissack et al 2008; Swift 2006), and will tend to increase the overall level of emissions in the economy. Output projections for the emissions-intensive manufacturing and agriculture sectors included in this report have been adjusted to accommodate the changed forecasts for the terms of trade.

The central policy scenario shows continued economic growth, with real GDP projected to grow by around one-third over the decade to 2020 and a further one-third over the decade to 2030. As the population grows and the economy expands, employment increases, by around 1.5 million people over the period to 2020 and a further 1.7 million over the decade to 2030.

The central policy scenario is also a story of ongoing structural transformation driven by demographic change, movements in the terms of trade, competition from producers in other countries and uneven productivity growth across industries. Near-term rates of productivity growth are based on historical patterns for each industry. Consumer preferences are projected to continue their historical trend changes. As discussed in section 3.6, carbon pricing has little effect on this process of structural transformation at the level of broad industry sectors.

Growth across sectors varies; the strongest percentage growth is in mining and related industries over the coming decade, due to the high level of investment in recent years and committed investment in coming years. Of particular note is the rapid expansion of the volume of gas production, particularly for liquefaction and export. The modelling assumes rising international gas prices and convergence of east coast domestic prices towards parity with international prices, net of export costs associated with liquefaction and transport. Production of coal and iron ore also continues to rise, with the strong investment of recent years boosting production and export growth in years to come.

Chart 3.3: Industry shares of employment, 1990 to 2030
Central policy scenario



Source: ABS; projections from MMRF.

The ongoing growth in the mining sector maintains pressure on other trade-exposed sectors. The period of very strong commodity prices in recent years contributed to a sustained high exchange rate, reducing the competitiveness of other trade-exposed industries, such as manufacturing. The expansion of investment and production in resource projects has also drawn capital and labour to the mining sector, where the rate of return has been higher. Over time, prices of some resource commodities are projected to decline as more supply comes on line, and the exchange rate falls, assisting those other trade-exposed industries.

The high commodity prices have accelerated the relative decline in the size of the manufacturing sector as a share of the economy in recent years, a process that has been underway since the middle of the twentieth century. Output in the manufacturing sector as a whole is projected to remain fairly flat over the period to 2020, with continued growth in areas like food manufacturing offsetting declines in sectors like aluminium smelting and petroleum refining. Manufacturing output returns to growth in the following decade, albeit at a slower pace than the economy as a whole.

The level of agricultural production and exports has also been affected by the high exchange rate over recent years and the near-term outlook is for moderate growth rates. With the improvement in seasonal conditions since 2010, farmers have rebuilt their flocks and herds to a level projected to stabilise in the short term. After 2020, herd levels are projected to continue to increase, as rising international demand and improved competitiveness from a declining real exchange rate expands production across all major agricultural commodities.

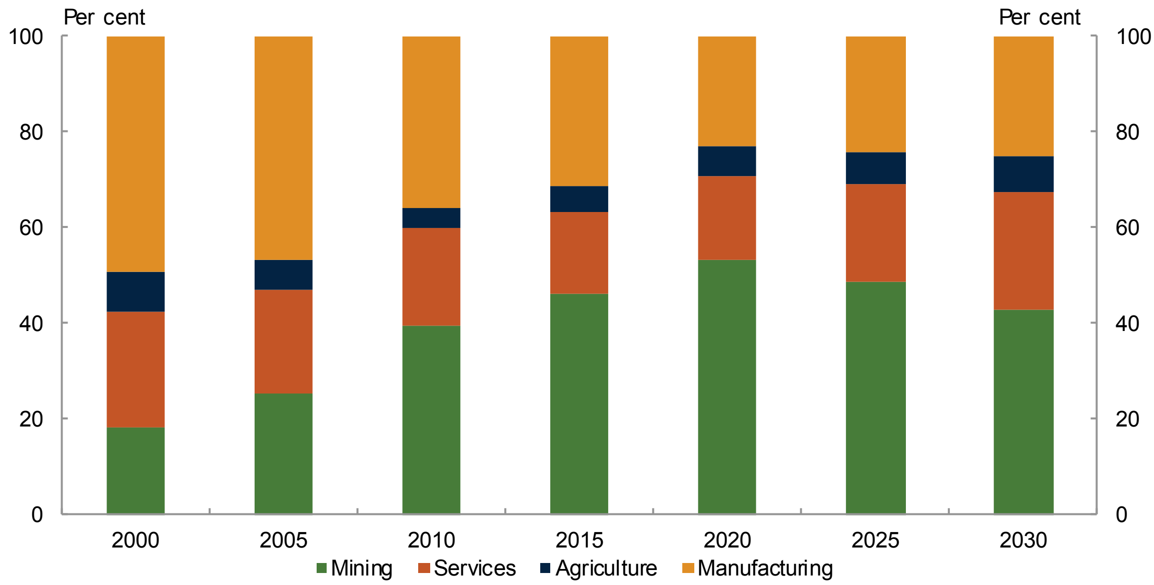
Australia's services sector, which is currently around two-thirds of the economy, expands to meet growing domestic and international demand. The sector, which includes education, tourism, business services, utilities, transport, retail and wholesale trade, continues to grow slightly faster than the economy overall.

Construction output continues to grow, but at a slower rate than in recent years as the peak in mining investment passes. The construction share of the economy declines over time from its recent high level.

Closer engagement and integration with the rapidly growing Asian economies continues to influence the volume and composition of Australian trade. Over the past decade, the most pronounced effect has been through stronger demand for Australia's mineral and energy resources. With the share of mining in Australia's exports projected to peak towards the end of the current decade, the burgeoning Asian middle class will generate growing demand for a wide range of Australian products, including higher-value foods, education, professional services and tourism.

Chart 3.4: Export shares by industry

Central policy scenario



Source: ABS; projections from MMRF.

Another key economic trend pertinent to the emissions outlook is the projection for electricity consumption. It is projected to grow throughout the entire projection period. This follows an unusual period of falling electricity consumption in the National Electricity Market (NEM), by 3 per cent over the three years to 2012. The drivers contributing to this historical reduction in energy demand include: electricity network and transmission costs feeding through to retail price increases; below-trend GDP growth for most of the period; slower growth in the energy-intensive industrial sectors of the economy; and more rapid installation of small-scale solar photovoltaic systems.

In the projections, expansion of the liquefied natural gas (LNG) industry in Queensland contributes strongly to near-term growth in electricity demand. Longer-term growth in electricity demand is driven by population and economic growth, which in turn drive growth in residential and commercial demand, while demand from heavy manufacturing stabilises.

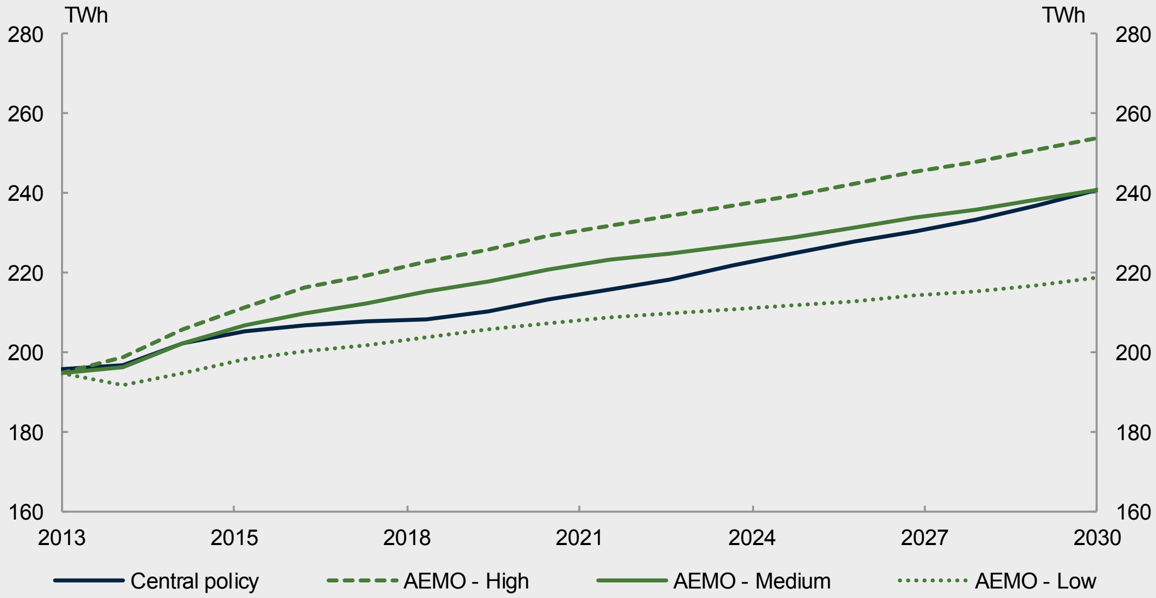
Box 3.2: Electricity demand in the NEM

The aggregate electricity demand figures in this chapter incorporate projections for the National Electricity Market (NEM), which represents around 85 per cent of total generation, as well as the South West Interconnected System, North West Interconnected System, Darwin-Katherine Interconnected System, off-grid generation, solar photovoltaic (PV) and small non-scheduled generation.

The Australian Energy Market Operator (AEMO) also publishes annual projections of generation in the NEM, as well as high and low sensitivity analyses, which can be compared with the NEM component of the aggregate electricity demand figures in this chapter.

The central policy scenario projections presented in this chapter are broadly in the middle of the high and low series published by AEMO. Compared to AEMO's medium projection, the main difference in the period to 2020 is the central policy scenario projections assume somewhat slower growth in industrial demand than AEMO's, with electricity-intensive industries such as aluminium reducing demand. This compares with relatively flat industrial demand in AEMO's medium scenario in all states except Queensland, where LNG production adds to demand. In the longer term, the central policy scenario projections converge towards the AEMO medium projection due to more rapid growth in residential and commercial electricity demand, partly reflecting more conservative assumptions in the current report around energy efficiency improvements.

Chart 3.5: NEM electricity generation sent out



Note: AEMO series are the sum of native energy (sent out basis), solar PV and small non-scheduled generation. Differences in coverage result in small differences in the starting level.
Source: Estimates from MMRF and AEMO (2013).

3.3 Australia's abatement task and net emissions

Australia has committed to unconditionally reducing emissions in 2020 by at least 5 per cent below 2000 levels. To meet the unconditional -5 per cent target, the projected abatement task is a cut of 131 Mt CO_2-e in 2020 compared to the no carbon price scenario.

Australia is projected to meet this abatement task through a combination of domestic abatement—including reductions from levels without carbon pricing or the CFI—and abatement sourced overseas through the purchase of international carbon permits. Abatement is more expensive in Australia than in many economies due to relatively cheap access to fossil fuels. The modelling assumes some abatement is sourced overseas so that Australia's net emissions match the national trajectory.

In the central policy scenario, half of the abatement challenge is met through the reduction in domestic emissions in 2020 and half through abatement sourced overseas. In the low carbon price scenario, a smaller share of the abatement challenge is met through reductions in domestic emissions and a larger share through abatement sourced overseas.

In the high price scenario, domestic abatement is more than twice as large in 2020 and 2030 as in the central policy scenario. However, the abatement task is also larger because the trajectory is assumed to decline faster, and internationally-sourced abatement continues to play a role.

Chart 3.6: Australia's net emissions and sources of abatement
Central policy scenario

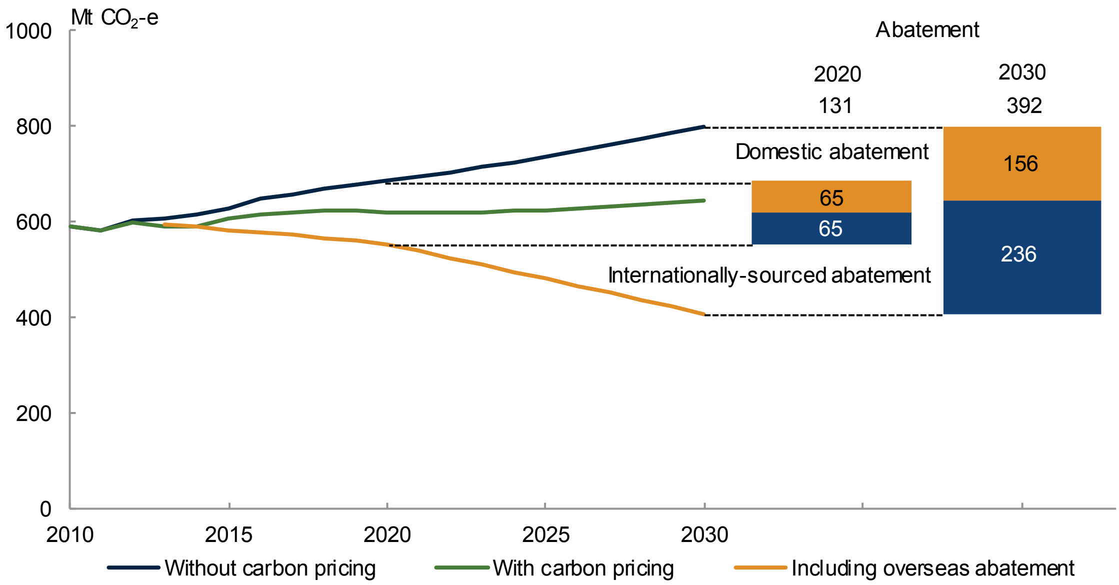
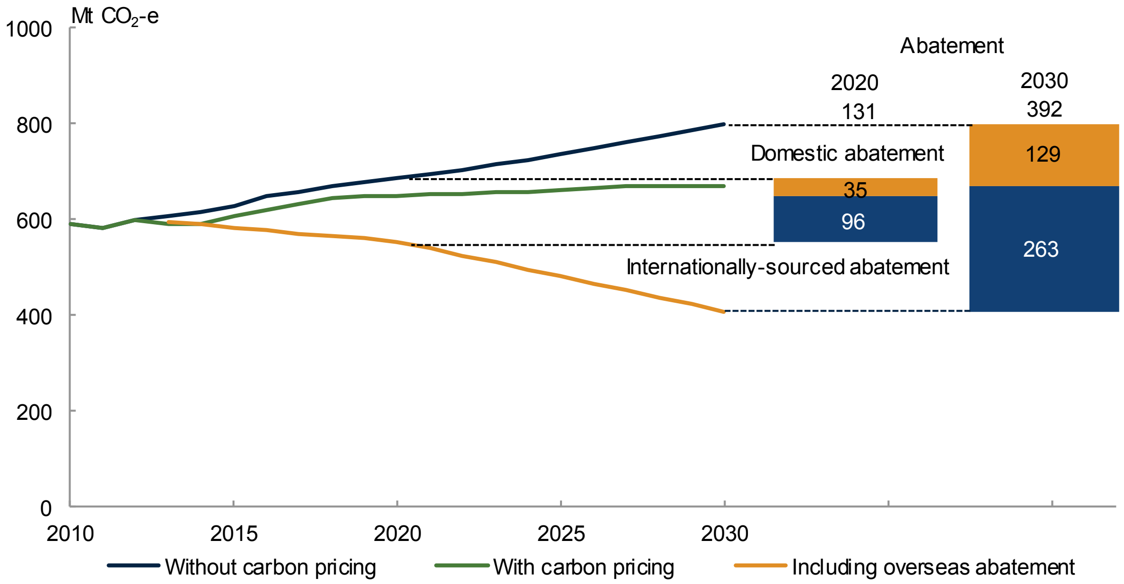
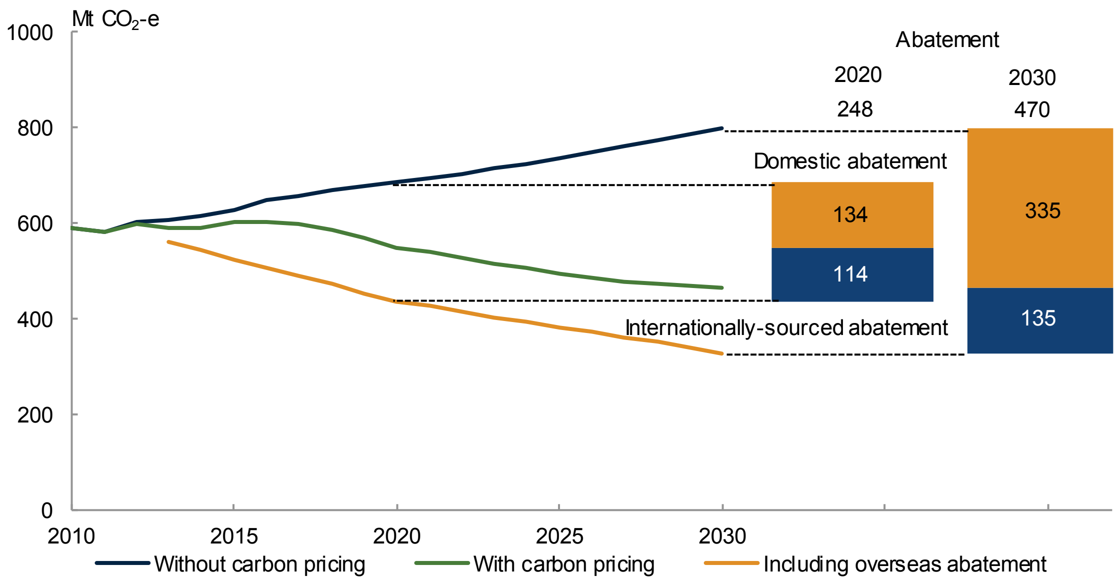


Chart 3.6: Australia's net emissions and sources of abatement (cont.)

Low price scenario



High price scenario



Source: Estimates from MMRF.

3.4 Domestic emissions projections

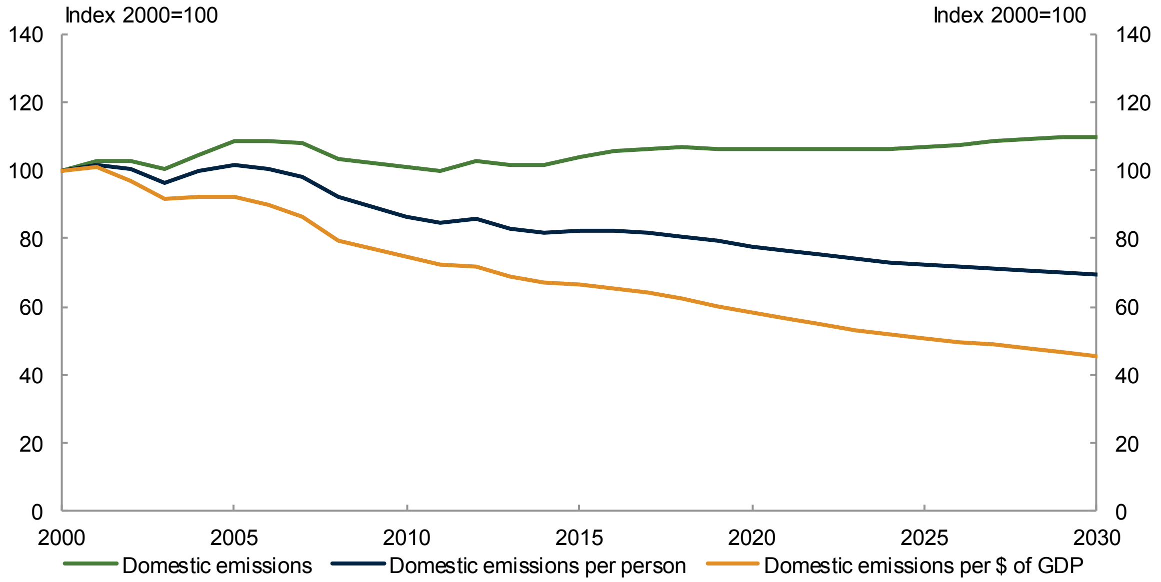
Domestic emissions projections are prepared at a sectoral level, with sectoral definitions consistent with international guidelines adopted by the UNFCCC for accounting under the Kyoto Protocol. The projections are prepared for Kyoto Protocol greenhouse gases and expressed in terms of carbon dioxide equivalent (CO_2-e) using the 100-year global warming potentials contained in the Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC 2007a). As greenhouse gases vary in their radiative activity and in their atmospheric residence time, converting emissions into CO_2-e allows the aggregate effect of emissions of the various gases to be considered.

The policy scenarios incorporate projected effects of carbon pricing and the CFI. Emissions covered by the carbon pricing mechanism include those from stationary energy; industrial processes; fugitive emissions from the production of coal and gas; and emissions from non-legacy waste (that is, waste deposited after the commencement of the carbon pricing mechanism). An equivalent carbon price is also applied to some transport fuels through the fuel tax regime and to importation of synthetic greenhouse gases. Overall, this covers around two-thirds of Australia's emissions directly and through other means. The CFI provides an incentive for emissions reductions in the land use, land-use change and forestry (LULUCF) and agriculture sectors, and the waste sector for legacy waste.

Detailed sectoral modelling has been integrated into the economic projections. This means that differences in carbon price assumptions flow through to differences in emissions levels both through their effects on the level and distribution of production across industries and through the incentive they create to reduce the emissions intensity of production within each industry.

The central policy scenario projects domestic emissions to rise slowly from current levels. Two contributors to this increase are direct combustion and fugitive emissions, both of which reflect the rapid growth projected for gas extraction and liquefaction. Another contributor is the steady increase in agriculture emissions, which is not covered by carbon pricing. Growth in domestic emissions is projected to average 0.4 per cent per year over the period from 2012 to 2030. This is below the rate of growth projected for the economy and population, so that indicators of the emissions intensity per unit of production in the economy or per person fall steadily over the period.

Chart 3.7: Economy-wide trends in emissions intensity
Central policy scenario

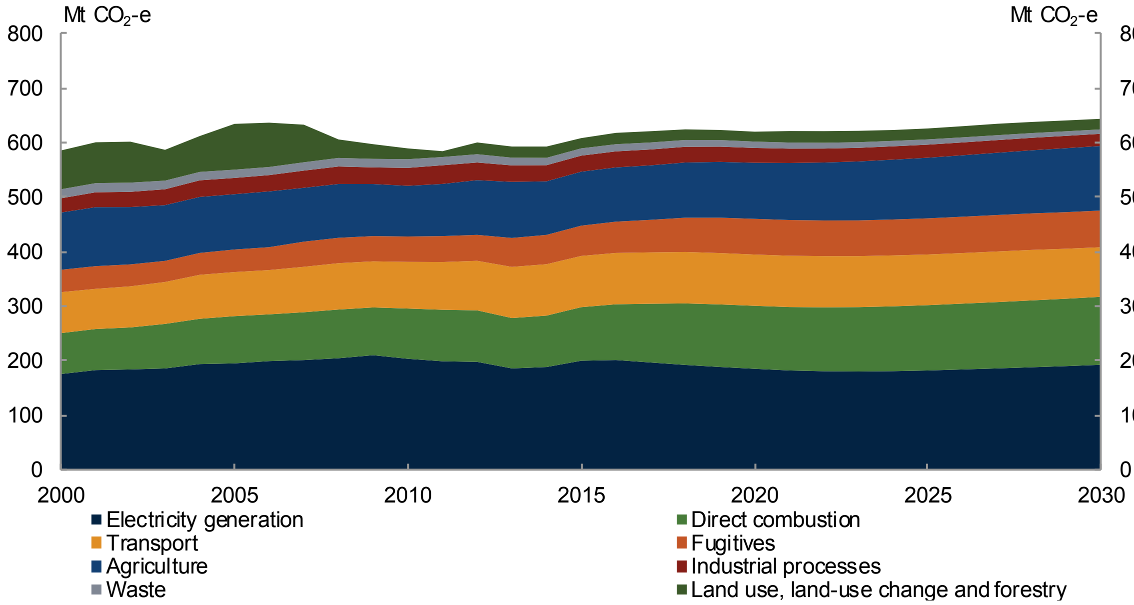


Source: Estimates from MMRF.

Carbon prices provide an incentive for firms to reduce the emissions intensity of their production processes and, by changing the relative costs of producing different goods and services, encourage the movement of resources towards lower emissions-intensive industries. Compared with the no carbon price scenario, the combination of carbon pricing and the effects of the CFI lead to 65 Mt CO_2-e of domestic abatement in 2020 and 156 Mt CO_2-e in 2030. Cumulative domestic abatement of 294 Mt CO_2-e is achieved to 2020 and 1444 Mt CO_2-e to 2030. Overall, changes in emissions intensities within industries contribute around three-quarters of domestic abatement in 2020 and two-thirds of abatement in 2030, while changes in the structure of the economy deliver the balance.

Chart 3.8: Emissions by sector

Central policy scenario



No carbon price scenario

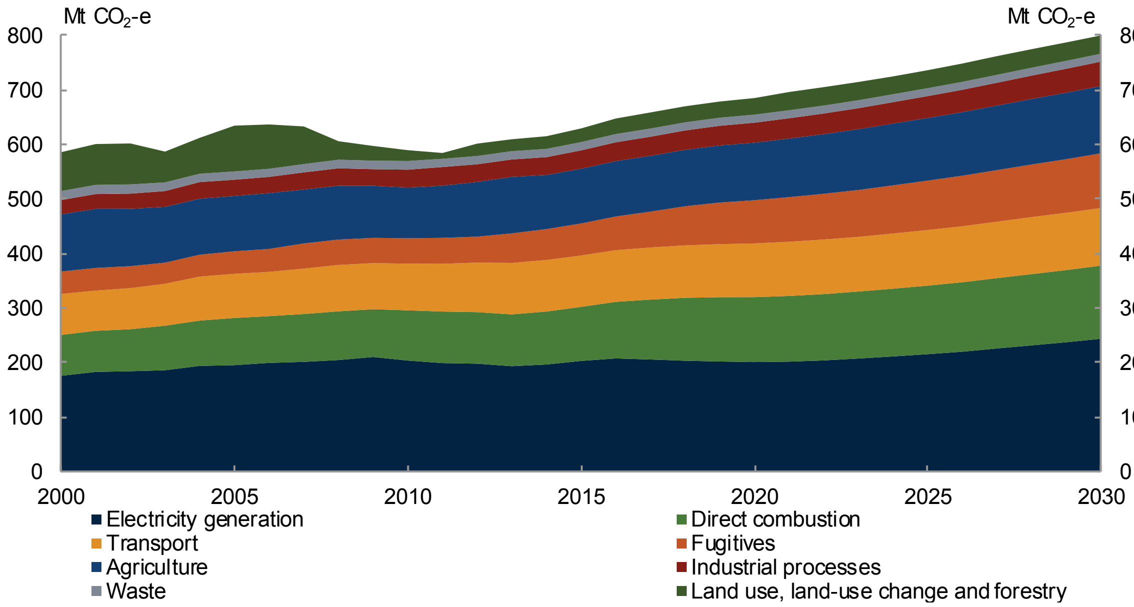
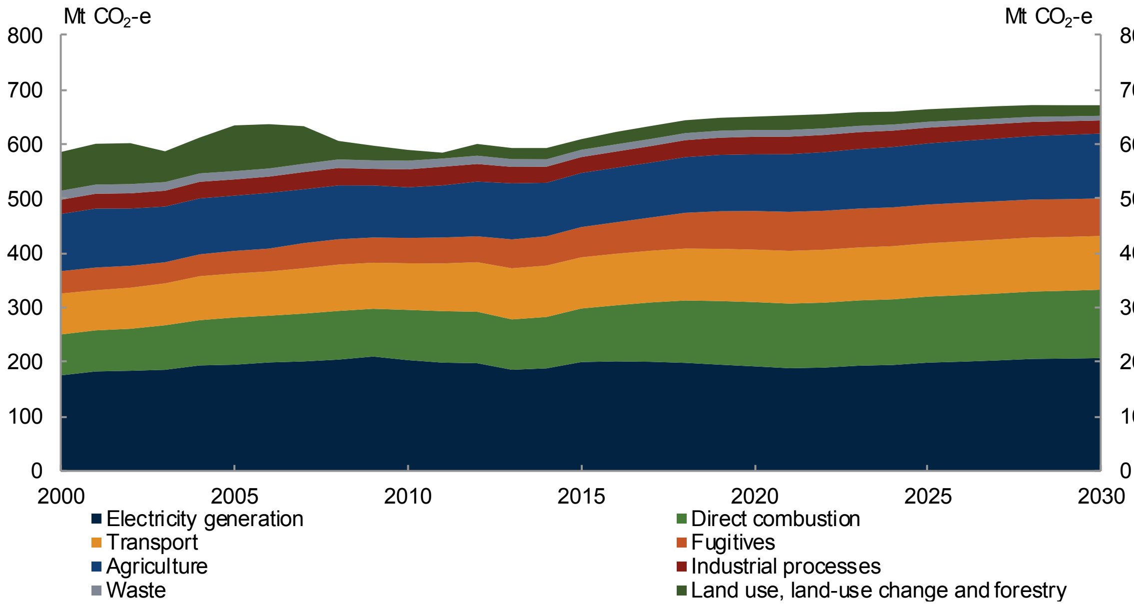
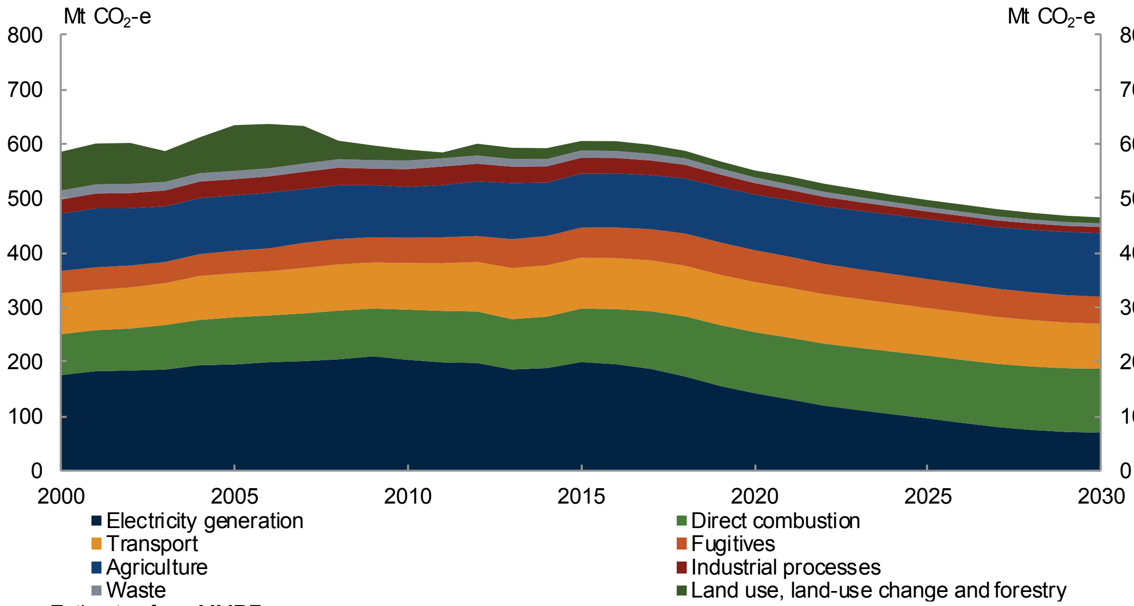


Chart 3.8: Emissions by sector (cont.)

Low price scenario



High price scenario

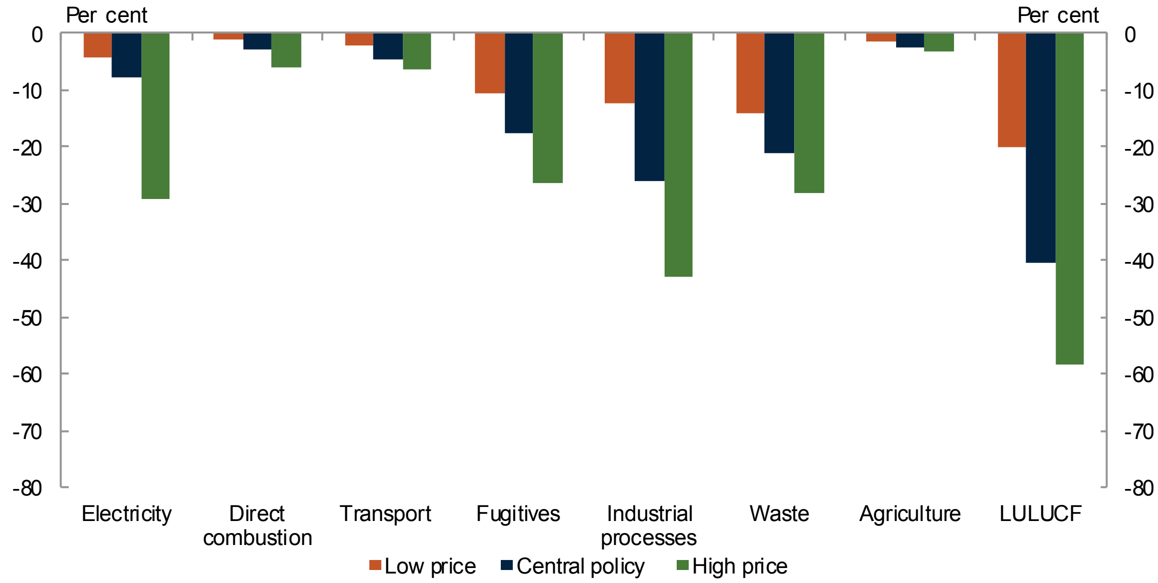


Source: Estimates from MMRF.

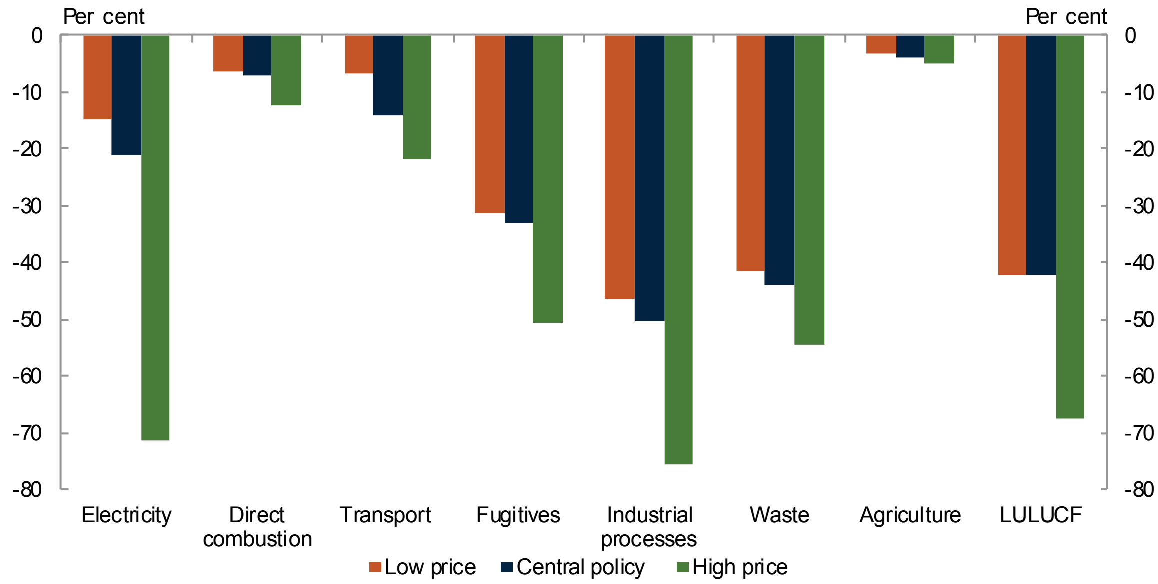
One way to compare each sector's role in meeting Australia's abatement task is to look at the percentage reduction in emissions within each sector. All economic activities covered by carbon pricing, or for which CFI credits are available, see reductions in emissions over time relative to levels in the no carbon price scenario. In the low price and central policy scenarios, the proportionate reductions are generally smaller in combustion emissions in electricity, transport and stationary energy than activity emissions. In the high price scenario, however, carbon pricing drives larger reductions in emissions from the electricity generation sector.

Chart 3.9: Emissions reductions by sector

Change from no carbon price scenario, 2020



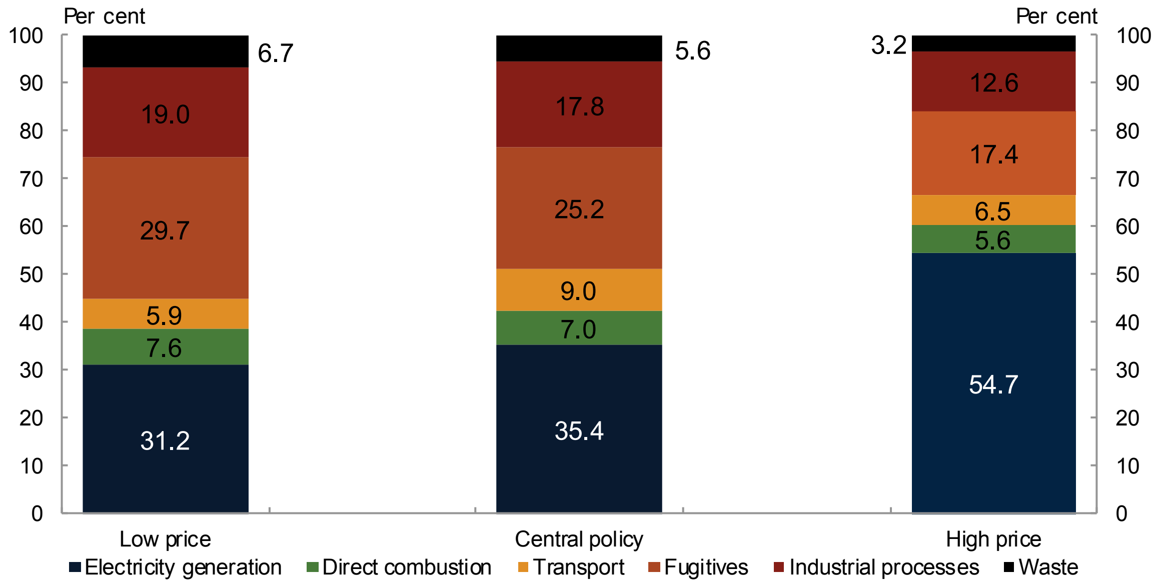
Change from no carbon price scenario, 2030



Source: Estimates from MMRF.

Another way to compare each sector's contribution to meeting Australia's abatement task is to add up the cumulative emissions reductions in the policy scenario compared to the no carbon price scenario over the period to 2030. Over this period, the electricity generation and fugitives sectors deliver the greatest share of the reduction in domestic emissions in all scenarios.

Chart 3.10: Share of cumulative emissions reductions by sector
Change from no carbon price scenario, 2013 to 2030



Source: Estimates from MMRF.

Detailed reports on the electricity sector prepared by ACIL Allen Consulting, the transport sector prepared by the CSIRO and the agriculture sector prepared by the CIE are available on the Climate Change Authority website.

Table 3.2: Domestic emissions projections

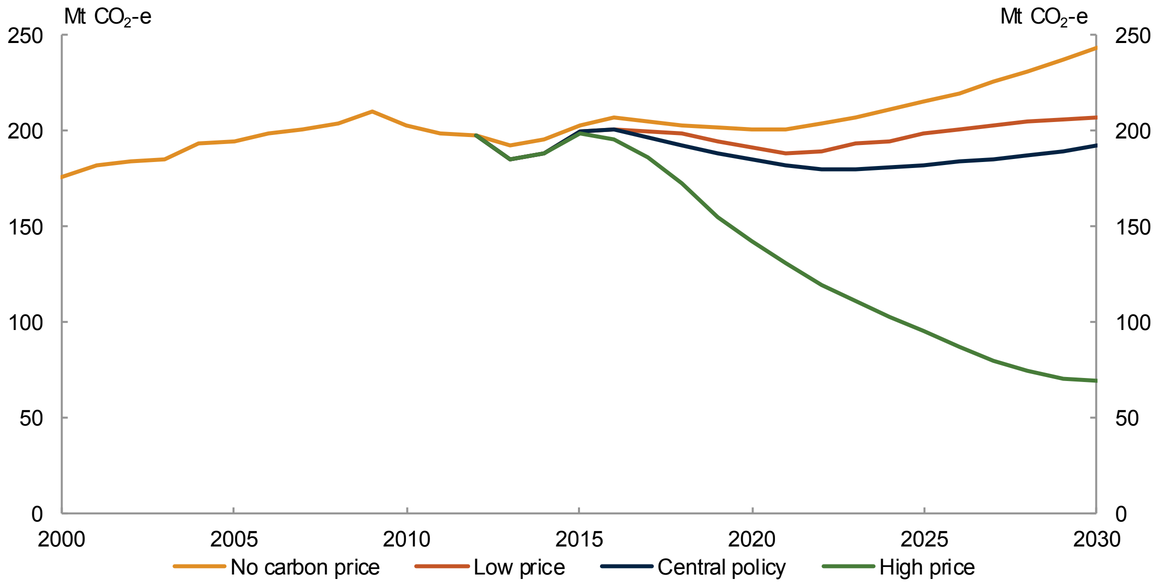
		1990	2000	2012	2020				2030			
					No carbon price	Low price	Central policy	High price	No carbon price	Low price	Central policy	High price
		Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e
Energy	Emissions	**294**	**367**	**431**	**498**	**477**	**460**	**405**	**584**	**500**	**476**	**319**
	Abatement					**-20**	**-37**	**-93**		**-84**	**-108**	**-265**
Stationary	Emissions	195	251	292	320	310	301	254	378	333	317	187
	Abatement					-10	-19	-66		-45	-61	-191
Transport	Emissions	62	75	91	99	96	94	92	106	99	91	83
	Abatement					-2	-4	-6		-7	-15	-23
Fugitive	Emissions	37	41	48	79	71	66	59	100	69	67	50
	Abatement					-8	-14	-21		-31	-33	-51
Industrial processes	Emissions	**26**	**26**	**32**	**37**	**32**	**27**	**21**	**45**	**24**	**22**	**11**
	Abatement					**-5**	**-10**	**-16**		**-21**	**-23**	**-34**
Agriculture	Emissions	**99**	**105**	**100**	**106**	**104**	**103**	**102**	**123**	**119**	**119**	**117**
	Abatement					**-1**	**-3**	**-3**		**-4**	**-5**	**-6**
Waste	Emissions	**21**	**17**	**15**	**15**	**13**	**12**	**11**	**15**	**9**	**8**	**7**
	Abatement					**-2**	**-3**	**-4**		**-6**	**-6**	**-8**
Forestry	Emissions	**0**	**-11**	**-25**	**-19**	**-22**	**-24**	**-26**	**-17**	**-23**	**-23**	**-26**
	Abatement					**-3**	**-5**	**-7**		**-6**	**-6**	**-8**
Land-use change	Emissions	**140**	**82**	**47**	**50**	**47**	**43**	**38**	**51**	**42**	**42**	**37**
	Abatement					**-3**	**-7**	**-11**		**-9**	**-9**	**-14**
Total	Emissions	**580**	**586**	**600**	**685**	**651**	**620**	**551**	**801**	**672**	**644**	**465**
	Abatement					**-35**	**-65**	**-134**		**-129**	**-156**	**-335**

Source: Historical data from the National Greenhouse Gas Inventory. Land use, land-use change and forestry estimates are from DIICCSRTE. All other estimates are from MMRF.

3.4.1 Electricity sector

Emissions from electricity are associated with fuels combusted to generate electricity, including both on-grid and off-grid generation. Electricity sector emissions accounted for around 198 Mt CO_2-e in 2012, or around 33 per cent of Australia's total domestic emissions.

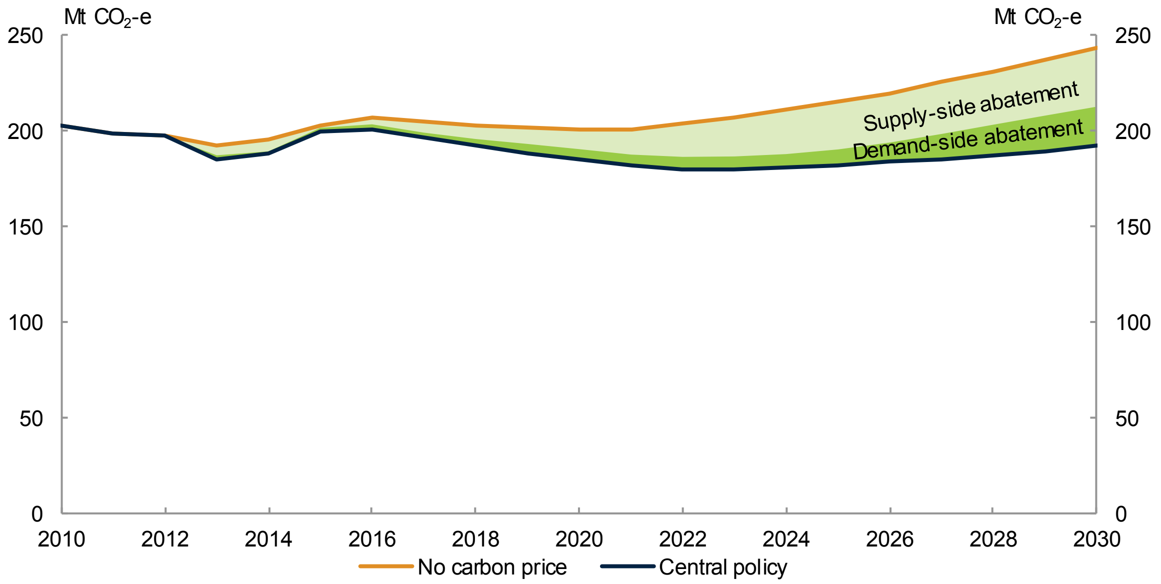
Chart 3.11: Electricity emissions, 2000 to 2030



Source: National Greenhouse Gas Inventory; projections from MMRF and ACIL Allen Consulting.

In the central policy scenario, the composition of electricity generation in Australia changes markedly over time. The carbon price drives changes in the mix of technologies and fuels used in the electricity sector in all policy scenarios in the period to 2020 and, particularly, over the decade to 2030. The electricity demand response to price changes also provides abatement throughout the projection period, though abatement from this source is smaller than that from the change in the composition of generation.

Chart 3.12: Electricity emissions, 2010 to 2030



Source: Estimates from MMRF based on ACIL Allen Consulting.

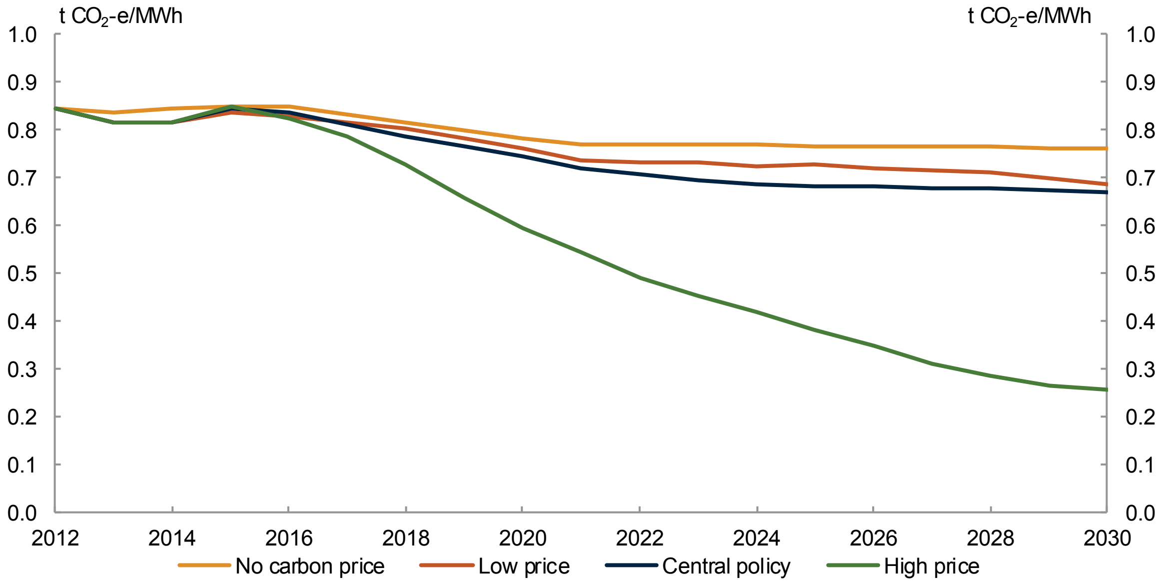
Transformation of the electricity sector

In the policy scenarios, a carbon price drives changes in the mix of technologies and fuels used in the electricity sector. Australia has a range of technological options available including gas, wind, solar and geothermal resources. Nuclear power is assumed not to be available, and carbon capture and storage does not come on stream until 2030 in the high price scenario, and later in other scenarios.

In the central policy scenario, the combination of the Large-scale Renewable Energy Target (LRET) and carbon pricing makes gas and renewable energy sources more competitive relative to coal, leading to a progressive transition from conventional coal-fired generation. Coal-fired electricity declines as a share of total generation across all scenarios after carbon is priced. Gas-fired electricity plays a more important role in delivering baseload generation with carbon pricing than in the no carbon price scenario, but rising gas prices over time in all scenarios limit the expansion of the sector. In the high carbon price scenario, there is faster transformation of the electricity generation sector, with gas and renewables together contributing over 83 per cent of the generation mix by 2030.

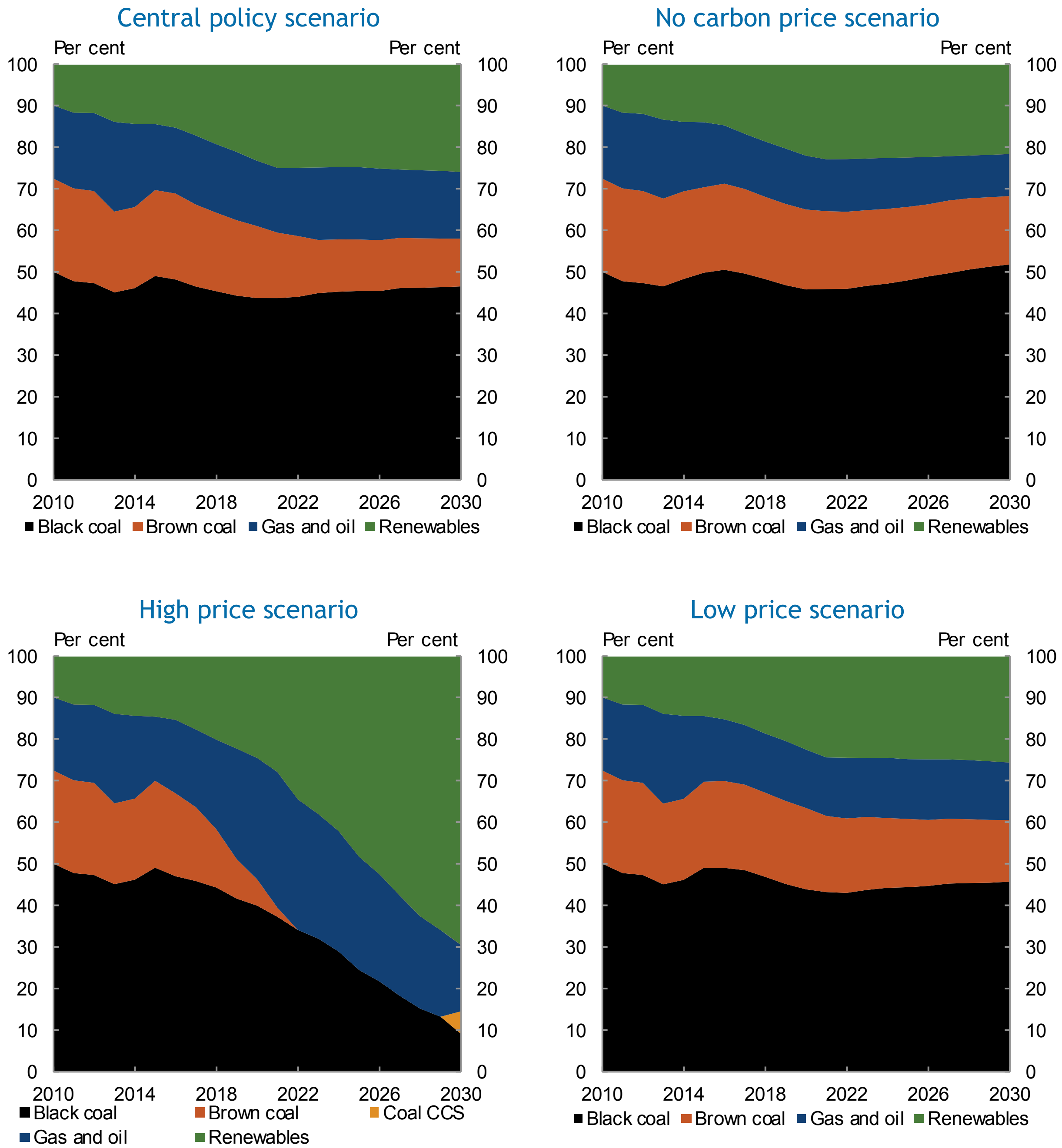
This transformation of the fuel and technology mix reduces the emissions intensity of electricity supply. The emissions intensity of generation in the high price scenario is projected to decline around 70 per cent by 2030 compared with current levels.

Chart 3.13: Emissions intensity of electricity generation



Source: Estimates from MMRF based on ACIL Allen Consulting.

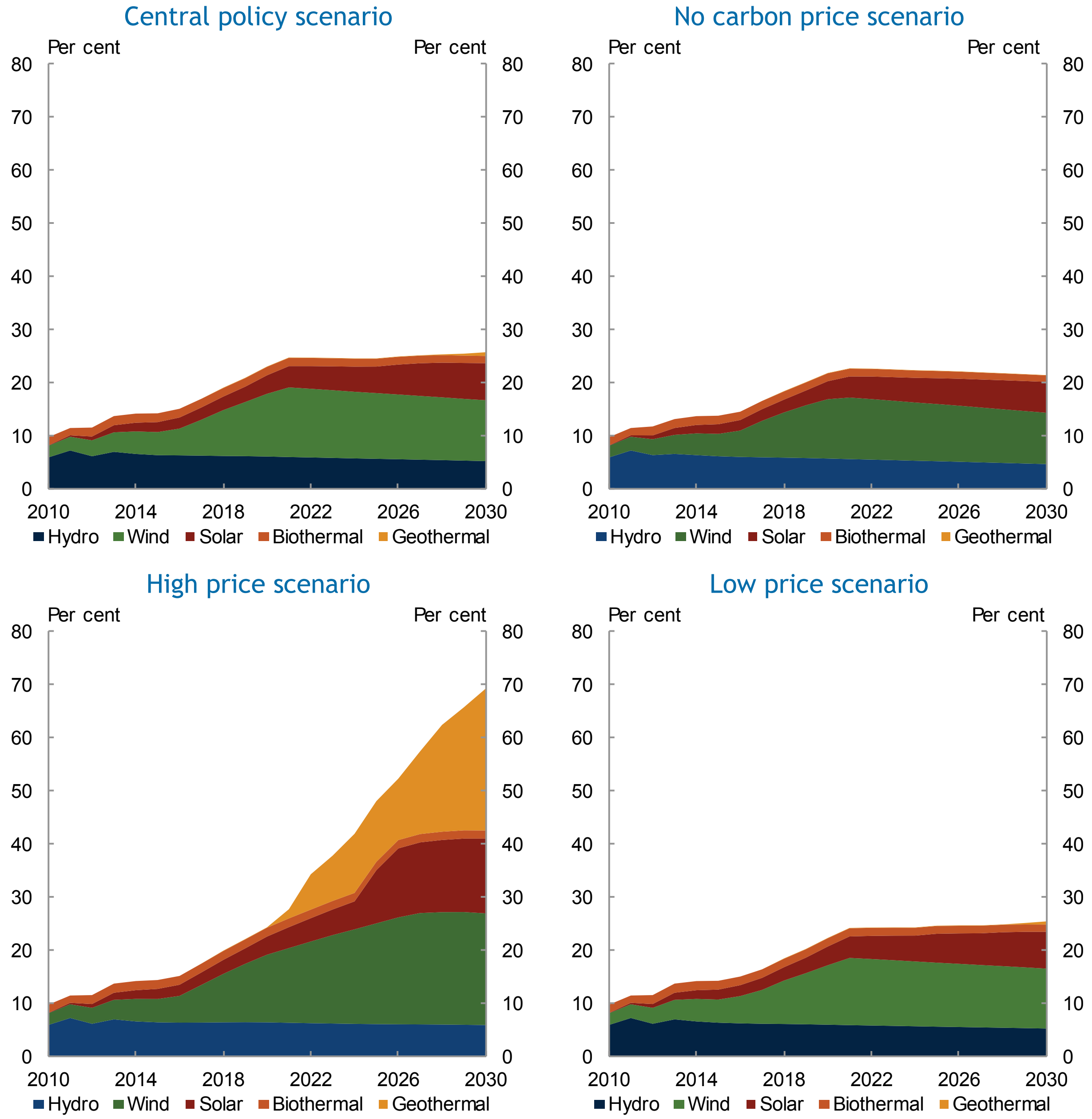
Chart 3.14: Sources of electricity generation



Source: ACIL Allen Consulting.

The increase in renewables driven by the LRET satisfies most growth in demand to 2020 in the central policy and no carbon price scenarios. Renewable generation reaches 23 per cent of total generation by 2020 in the central policy scenario and 24 per cent of total generation by 2020 in the high price scenario. This includes renewable generation driven by the Small-scale Renewable Energy Scheme (SRES). The relatively small additional increase in renewable generation in 2020 in the central policy scenarios is a result of partially offsetting movements in the modelled prices of renewable energy certificates.

Chart 3.15: Renewables by technology — share of total generation



Source: ACIL Allen Consulting.

Renewable generation continues to grow to 2030 in the central policy scenario, to around 26 per cent of total generation. In the high price scenario, the uptake of renewable generation after 2020 is much stronger, reaching 69 per cent and replacing the majority of coal-fired generation by 2030.

The early increase in renewables is largely driven by increased wind generation. However, over time, other renewables become increasingly competitive. In the high carbon price scenario, substantially higher levels of geothermal come on stream after 2020.

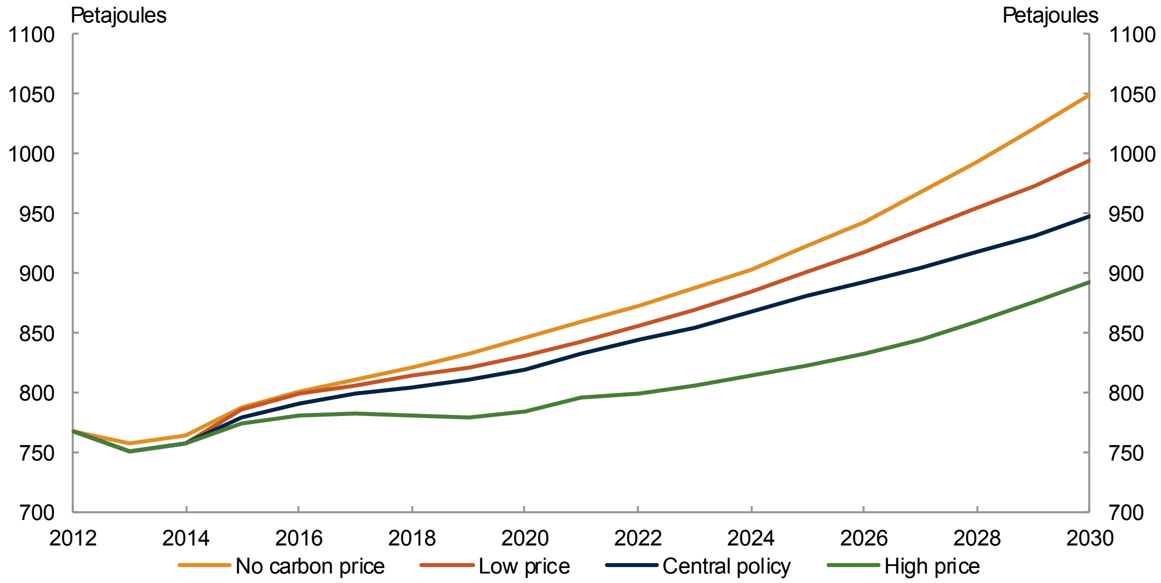
Electricity demand and prices

Overall, electricity consumption is lower in the scenarios with higher carbon prices. This occurs through households and firms moving towards lower levels of electricity use in consumption and production in response to higher electricity prices, and through restructuring of the economy towards less electricity-intensive industries. This is offset partly by the uptake of electric vehicles, which has a small impact on electricity demand by 2030. Compared to the no carbon price scenario, electricity demand is around 3 per cent lower in the central policy scenario in 2020 and around 7 per cent lower in the high carbon price scenario.

Wholesale electricity prices rise over time even in the no carbon price scenario, driven by rising gas prices and the capital costs associated with new plants entering the market to meet growing demand. Carbon pricing flows through into electricity prices, increasing wholesale electricity prices by around $10 per MWh on average over the first five years relative to the no carbon price scenario. The deployment of lower emissions and higher cost technologies over time sees electricity prices continue to increase to 2030.

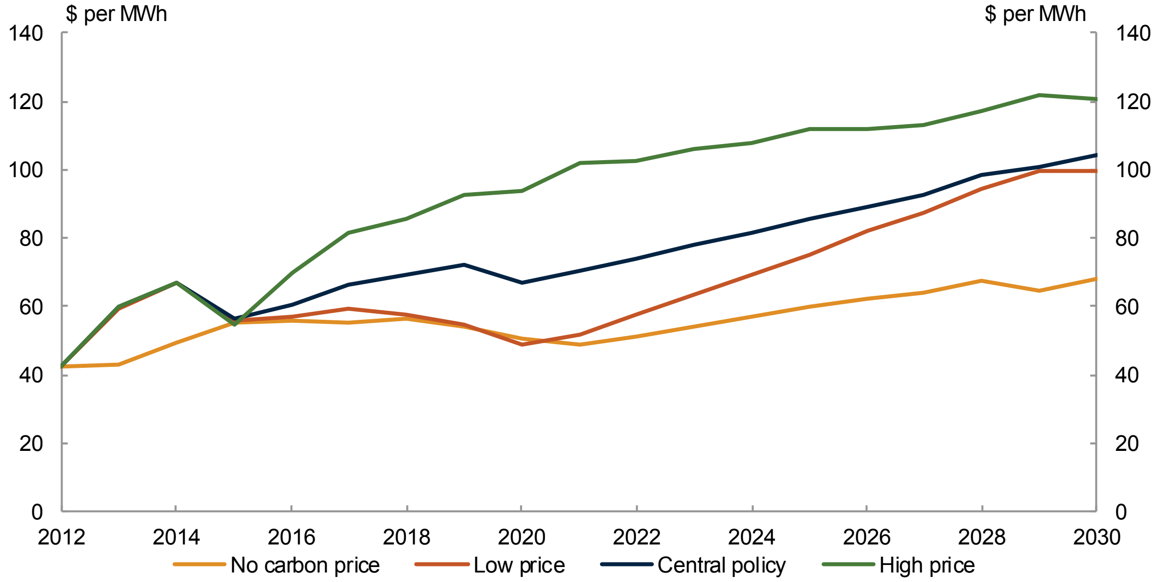
Wholesale electricity prices are sensitive to assumptions about energy commodity prices and capital costs. Changes in the prices of coal and gas have an immediate impact on electricity prices. In contrast, changes in the capital costs of new generators have a greater impact over time, as new generation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

Chart 3.16: Electricity demand



Source: Estimates from MMRF based on ACIL Allen Consulting.

Chart 3.17: Average wholesale electricity prices



Note: Prices are in 2012 dollars.
Source: ACIL Allen Consulting.

Box 3.3: Domestic fuel price assumptions

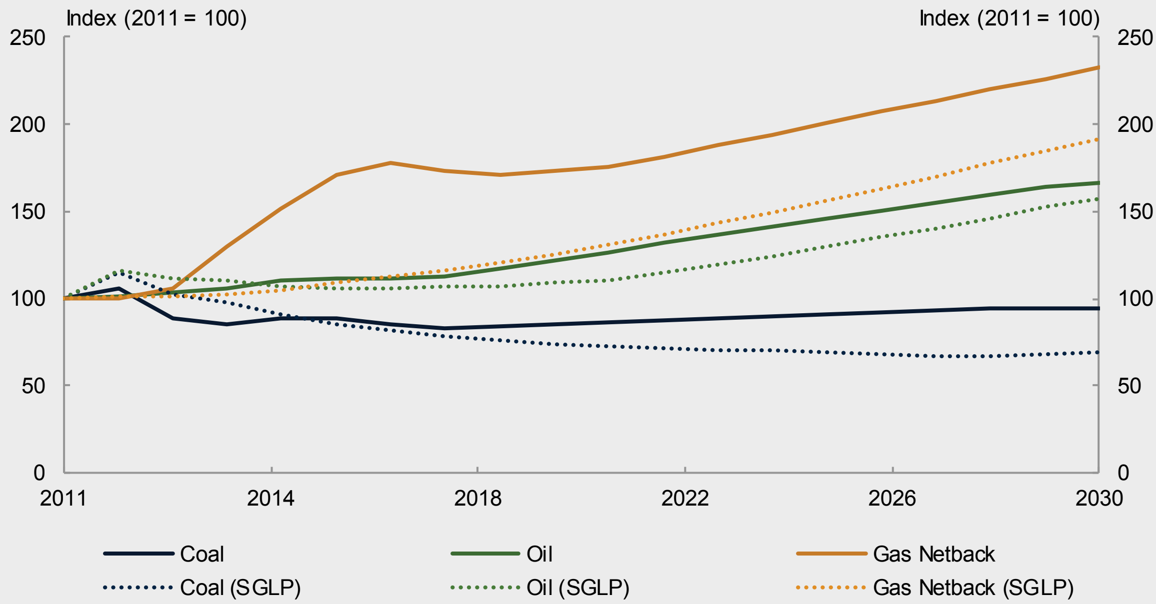
The modelling incorporates assumptions about the future path of coal, oil and gas prices. International prices for oil and gas are based on projections from the International Energy Agency *2012 World Energy Outlook (IEA 2012a)*, and coal prices are based on Treasury's medium-term projections, informed by stakeholders and domestic and international experts. These figures are converted to Australian dollars based on projected exchange rates.

Long-run coal prices are projected to be higher than those presented in the *Strong growth, low pollution* (SGLP) report (Australian Government 2011). Following falls in coal prices in mid-2011, on the back of weak demand and increased world supply in international markets, prices are projected to stabilise over the next five to ten years.

Over recent years, oil prices have risen and are projected to remain at elevated levels. Recent strength in the level of oil prices, relative to other fuels, is driving a worldwide structural shift in fuel use with substitution towards cheaper alternative fuels.

The modelling incorporates assumptions regarding Australian netback gas prices, which are derived from international gas prices. Netback prices can be considered 'wellhead prices', and are formulated as a proportion of market prices. This proportion represents the costs of bringing the commodity to market and can include, but are not limited to, liquefaction, pipeline and shipping transportation, royalties and import duties. ACIL Allen Consulting provided estimates of costs associated with LNG production to inform gas netback price assumptions.

Chart 3.18: Domestic fuel prices



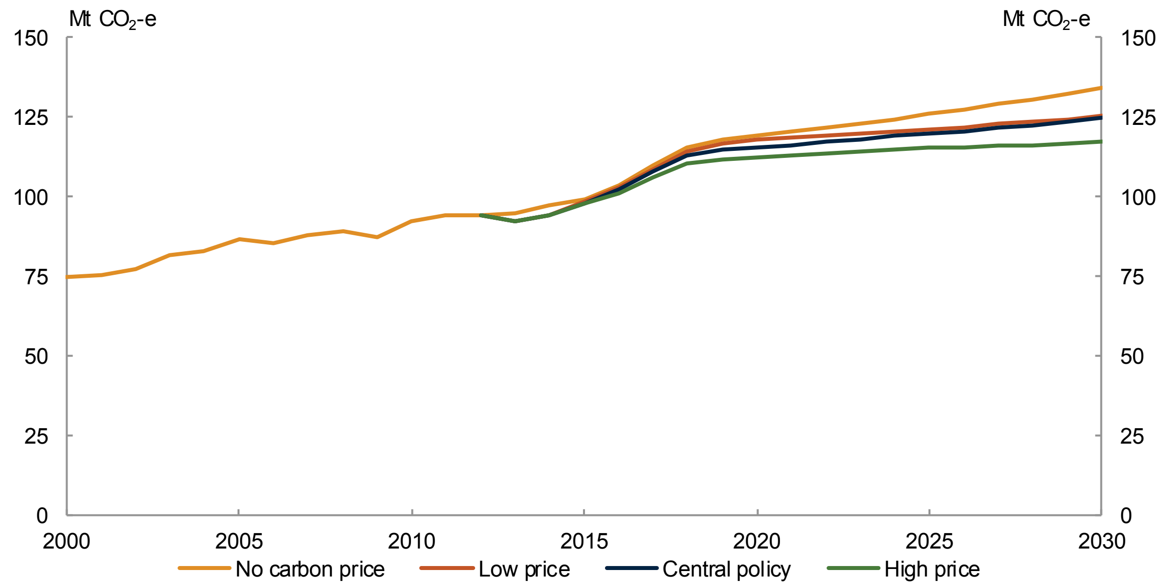
Source: IEA (2012a), Australian Government (2011) and ACIL Allen Consulting.

3.4.2 Direct combustion

Direct combustion emissions arise from the combustion of fuels for energy used directly, in the form of heat, steam or pressure. Direct combustion emissions arise in all sectors of the economy, including agriculture, mining, manufacturing, services and residential sectors. The two main sources are the manufacturing and mining industries, which together contribute around three-quarters of all direct combustion emissions. Within the mining sector, oil and gas extraction and particularly the production of LNG is the largest source, contributing around 20 per cent of direct combustion emissions in 2012. Within the manufacturing sector, non-ferrous metal manufacturing, particularly alumina production, is the largest source, contributing 12 per cent of direct combustion emissions in 2012.

Direct combustion emissions accounted for around 95 Mt CO_2-e in 2012, or around 16 per cent of Australia's total domestic emissions. The oil and gas extraction industry has been the largest contributor to growth in direct combustion emissions since 2000, due in part to growth in LNG production for export.

Chart 3.19: Direct combustion emissions, 2000 to 2030



Source: National Greenhouse Gas Inventory; projections from MMRF.

Direct combustion emissions are projected to grow to 116 Mt CO_2-e in 2020 and 125 Mt CO_2-e in 2030 in the central policy scenario. Emissions from the mining industry are projected to rise by 22 Mt CO2-e between 2012 and 2020. Much of this growth is a result of the development of the LNG industry, with seven new projects, all of which have taken final investment decisions, expected to commence production during this period.

Manufacturing sector emissions are projected to decline over the period to 2020, with emissions falling by 3 Mt CO_2-e between 2012 and 2020. Some of this change is due to declining production. For example, petroleum refining volumes are projected to contract due to competitive pressure from larger international refineries, and the projections incorporate announced closures. Emissions from other manufacturing sectors are also projected to fall slightly due to declining emissions intensity of production.

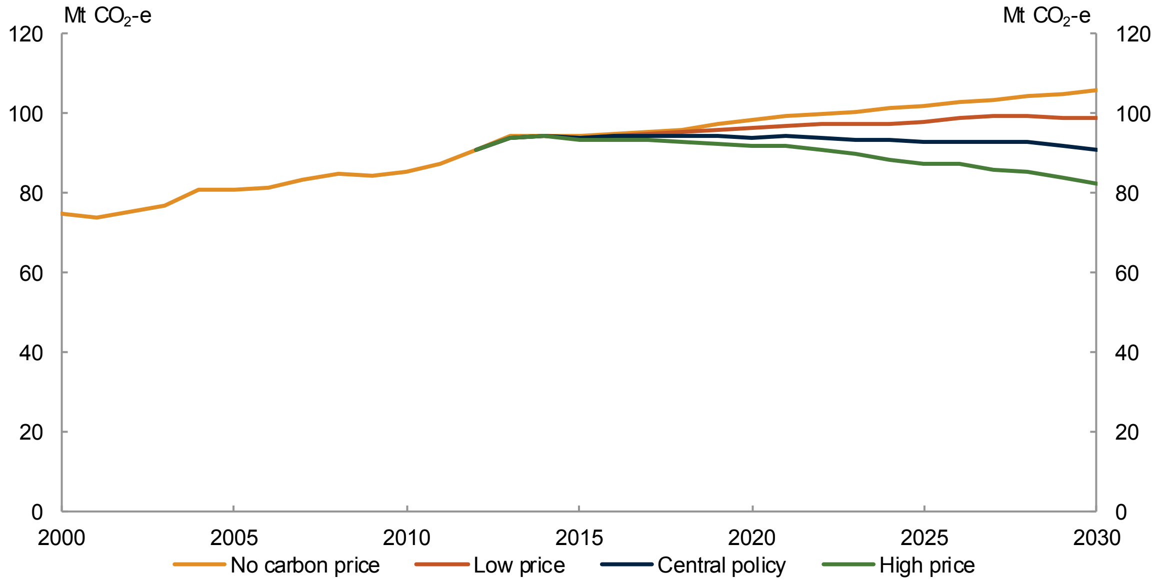
Compared with the no carbon price scenario, carbon pricing is projected to reduce direct combustion emissions by 4 Mt CO_2-e by 2020 in the central policy scenario. Abatement is projected to grow in the longer term as new infrastructure investments incorporate low-emissions technologies in response to a carbon price and the structure of the economy moves towards production of less emissions-intensive goods and services.

3.4.3 Transport

The transport sector covers emissions from the direct combustion (or end-use emissions) of fuels by road, rail, domestic aviation and domestic shipping. Emissions from domestic air, rail and water transport are covered by the carbon price and the modelling assumes emissions from heavy on-road transport are covered by an equivalent carbon price from 2014-15.

Transport emissions were 91 Mt CO_2-e in 2012, contributing 15 per cent of Australia's total domestic emissions. Road transport was the largest subsector with emissions of 77 Mt CO_2-e, contributing 84 per cent of total transport emissions in 2012, followed by domestic aviation, which contributed around 8 per cent of transport emissions or 7 Mt CO_2-e in 2012.

Chart 3.20: Transport emissions, 2000 to 2030

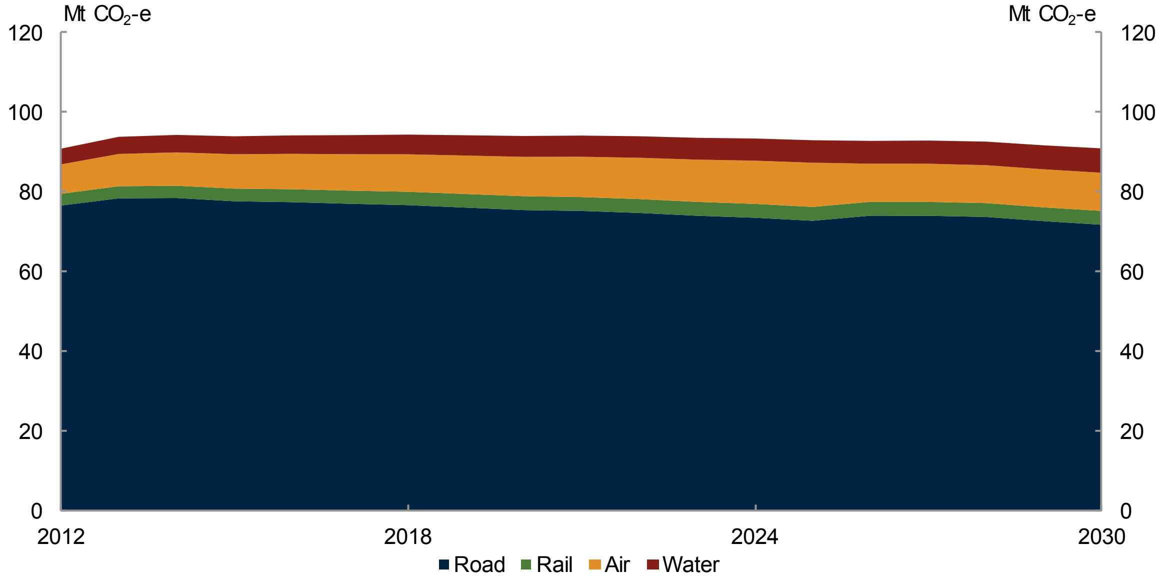


Source: National Greenhouse Gas Inventory; projections from MMRF and CSIRO.

Transport sector emissions are driven primarily by economic activity, population growth and oil prices. Improvements in vehicle technology, such as fuel efficiency and engine design standards, also play a significant role, as do consumer preferences such as changes in the fleet mix, and modal switching (for example between road and air transport). Activity levels in rail and shipping have been driven primarily by bulk commodity production.

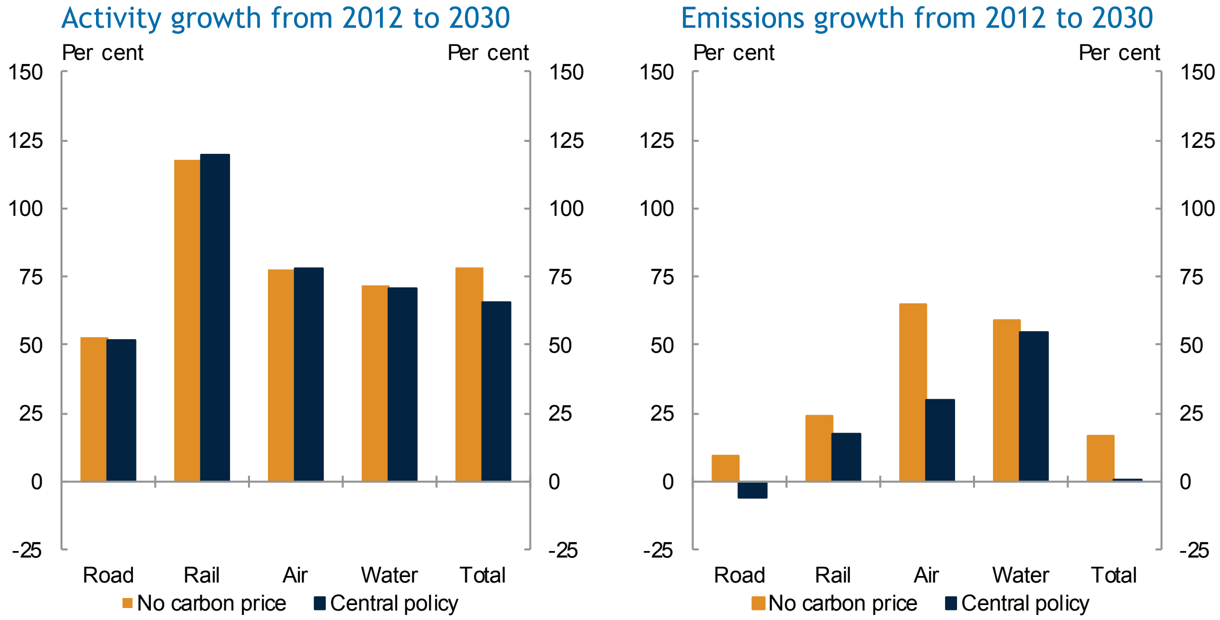
Transport activity growth continues in the central policy scenario. Freight activity is projected to grow with economic activity, while private transport growth is lower due to saturation effects as household incomes rise. Despite this growth, emissions in the transport sector remain relatively flat. The fall in emissions intensity is due largely to ongoing fuel efficiency improvements in all scenarios and fuel switching driven by the carbon price in the central policy scenario. Growth in activity remains similar across most sectors, although there is some substitution from road transport to rail. Domestic air transport is slightly higher in the central policy scenario than in the no carbon price scenario as the lower real exchange rate encourages tourism.

Chart 3.21: Transport emissions by mode, 2012 to 2030
Central policy scenario



Source: Estimates from CSIRO and MMRF.

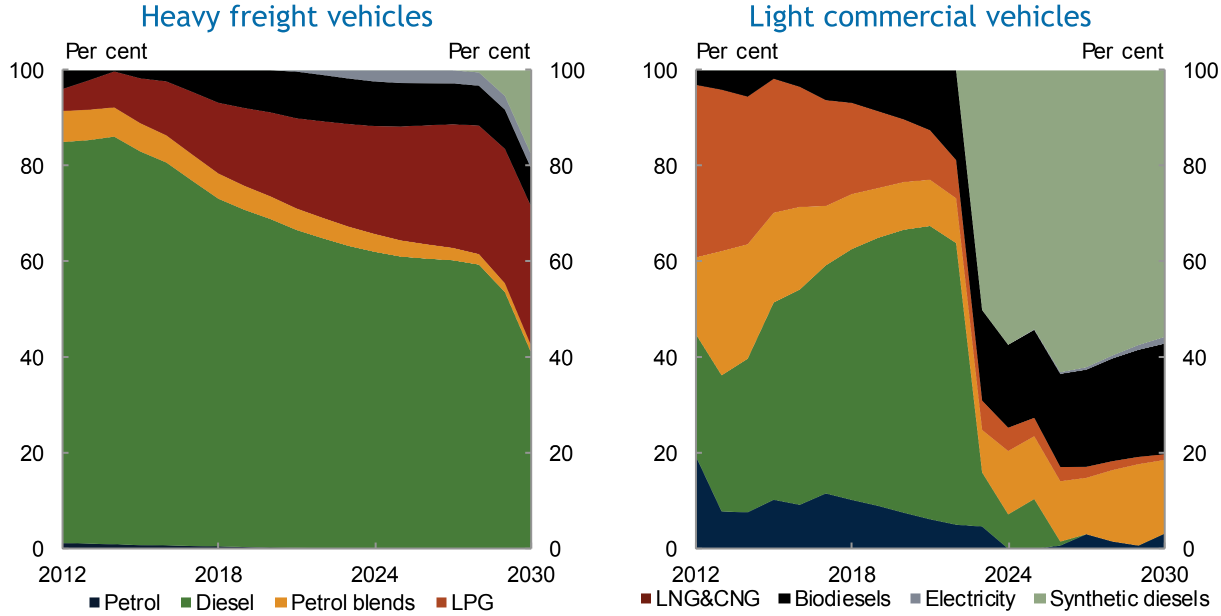
Chart 3.22: Transport activity and emissions



Note: Activity refers to gross output.
Source: Estimates from CSIRO and MMRF.

The carbon price leads to a fall in emissions intensity for all transport sectors relative to the no carbon price scenario by driving changes in fuel use. Transport delivers about 9 per cent of total domestic abatement out to 2030 in the central policy scenario with the road transport sector providing the majority of abatement. Road transport is projected to deliver 4 Mt CO_2-e of abatement due to the carbon price in 2020 and 12 Mt CO_2-e of abatement in 2030, relative to the no carbon price scenario. Abatement is limited in the near term by the time required to turn over the vehicle fleet and the higher upfront costs of cleaner technologies. However, after 2020, the carbon price accelerates the uptake of hybrids and electric vehicles.

Chart 3.23: Road fuel mix, central policy scenario



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

In the heavy road freight vehicle sector, the most significant change in fuel mix is the adoption of liquefied or compressed natural gas (LNG or CNG) and biodiesel. There is also an uptake of electric vehicles, although these remain fairly small shares of the overall mix. Despite the adoption of lower emissions fuel types, emissions from trucks in 2030 are around 12 per cent higher than 2012 levels, due to the increase in freight activity.

Changes in transport fuels and technologies driven by heavy vehicle demand are also projected to have spill over effects on light commercial vehicle users (as well as private transport). This in part drives fuel switching to biodiesel. After 2022, a significant switch to synthetic diesels is projected. Emissions from light commercial vehicles in 2030 are 14 per cent below 2012 levels.

The policy of applying an equivalent carbon price to heavy on-road transport from 2014-15 has not yet been legislated. A sensitivity analysis was undertaken to look at the effects on emissions of this proposed policy change. In the absence of coverage of heavy on-road transport, domestic emissions would be higher by 4 Mt CO_2-e in 2020 and by 12 Mt CO_2-e over the period from 2013 to 2020. By 2030, domestic emissions would be 11 Mt CO_2-e higher than in the central policy scenario.

Air, rail and water transport

Domestic aviation, domestic shipping and rail together account for less than 1 Mt CO_2-e of abatement in 2020 and 3 Mt CO_2-e of abatement in 2030, mainly due to fuel switching in domestic aviation.

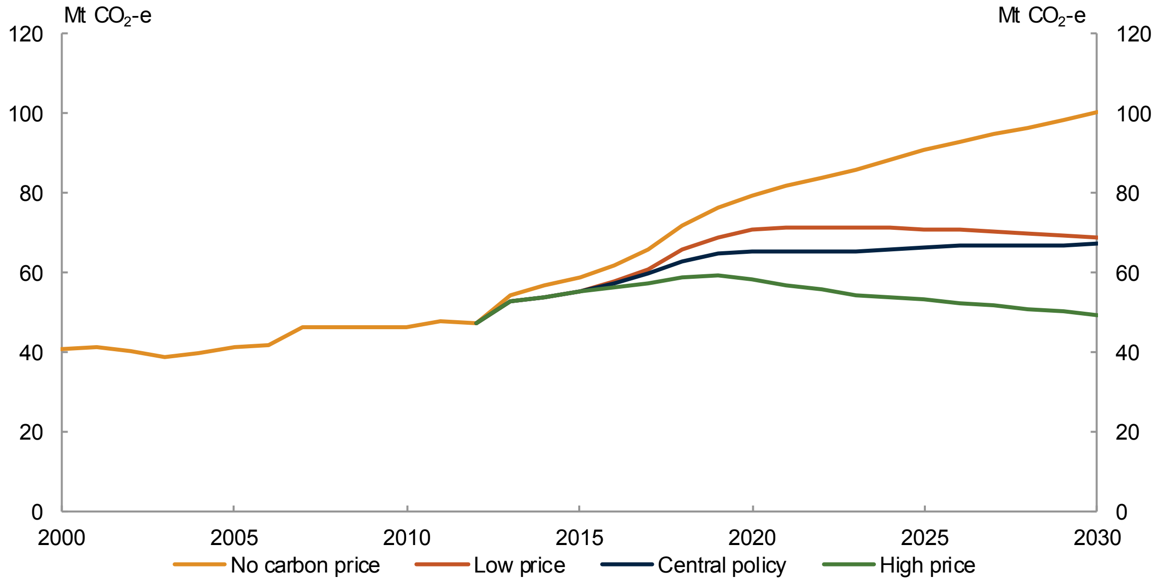
Biofuels are projected to represent the best opportunity for decreasing emissions in the aviation sector. A shift from petroleum-based jet fuel towards bio-derived jet fuel is projected to occur after 2025. This shift is driven by increased availability of biofuels and decreased production costs for bio-derived jet fuel, as well as a shift toward fully or partially electrified vehicles in the road sector which reduces growth in liquid fuel demand from road vehicles.

The carbon price drives a shift from fuel oil to diesel as the main fuel source for shipping. Abatement in the rail sector is slow as infrastructure is slow to turn over, but substitution of diesel with biodiesel and natural gas is projected to drive a modest reduction in emissions intensity to 2030.

3.4.4 Fugitives

The fugitives sector covers emissions associated with the production, processing, transport, storage, transmission and distribution of fossil fuels such as black coal, oil and natural gas. Emissions from decommissioned underground coal mines are also included in this sector. The fugitives sector does not include the emissions arising from the combustion of these fuels; these emissions are accounted for under the stationary energy and transport sectors. A key driver of fugitive emissions is growth in the production of coal, oil and natural gas, which is influenced strongly by export demand. Fugitive emissions were 48 Mt CO_2-e in 2012, or around 8 per cent of Australia's total domestic emissions, of which 34 Mt CO_2-e were associated with coal mining and 14 Mt CO_2-e with oil and gas extraction.

Chart 3.24: Fugitive emissions, 2000 to 2030



Source: National Greenhouse Gas Inventory; projections from MMRF.

Coal fugitive emissions are projected to grow to 46 Mt CO_2-e in 2020 in the central policy scenario. Production of black coal grows strongly over the next few years in response to sustained high export demand, primarily from China and India, notwithstanding global action to reduce emissions. Australian coal plays a role in meeting China's increasing demand, which is projected to peak around 2020. After 2020, growth in coal production is slower in all scenarios due to the higher international carbon price and greater Chinese integration into international carbon markets.

The carbon price is projected to achieve 11 Mt CO_2-e of domestic abatement in the coal fugitive sector in 2020. The carbon price reduces fugitive coal emissions by encouraging a relative expansion of less gassy mines and the deployment of technologies to capture fugitive emissions, which become increasingly available over the projection period. Pre-2020, indirect abatement systems such as pre- and post-mine drainage are projected to reduce emissions, especially where there are opportunities for co-benefits such as electricity generation. Flaring of waste mine methane is projected to become common practise amongst mines employing drainage. After 2020, technological advances are projected to support the application of pre-mine drainage to complex deep seam, multi-seam and low permeability mines that are not accessible with surface drilling. Direct abatement systems such as the capture and use of ventilation air methane are projected to become widespread in Australian coal mines in the next five to ten years under a carbon price.

In 2020, oil and gas fugitive emissions are projected to grow to 19 Mt CO_2-e in the central policy scenario. Emissions from the subsector increase over the projection period due to strong growth in the production of natural gas, particularly LNG. The carbon price is projected to achieve 3 Mt CO_2-e of domestic abatement in the oil and gas fugitive sector in 2020 through equipment upgrades and reduced transmission losses.

3.4.5 Industrial processes

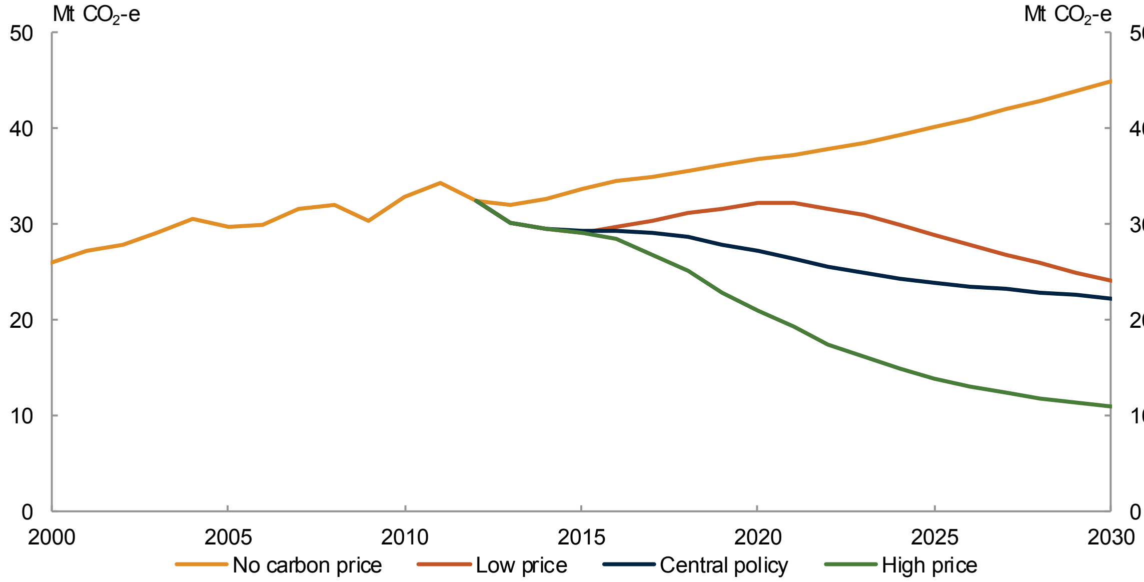
The industrial processes sector encompasses emissions generated from a range of production processes in metal production (32 per cent), mineral production (19 per cent), the chemical industry (18 per cent), consumption of halocarbons and sulphur hexafluoride (30 per cent), and other production (1 per cent).

Carbon dioxide emissions are produced from clinker and lime production; from limestone and dolomite use; ammonia production; other chemical production; and aluminium, steel and other metal smelting. Methane emissions are produced from steel smelting and chemical production, nitrous oxide emissions from nitric acid production and perfluorocarbons from aluminium smelting.

Synthetic greenhouse gas emissions (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) are produced from refrigeration and air-conditioning equipment, foam blowing, fire extinguishers, solvents, metered dose inhalers and other electric equipment.

In 2012, industrial processes sector emissions accounted for around 32 Mt CO_2-e in 2012, around 5 per cent of Australia's total domestic emissions.

Chart 3.25: Industrial processes emissions, 2000 to 2030



Source: National Greenhouse Gas Inventory; projections from MMRF.

Industrial processes emissions are projected to decline to 27 Mt CO_2-e in 2020 in the central policy scenario primarily through a decline in emissions intensity in each industry. In the central policy scenario, around 10 Mt CO_2-e of abatement is achieved in the industrial processes sector in 2020. The biggest sources of abatement are expected to be the implementation of nitrous oxide conversion catalysts in chemical production; substitution to less emissions-intensive input materials in metal and mineral production; and the replacement and destruction of halocarbon refrigerants.

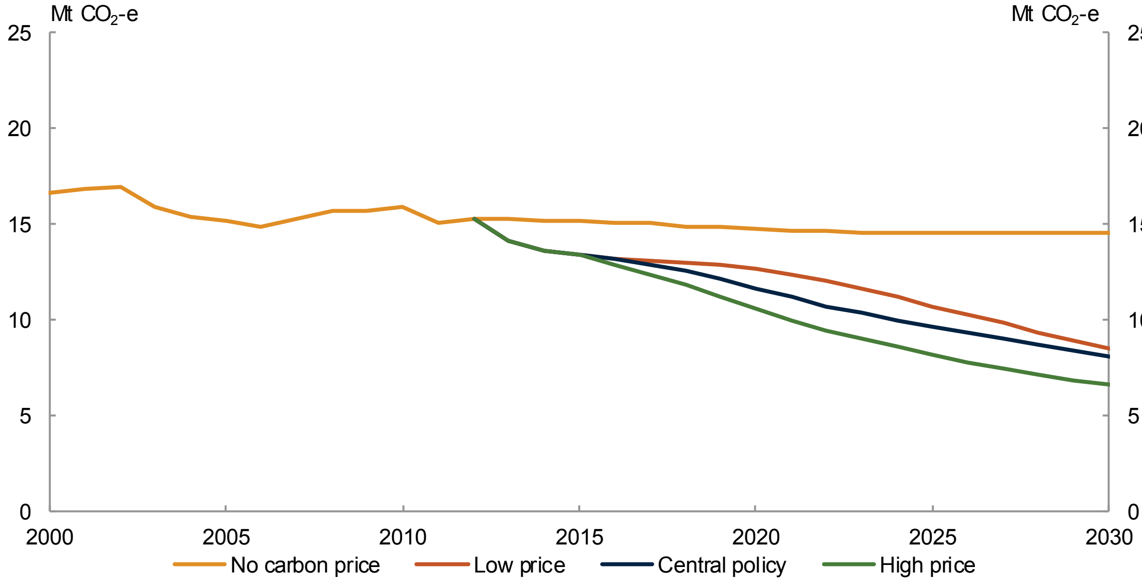
The projections incorporate a transition towards lower production capacity in Australia's aluminium smelting sector. In the chemical industry, production increases as ammonium nitrate plants are built and expanded to produce explosives (for use in mining) and fertiliser. In the cement industry, increased importation of clinker is projected to limit the expansion of domestic production and emissions.

Halocarbons and sulphur hexafluoride are covered under an equivalent carbon price. These synthetic greenhouse gases are not made in Australia — they are imported. Emissions arise from the leaking of these gases into the environment. Abatement is projected through recovery and destruction of synthetics at the end of the lifetime of appliances under the Destruction Incentives Program, and replacement with less emissions-intensive refrigerants. In the central policy scenario, 4 Mt CO_2-e of abatement is achieved in this subsector in 2020.

3.4.6 Waste

The waste sector includes emissions from landfills; domestic, commercial and industrial wastewater treatment; waste incineration; and the biological treatment of solid waste. Emissions consist largely of methane, which is generated when organic matter decays under anaerobic conditions. Waste sector emissions accounted for around 15 Mt CO_2-e in 2012, or about 3 per cent of Australia's total emissions.

Chart 3.26: Waste emissions, 2000 to 2030



Source: National Greenhouse Gas Inventory; projections from DIICCSRTE and MMRF.

Waste emissions are projected to decline to 12 Mt CO_2-e in 2020 in the central policy scenario.

The main drivers of emissions from the solid waste subsector are population growth, increasing waste generation per person, and waste diversion and methane capture rates. In the wastewater subsector key drivers are population growth, growth in industrial production and methane capture rates.

Emissions from solid waste are projected to decrease over time in the central policy scenario due to improvements in methane capture rates and waste diversion, which more than offset the effects of population growth and increased waste generation per person. Wastewater emissions are also projected to decrease over the projections period due to increased methane capture in response to the carbon price.

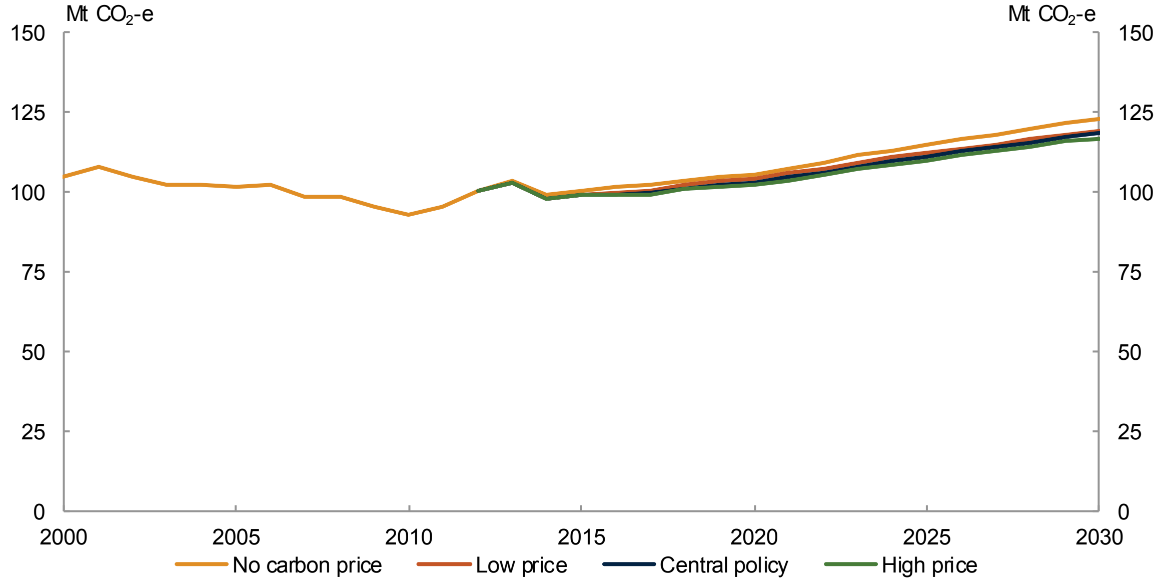
The carbon price and CFI are projected to achieve 3 Mt CO_2-e of abatement in 2020 in the central policy scenario. The biggest sources of abatement in the waste sector are projected to be methane capture for electricity generation or flaring, and the diversion of waste from landfill to recycling and composting facilities. Diversion of waste to biological treatment facilities reduces overall waste emissions, but increases emissions from the biological treatment of solid waste by two-thirds over the period to 2030.

Abatement of emissions from legacy waste is eligible for CFI credits. The CFI is projected to drive a steep reduction in legacy emissions in the early years of the projections period. The abatement achieved through the CFI in the waste sector is projected to decline from 2015 as legacy waste emissions decline. Non-legacy emissions abatement achieved by the carbon price continues to increase across the projections period.

3.4.7 Agriculture

The agriculture sector includes emissions from enteric fermentation, manure management, rice cultivation, agricultural soils, prescribed burning of savanna and field burning of agricultural residues. It does not include emissions from fuel combustion from operating equipment, which are included in the stationary energy sector, or cropland and grazing land management, which are in LULUCF. In 2012, agriculture emissions accounted for 100 Mt CO_2-e, 17 per cent of Australia's total emissions.

Chart 3.27: Agriculture emissions, 2000 to 2030



Source: National Greenhouse Gas Inventory; projections from DIICCSRTE and MMRF.

Agriculture emissions are projected to grow to 103 Mt CO_2-e in 2020 in the central policy scenario. Enteric fermentation from livestock is the main agricultural emissions source (over 65 per cent of agricultural emissions), with beef cattle the largest contributor. Projected international demand for beef, which in turn drives the domestic cattle herd size, is the main factor influencing agricultural emissions. Global income growth, particularly in South-East Asia, is projected to lead to increased demand for Australian exports.

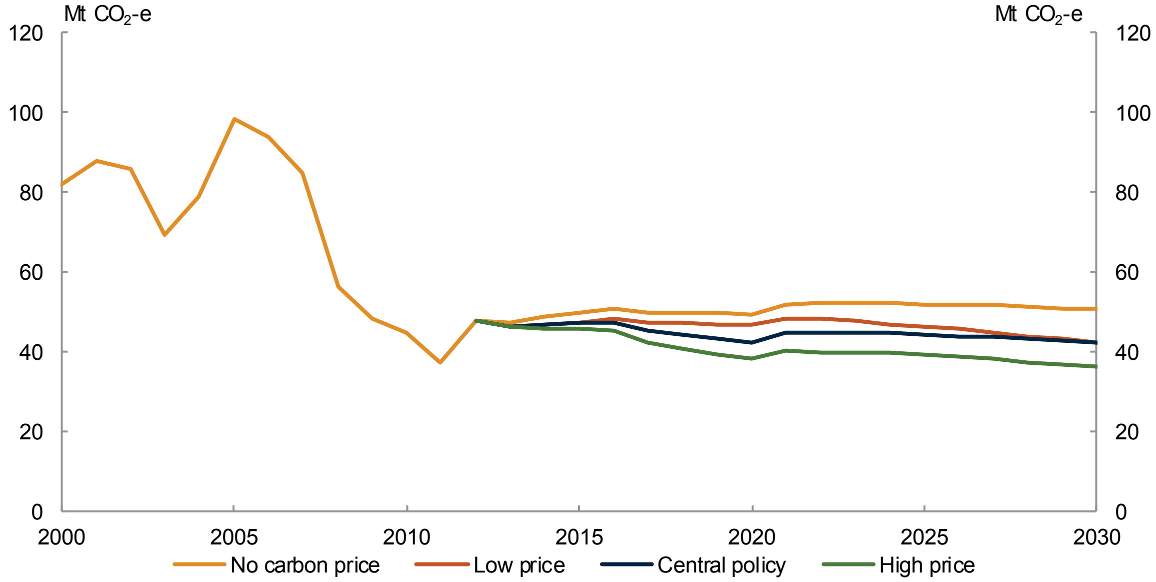
Agriculture emissions are not covered by a carbon price and abatement is driven by the CFI. The CFI is projected to achieve 3 Mt CO_2-e of domestic abatement in 2020 in the central policy scenario, primarily through reduced emissions from livestock (such as capturing methane from manure ponds) and improved savanna fire management practices.

3.4.8 Land use, land-use change and forestry (LULUCF)

The LULUCF sector includes emissions and removals from deforestation, afforestation and reforestation activities. From 2013, emissions and removals from forest management, cropland management, grazing land management and revegetation are also reflected in the LULUCF sector. These new subsectors have been added to reflect the new scope and coverage of Australia's emissions in the second commitment period.

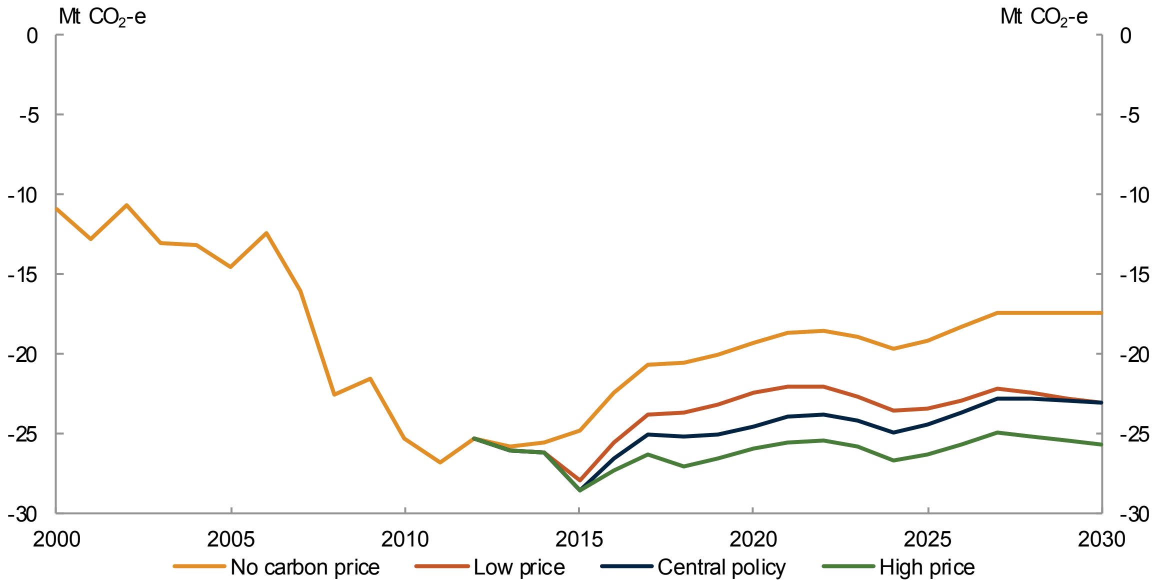
In 2012, emissions from the LULUCF sector accounted for 21 Mt CO_2-e, 4 per cent of Australia's total emissions. The two largest subsectors of the LULUCF sector, deforestation and reforestation account for 47 Mt CO_2-e and -25 Mt CO_2-e of emissions and removals respectively. Annual rates of land clearing have decreased substantially since 1990 with consequent reductions in estimated emissions.

Chart 3.28: Land use and land-use change emissions, 2000 to 2030



Source: DIICCSRTE.

Chart 3.29: Forestry emissions, 2000 to 2030



Source: DIICCSRTE.

LULUCF emissions are projected to be 18 Mt CO_2-e in 2020 in the central policy scenario. The key drivers of LULUCF emissions and removals are government regulations restricting land clearing, and economic conditions in the agricultural and forest sectors. After a slowdown in deforestation from stricter Queensland land clearing laws, easing of these laws through the *Vegetation Management Framework Amendment Act 2013 (Qld)* means land managers are now less likely to require a permit to undertake land clearing activity. Upward pressure on land clearing activity could be expected particularly to the extent that there is excess demand in the farm sector that could be met through an increase the area of land under production. Deforestation levels are projected to stabilise at a level of around 50 Mt CO_2-e per year, assuming no significant changes to land clearing regulations and a balance between growth and harvesting of plantation estates.

Key drivers for removals from reforestation activities include the size of plantation forest estates, past rates of plantation establishment, and harvesting rates. The removals result when carbon is sequestered by forest plantations growing on this land. The projections assume slow growth in the total area of forest plantations to 2030. The high exchange rate has made exporting plantation products more challenging in recent years and economic conditions are projected to remain subdued. New plantation establishment is projected to continue at historically low rates, while in some cases plantation land will be converted to agricultural use following final harvest rather than being re-planted.

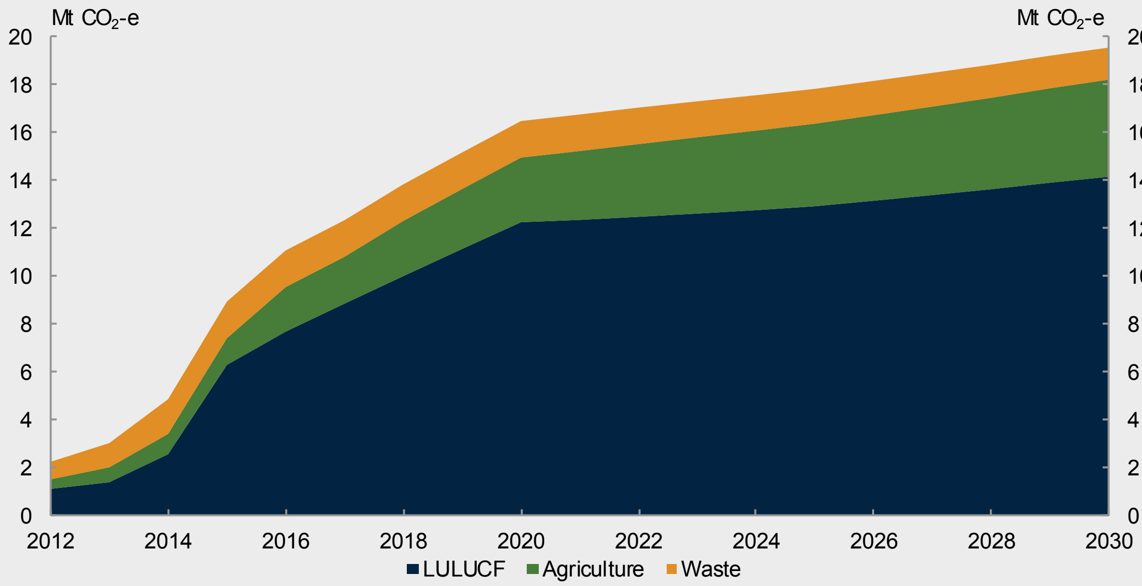
The carbon pricing mechanism does not cover LULUCF activities. However, the CFI provides farmers, land-owners and plantation managers with the opportunity to create credits for Kyoto-compliant land sector activities. The CFI is projected to achieve 12 Mt CO_2-e of domestic abatement in the LULUCF sector in 2020 in the central policy scenario. Avoided deforestation (4 Mt CO_2-e) and forest management practices (3 Mt CO_2-e) are the largest contributors to this CFI abatement.

Forest management emissions are projected to remain at low levels due to continued historically low harvesting rates in native forests. This decline has been associated with changes in supply factors such as increasing supply from plantations. Demand factors such as the international price of harvested wood products, the value of the Australian dollar and shifts in demand patterns, especially between Japan and China, have also contributed to the decline in harvesting.

Box 3.4: Abatement from the Carbon Farming Initiative

The reduction in domestic emissions achieved in the policy scenarios, as described above, is delivered partly through the application of a carbon price (or equivalent) to emissions from a range of sources, and partly through the CFI. The CFI provides an incentive for emissions reductions in the LULUCF and agriculture sectors, and the waste sector for legacy waste. These sectors are not covered by the carbon price. In the central policy scenario, CFI abatement is estimated to be 16 Mt CO_2-e, in 2020, rising to 20 Mt CO_2-e in 2030. The biggest sources of abatement are projected to be from avoided deforestation and forest management activities, which are included within the LULUCF sector. Further details on projected CFI abatement are in Appendix C.

Chart 3.30: Abatement from the CFI by sector
Central policy scenario



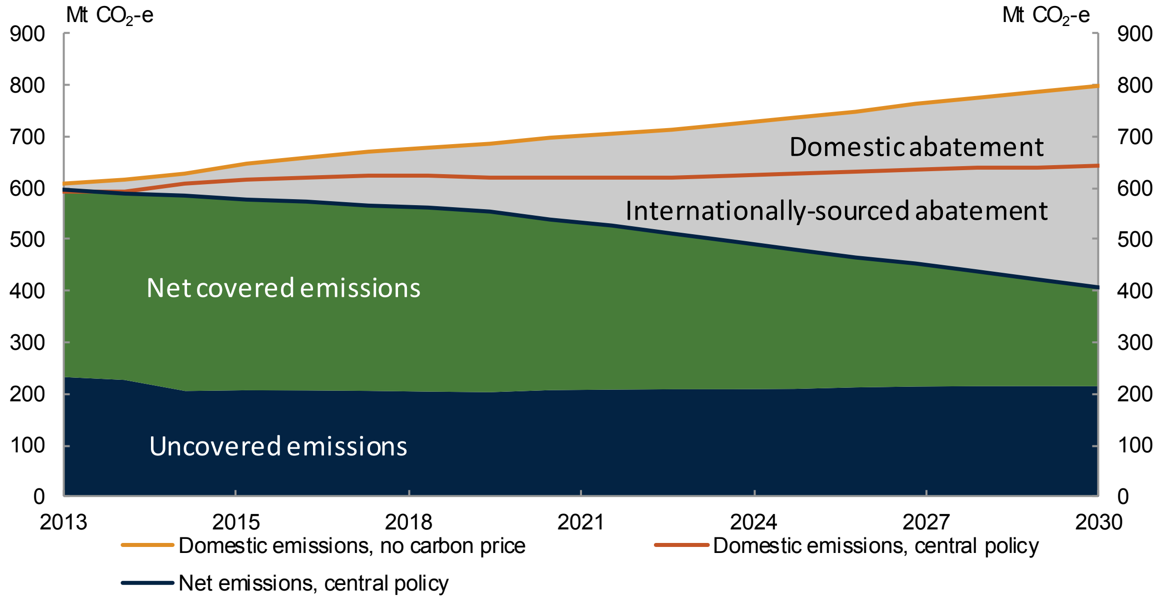
Source: Projections from DIICCSRTE.

3.5 Covered emissions

Under the carbon pricing mechanism, entities that emit greenhouse gases that are covered by the scheme attract a liability. Covered emissions are those that attract a liability under the carbon pricing mechanism as well as those under an equivalent carbon price. Direct coverage includes emissions from stationary energy, industrial processes, fugitive emissions (other than from decommissioned coal mines), and emissions from non-legacy waste. An equivalent carbon price is applied to some transport fuels and importation of synthetic greenhouse gases. Overall, this covers around two-thirds of Australia's emissions directly and through other means. Emissions from agriculture, deforestation and reforestation are not covered by the carbon price or an equivalent carbon price, but the CFI provides a link to the carbon price by allowing these sectors to create offset units to trade into the compliance market.

The projections indicate that net covered emissions will decline as the carbon pollution cap binds. Total covered emissions—under the mechanism and through effective carbon pricing—net of international abatement are projected to reach 352 Mt CO_2-e in 2020 and 194 Mt CO_2-e in 2030 in the central policy scenario. After the inclusion of heavy road vehicles under the carbon price, the level of uncovered emissions are projected to remain relatively stable in the absence of new policies, with declines over time in legacy emissions in waste and synthetic greenhouse gases and light vehicle transport offset by growth in agriculture sector emissions.

Chart 3.31: Covered and uncovered emissions, 2013 to 2030
Central policy scenario



Note: Net covered emissions are emissions covered directly by a carbon price and through an effective carbon price, less abatement sourced overseas.
Source: Estimates from MMRF.

3.6 Economic effects in alternative price scenarios

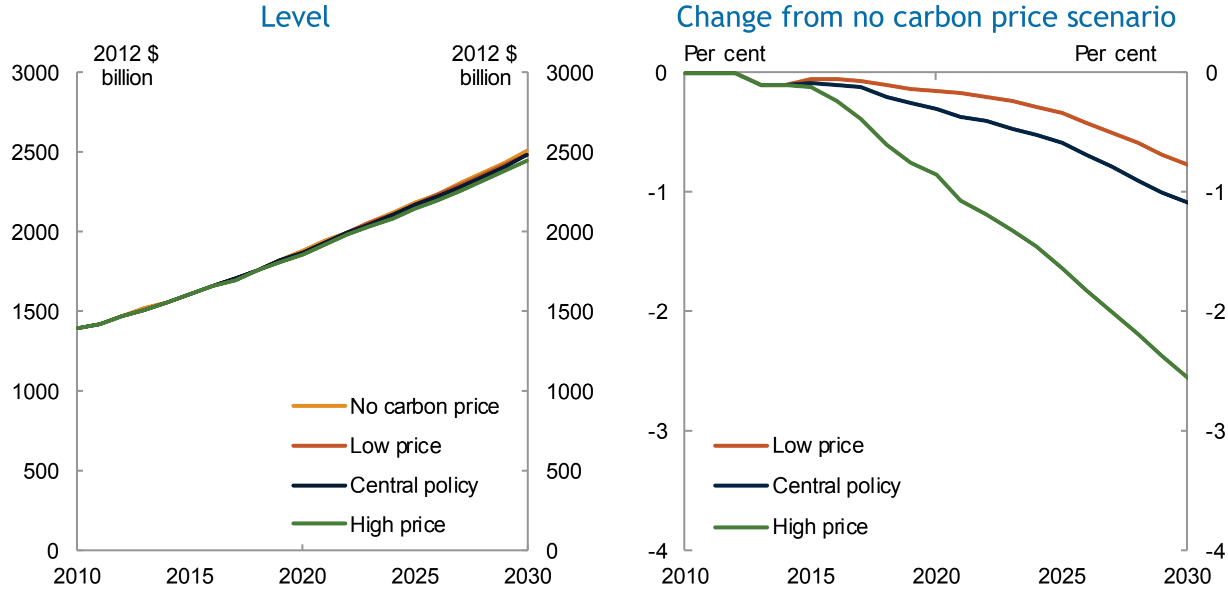
The economic effects of carbon pricing vary with the level of the carbon price and the level of the emissions cap. The level of the carbon price determines the extent of transformation of the emissions intensity of production within industries and the industry structure of the economy, which tends to reduce national production and income compared to their levels in the absence of carbon pricing. While this process reduces domestic emissions, for a country like Australia with a rapidly growing economy and relatively cheap fossil fuels, it would be more expensive to meet the whole abatement task through domestic abatement. Buying international carbon permits allows Australia to run a higher level of domestic emissions while achieving a particular net emissions target. However, buying international permits involves transferring income overseas, which tends to reduce national income compared to a scenario with no carbon pricing. In all scenarios, these effects are small compared with the ongoing growth in GDP and GNI per person over time.

The high price scenario is set in a world taking more ambitious action than the other scenarios. Differences in economic outcomes in that scenario, compared with the other three scenarios, partly reflect the effects of action domestically and partly the effects of international action on Australian trade flows.

3.6.1 Economic growth

The alternative carbon pricing scenarios present only modestly different economic outlooks. In each of the scenarios, GDP continues to grow, to be more than 65 per cent larger in 2030 than it was in 2012. Over the period from 2012 to 2030, the average annual rate of GDP growth is 2.9 per cent in the central policy scenario compared with 3.0 per cent in the no carbon price scenario.

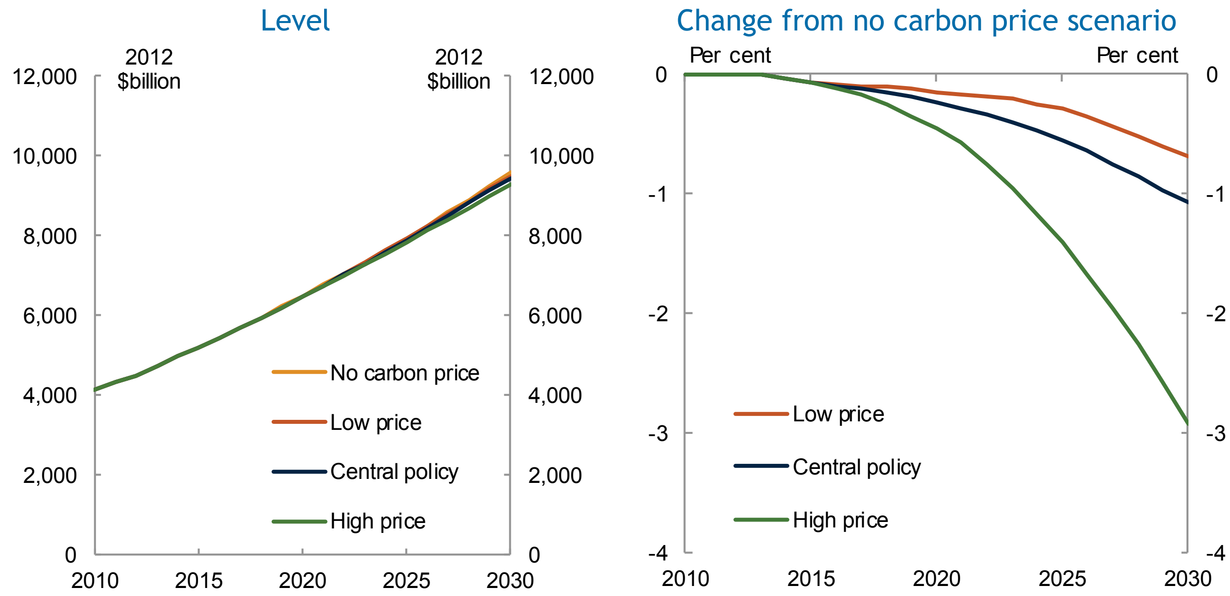
Chart 3.32: Gross domestic product



Source: Estimates from MMRF.

Carbon pricing affects factors of production, such as labour and capital, in different ways. The size of the capital stock depends upon the rate of return available on investment. Higher carbon prices increase the cost of constructing and running some capital equipment, which reduces slightly firms' incentives to invest in capital, and also reduces the rate of growth of some emissions-intensive sectors, which are typically more capital-intensive than the rest of the economy.

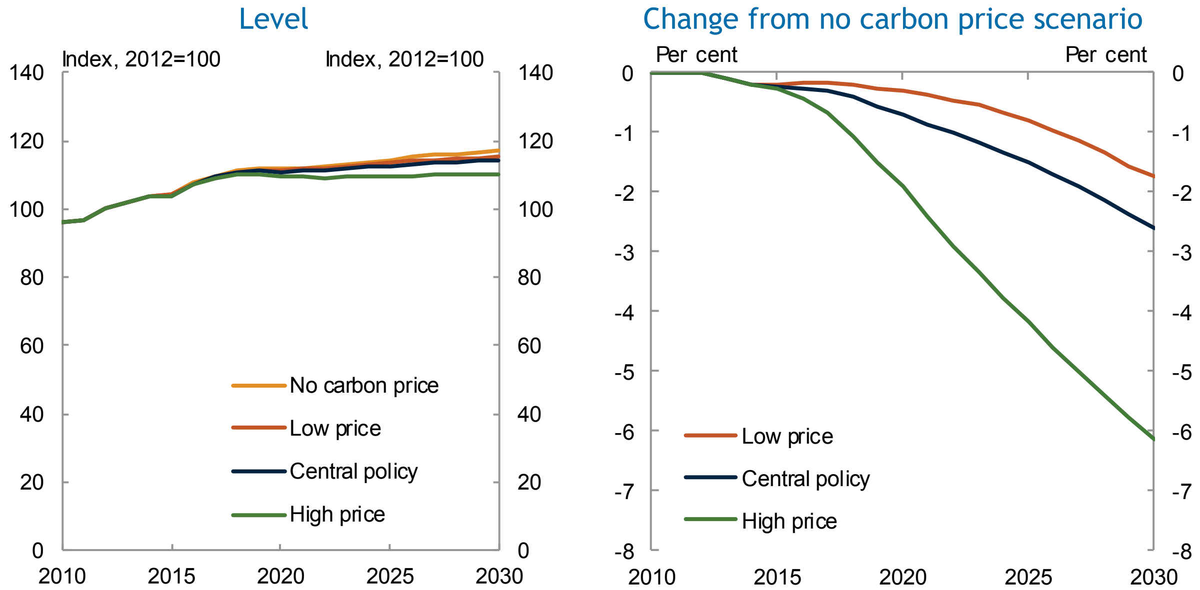
Chart 3.33: Capital stock



Source: Estimates from MMRF.

Higher carbon prices also affect the demand for labour, as a result of slower output and capital growth. Household choices around their level of labour force participation are assumed not to change, so the level of employment is largely unaffected. Real wages grow more slowly in the scenarios with higher carbon prices.

Chart 3.34: Real wages



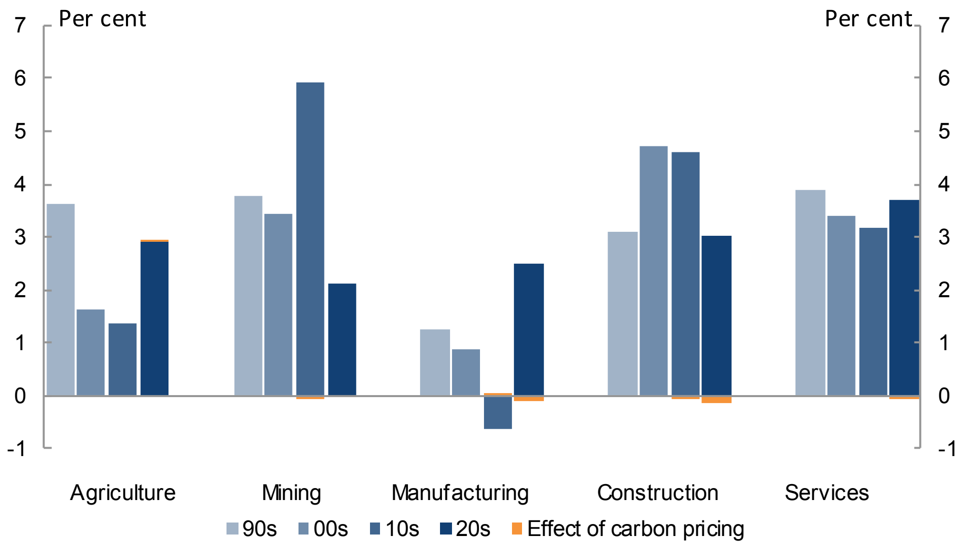
Source: Estimates from MMRF.

Higher or lower carbon prices would also affect the composition of the Australian economy. Over time, higher prices would see resources shift from emissions-intensive to low or less emissions-intensive industries. At the broad sectoral level, structural changes due to higher or lower carbon prices would be small compared to other ongoing changes in the economy. Some sectors, such as mining and construction, grow more slowly with carbon pricing. 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 grow at similar rates in all scenarios.

Chart 3.35: Output growth by broad sector, 1990 to 2030

Annual average growth

No carbon price scenario and effect of carbon pricing



Source: ABS; projections from MMRF.

Much of the effect of carbon pricing on the structure of the economy is through the transition of resources between different industries within the same sector. Relative carbon intensity affects how industries respond to pricing carbon. Responses also differ to changes in assumptions about global ambition, which affect export demand for Australian energy through changes in carbon prices in Australia and overseas, and changes in assumptions about domestic prices alone.

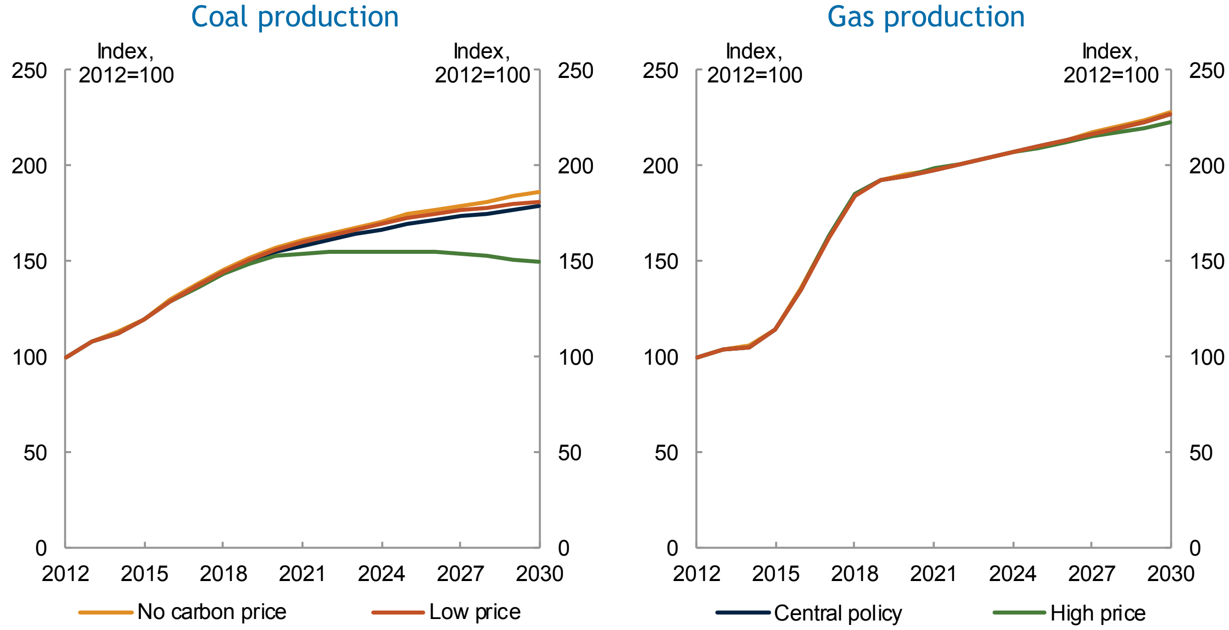
For example, within mining, some sectors, such as iron ore mining, grow faster with a higher domestic carbon price. Energy extraction industries, particularly coal mining, grow less quickly than they otherwise would. While domestic pricing of fugitive emissions in coal mining reduces somewhat production in the industry, the extent of international action to reduce emissions has a larger effect, as is evident in the high price scenario. Coal production grows steadily throughout the period in all scenarios set against a backdrop of medium global action. In the high price scenario with a backdrop of more ambitious global action, however, coal production grows over the period to 2020 but is flat through the decade to 2030. Note that internationally, as presented in Chapter 2, carbon capture and storage is projected not to be installed prior to 2030.

Table 3.3: National economic indicators

	At 2000	At 2010	At 2012	At 2020				At 2030			
				No carbon price	Low price	Central policy	High price	No carbon price	Low price	Central policy	High price
Emissions target											
Change from 2000 level, per cent					-5	-5	-25		-80	-80	-80
Domestic emissions, Mt CO_2-e	586	590	600	685	651	620	551	801	672	644	465
Change from no carbon price scenario, Mt CO2-e	-	-	-	-	35	65	134	-	129	156	335
Change from 2000 level, per cent	-	1	2	17	11	6	-6	37	15	10	-21
Internationally-sourced abatement, Mt CO_2-e	-	-	-	-	96	65	114	-	263	236	135
Emissions intensity of GDP, kg CO_2-e/$	0.57	0.42	0.41	0.36	0.35	0.33	0.30	0.32	0.27	0.26	0.19
Emissions per person, t CO_2-e per person	31	26	26	26	25	24	21	26	22	21	15
Carbon price, real, $/t CO_2-e		-	-	0	6	30	73	0	54	54	134
GNI per person, $ '000	45.9	57.7	62.3	66.7	66.6	66.5	65.8	73.3	72.3	72.1	70.1
Average annual growth, per cent per year	-	-	-	0.8	0.8	0.8	0.7	0.9	0.8	0.8	0.7
GDP, $ '000 billion	1.030	1.392	1.475	1.882	1.880	1.877	1.866	2.510	2.491	2.483	2.446
Average annual growth, per cent per year	-	-	-	3.1	3.1	3.1	3.0	3.0	3.0	2.9	2.9
Employment, million people	8.9	11.0	11.5	12.9	12.9	12.9	12.9	14.7	14.6	14.6	14.6
Household consumption per person, average annual growth, per cent per year	-	-	-	1.2	1.2	1.2	1.0	0.9	0.9	0.8	0.7
Real wages, average annual growth, per cent per year	-	-	-	1.4	1.4	1.3	1.2	0.9	0.8	0.8	0.5
Capital stock, average annual growth, per cent per year	-	-	-	4.7	4.7	4.7	4.6	4.3	4.2	4.2	4.1

Note: All dollar values are in Australian dollars at 2012 prices. Annual growth rates are from 2012. Emissions intensities relate to domestic emissions only. Domestic emissions reductions associated with GreenPower of around 2 Mt CO_2-e per year are in addition to the stated emissions target.
Source: ABS, National Greenhouse Gas Inventory; projections from MMRF.

Chart 3.36: Energy extraction industries



Source: Estimates from MMRF.

Within manufacturing, the effects of carbon pricing depend upon the level of assistance provided to emissions-intensive industries through the Jobs and Competitiveness Program, and the responsiveness of the sectors to changes in the real exchange rate. Many emissions-intensive industries receiving assistance are projected to grow as fast to 2020 in the central policy scenario as in the no carbon price scenario, but grow slower after assistance is assumed to be phased out in the first half of the 2020s. Over time, employment and investment flows into less emissions-intensive manufacturing sectors which become more competitive. Industries like textiles, clothing and footwear and motor vehicles and parts grow a little faster in the central policy scenario than in the no carbon price scenario.

Comparisons between the central policy scenario and the high price scenario are more complex. The latter makes the modelling assumption that the world takes more ambitious action, without assistance to emissions-intensive industries in other countries. This tends to push up production costs and world prices for emissions-intensive goods. In the near term, this scenario would tend to increase the competitiveness of some Australian industries—such as steel and petroleum refining—and in the long term the effect on competitiveness depends on how the emissions intensities of production in Australia compared to competitors in other countries.

Agricultural activity emissions are assumed to be excluded from carbon price coverage, but abatement occurs through the CFI. Overall, agricultural output tends to grow at a similar rate in all scenarios.

Construction activity follows the level of investment in the capital stock overall and is lower in the scenarios with higher carbon prices, as is the output of the cement industry, which provides the construction sector with intermediate inputs.

Table 3.4: Gross output, by industry, 2020

Industry	Change from 2012			
	No carbon price	Low price	Central policy	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture	**15**	**15**	**15**	**16**
Sheep and cattle	20	20	20	20
Dairy cattle	17	17	17	18
Other animals	23	25	25	26
Grains	1	1	1	2
Other agriculture	23	23	23	24
Agricultural services and fisheries	18	18	19	20
Mining	**60**	**60**	**59**	**59**
Coal	58	57	55	53
Oil	1	1	1	1
Gas	95	95	95	95
Iron ore	71	71	71	73
Non-ferrous ore	60	60	59	59
Other	32	32	32	33
Manufacturing	**0**	**0**	**0**	**0**
Meat products	21	21	21	22
Other food	11	11	11	12
Textiles, clothing and footwear	-12	-12	-12	-9
Wood products	10	10	10	11
Paper products	-1	-1	-1	0
Printing	12	12	12	12
Refinery	-25	-26	-26	-24
Chemicals	-21	-21	-21	-21
Rubber and plastic products	-6	-6	-6	-6
Non-metal construction products	8	8	8	7
Cement	8	8	7	6
Iron and steel	-7	-7	-7	-5
Alumina	27	28	30	25
Aluminium	-17	-17	-16	-17
Other metals	-9	-9	-8	-16
Metal products	5	5	5	5
Motor vehicles and parts	-13	-13	-13	-11
Other	-5	-5	-5	-4
Construction	**38**	**37**	**37**	**35**
Services	**28**	**28**	**28**	**27**
Electricity: coal-fired	3	-2	-7	-36
Electricity: gas-fired	-23	-18	-11	54
Electricity: hydro	1	4	5	5
Electricity: other	210	215	222	263
Electricity supply	13	11	9	5
Gas supply	36	36	37	40
Water supply	15	14	14	14
Trade	22	22	21	21
Accommodation and hotels	18	17	17	16
Road transport: passenger	21	21	21	20
Road transport: freight	26	26	26	25
Rail transport: passenger	26	26	27	29
Rail transport: freight	55	55	55	55
Water transport	24	24	24	24
Air transport	34	34	33	33
Communication	40	40	40	39
Financial	35	35	35	34
Business	40	40	40	40
Public	21	21	21	20
Other	23	23	23	21

Source: Estimates from MMRF.

Table 3.5: Gross output, by industry, 2030

Industry	Change from 2012			
	No carbon price	Low price	Central policy	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture	**54**	**54**	**54**	**54**
Sheep and cattle	43	43	42	44
Dairy cattle	31	32	32	33
Other animals	56	58	58	61
Grains	30	30	29	27
Other agriculture	83	84	84	84
Agricultural services and fisheries	89	91	91	93
Mining	**98**	**97**	**96**	**92**
Coal	86	81	79	50
Oil	2	2	2	2
Gas	128	127	127	123
Iron ore	139	141	143	152
Non-ferrous ore	106	106	104	109
Other	57	58	58	61
Manufacturing	**27**	**27**	**26**	**28**
Meat products	63	65	65	68
Other food	43	44	44	46
Textiles, clothing and footwear	24	27	28	39
Wood products	57	56	55	60
Paper products	28	28	28	31
Printing	53	54	54	55
Refinery	-17	-21	-22	-22
Chemicals	-15	-17	-17	-14
Rubber and plastic products	18	18	18	21
Non-metal construction products	41	41	40	43
Cement	22	18	17	13
Iron and steel	-5	-10	-11	-11
Alumina	77	57	52	25
Aluminium	17	-5	-22	-46
Other metals	-3	-3	-3	-5
Metal products	35	34	33	32
Motor vehicles and parts	30	32	32	38
Other	30	31	31	37
Construction	**85**	**82**	**82**	**74**
Services	**85**	**83**	**83**	**82**
Electricity: coal-fired	32	8	-1	-70
Electricity: gas-fired	-28	1	6	3
Electricity: hydro	5	10	6	6
Electricity: other	315	373	362	1154
Electricity supply	39	33	27	21
Gas supply	61	61	62	58
Water supply	39	38	38	37
Trade	65	64	63	62
Accommodation and hotels	43	41	41	38
Road transport: passenger	44	43	43	40
Road transport: freight	79	79	78	79
Rail transport: passenger	45	51	53	67
Rail transport: freight	125	127	127	129
Water transport	72	71	71	70
Air transport	78	78	78	81
Communication	112	110	110	107
Financial	98	97	97	96
Business	124	124	123	123
Public	75	75	75	74
Other	58	56	55	51

Source: Estimates from MMRF.

Table 3.6: Gross output, by sector, 2020
Change from 2012

	No carbon price	Low price	Central policy	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture	**15**	**15**	**15**	**16**
Mining	**60**	**60**	**59**	**59**
Coal, oil & gas	65	64	63	62
Other mining industries	57	56	56	57
Manufacturing	**0**	**0**	**0**	**0**
High emissions-intensive manufacturing	-9	-9	-9	-11
Low emissions-intensive manufacturing	5	5	5	6
Construction	**38**	**37**	**37**	**35**
Services	**28**	**28**	**28**	**27**

Source: Estimates from MMRF

Table 3.7: Gross output, by sector, 2030
Change from 2012

	No carbon price	Low price	Central policy	High price
	Per cent	Per cent	Per cent	Per cent
Agriculture	**54**	**54**	**54**	**54**
Mining	**98**	**97**	**96**	**92**
Coal, oil & gas	91	88	87	72
Other mining industries	103	103	103	108
Manufacturing	**27**	**27**	**26**	**28**
High emissions-intensive manufacturing	5	2	0	-1
Low emissions-intensive manufacturing	42	43	43	46
Construction	**85**	**82**	**82**	**74**
Services	**85**	**83**	**83**	**82**

Source: Estimates from MMRF.

3.6.2 Regional projections

The economies of all states are projected to grow. Differences in growth rates across states and industries reflect different assumptions about population growth and different patterns of industrial production. The expansion of the LNG industry will play an important role in Queensland and Western Australia, but not in other states, for example. The technical assumptions used to allocate national growth by state are described in Appendix A.

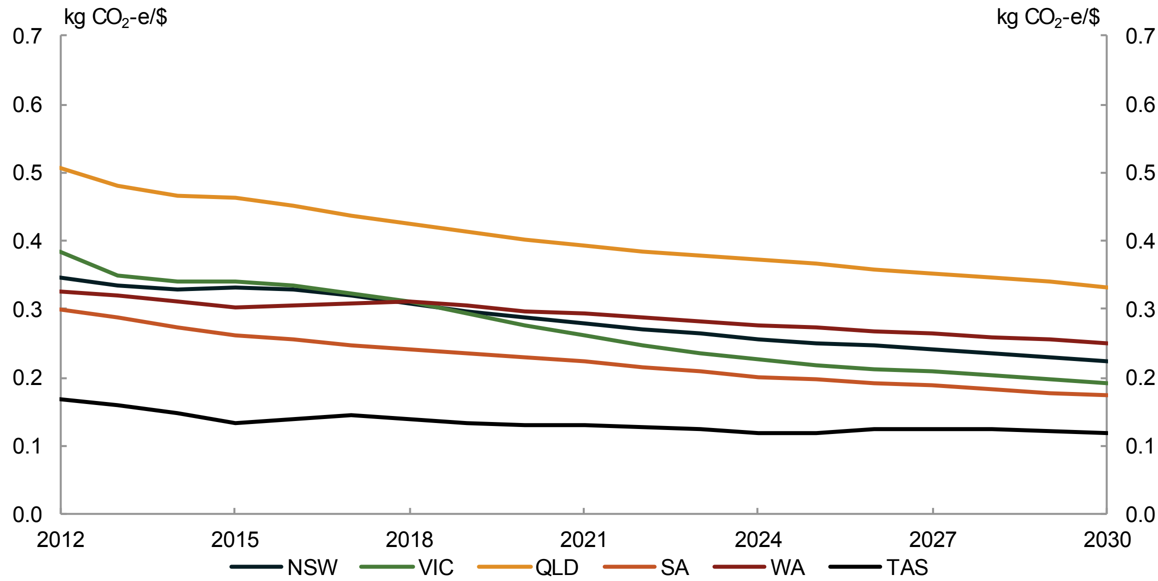
Table 3.8: Growth in output by state and sector
Change from 2012 to 2030

	New South Wales		Victoria		Queensland	
	No carbon price	Central policy	No carbon price	Central policy	No carbon price	Central policy
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Agriculture	50	49	53	53	55	56
Mining	105	92	58	55	116	114
Manufacturing	21	20	27	27	39	36
Construction	63	59	80	77	106	102
Services	81	80	83	82	97	95
	South Australia		Western Australia		Tasmania	
	No carbon price	Central policy	No carbon price	Central policy	No carbon price	Central policy
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Agriculture	58	60	51	51	65	65
Mining	-8	-12	116	116	101	95
Manufacturing	28	29	31	27	15	13
Construction	37	33	126	123	70	68
Services	65	64	97	95	51	49

Source: Estimates from MMRF.

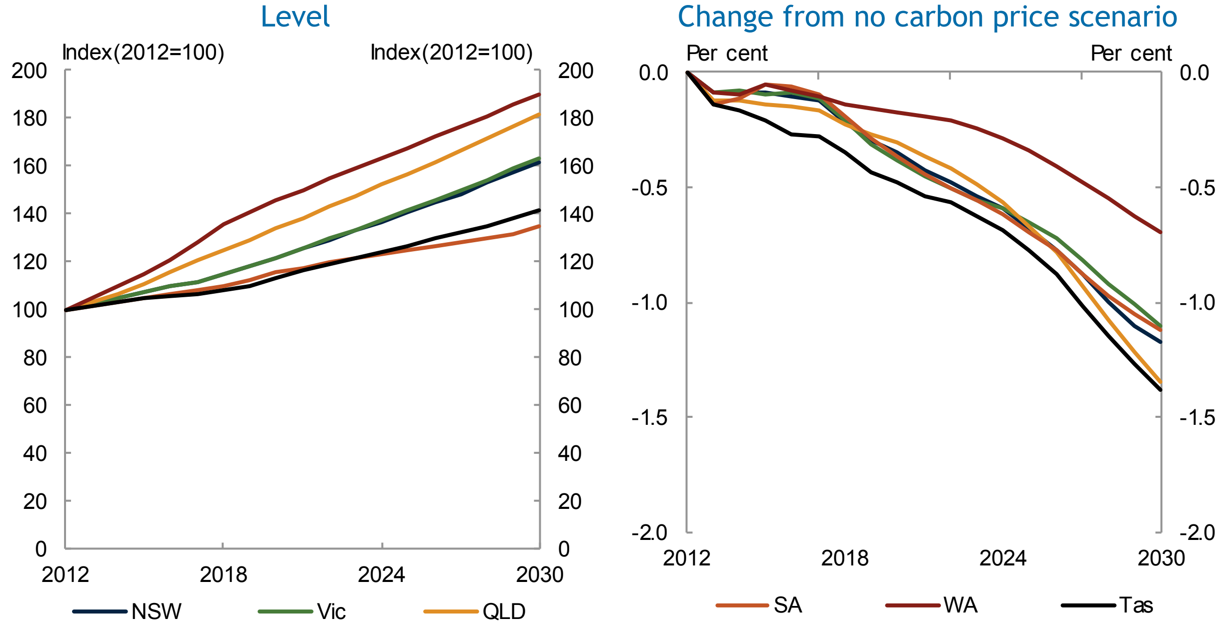
The effect of carbon pricing on gross state product (GSP) depends upon the extent of abatement achieved within each state. This depends upon each state's emissions intensity, which in turn depends on its industry structure, and the extent of reduction in emissions intensity achieved. To the extent the carbon price affects the exchange rate, the state's trade intensity also matters.

Chart 3.37: Emissions intensity by state
Central policy scenario



Source: Estimates from MMRF.

Chart 3.38: Gross state product, central policy scenario



Source: Estimates from MMRF.

It is difficult to quantify the impact of carbon pricing at a sub-state regional level, or for relatively small economies such as the Northern Territory and Australian Capital Territory, 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.

Box 3.5: Timing of the move to a flexible price

The central policy scenario assumes a transition to a flexible price from 1 July 2014. Australia's domestic emissions in 2014-15 are projected to be 609 Mt CO_2-e and, with additional abatement sourced overseas, net emissions are 584 Mt CO_2-e in that scenario.

A sensitivity analysis was undertaken to explore the effect of retaining the fixed price of $25.40 in 2014-15, as legislated as part of the Clean Energy Future plan. The higher carbon price means that more of Australia's abatement task in that year would be achieved through domestic abatement. The modelling projects domestic emissions to be 598 Mt CO_2-e in 2014-15. With more of the abatement task achieved through domestic emissions reductions, GDP is projected to be lower than in the central policy scenario by 0.03 per cent in that year. Changes in GNI would depend upon assumptions about how the difference between domestic and net emissions is addressed. In subsequent years, domestic emissions and GDP are projected to be essentially the same as in the central policy scenario.

3.6.3 Implications for national income

Real income continues to grow in all scenarios. This section focuses on the effects of the alternative policy scenarios on real gross national income (GNI) per person, which is a measure of the volume of goods and services that Australians can buy with the income they generate from production and how those effects come about.

While 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 movements in the terms of trade, which is the price of the goods and services Australia exports relative to the price of imports.

Purchasing foreign permits involves a transfer of income from Australia to other countries. The income outflow leads to lower terms of trade and a lower exchange rate, further reducing income and welfare. The effect on GNI depends on the prevailing world carbon price and the exchange rate, as well as Australia's national emissions trajectory. 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 trajectory.

GNI per person is projected to grow around 0.8 per cent per year over the period to 2030 in the central policy scenario. This projected growth rate is below the rates achieved in the previous two decades of economic growth due to the assumed return of the terms of trade towards more sustainable long-run levels and the ageing of the population. It compares with projected growth in GNI per person of 0.9 per cent per year over the period to 2030 in the no carbon pricing scenario. The difference in rates of growth means that the level of GNI per person attained in the no carbon price scenario in 2030 is attained 24 months later in the central policy scenario.

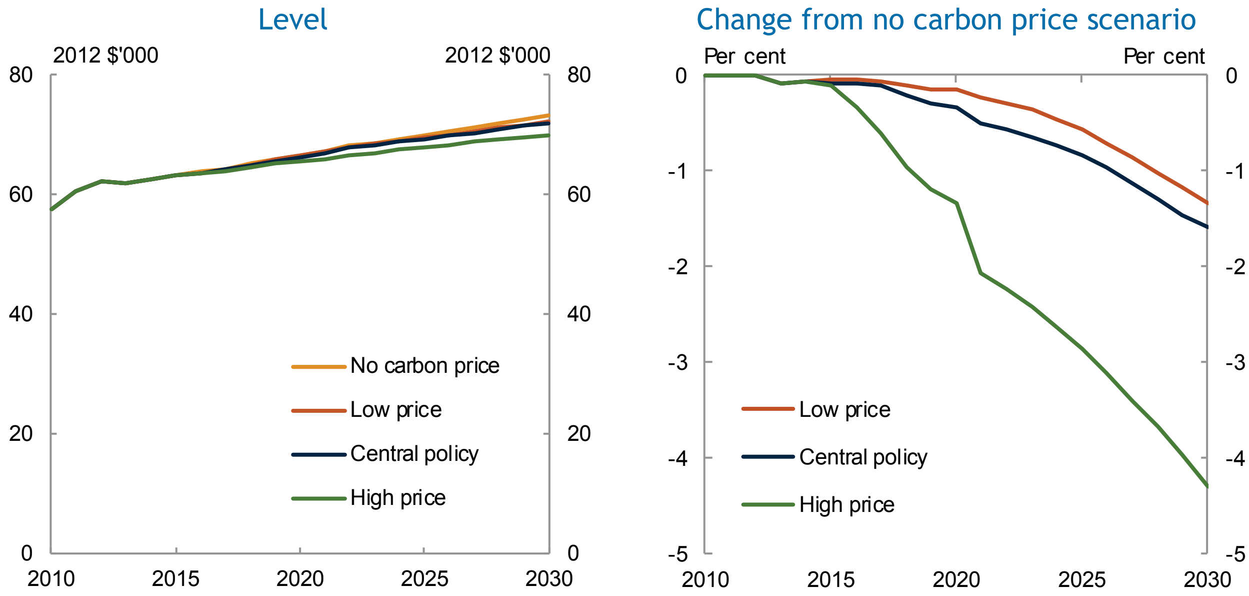
Table 3.9: GNI per person

Average annual growth

	No carbon price	Low price	Central policy	High price
	Per cent	Per cent	Per cent	Per cent
2012 to 2020	0.8	0.8	0.8	0.7
2020 to 2030	0.9	0.8	0.8	0.6
Average, 2012 to 2030	0.9	0.8	0.8	0.7

Source: Estimates from MMRF.

Chart 3.39: GNI per person



Source: Estimates from MMRF.

Box 3.6: Comparison of economic effects with previous modelling

Estimates of the economic effects of carbon pricing are somewhat lower in the current report than in previous modelling (Australian Government 2011). There are a number of contributors to the changes including lower projections for the international carbon price consistent with achieving stabilisation of atmospheric concentrations at 550ppm in the long term, lower projections for emissions in the no carbon price scenario implying a reduction in the estimated abatement task in 2020, and access to cheaper international abatement up to the CER sub-limit over the period between 2015 and 2020.

Table 3.10: Comparison of economic effects in 2020

	Current report	Strong growth, low pollution
	Central policy scenario compared with no carbon price scenario	Government policy scenario compared with medium global action scenario
Australian carbon unit price, nominal $	36	38
Domestic abatement, Mt CO2-e	65	58
GDP, change from no price scenario, per cent	-0.31	-0.34
Internationally-sourced abatement, Mt CO2-e	65	94
GNI, change from no price scenario, per cent	-0.34	-0.50

Note: CFI abatement was included in the medium global action scenario, but is not included in the no carbon price scenario.
Source: Australian Government (2011) and estimates from MMRF.

3.7 Implications of alternative targets

This section steps through, from a conceptual perspective, the key economic effects that would flow from changes in the levels of the caps, and then presents modelled estimates of the effects of alternative targets on GNI that take account of some of these economic effects.

3.7.1 Economic effects of alternative targets

A more ambitious emissions reduction target would require a reduction in the scheme cap. Reducing the level of the scheme cap involves reducing the number of carbon units sold by the Australian Government. The main economic effects will be an increase in the purchase of foreign permits and a reduction in Government revenue from permit sales. It is assumed that the price of Australian carbon units will move in line with the EUA price and the changes in the level of the Australian scheme cap will have no material impact on that price, so that there is no direct change in business demand for permits. That is, the direct economic effects of reducing the level of the scheme cap by one tonne CO_2-e will be to increase foreign income outflows by the carbon price, and reduce Australian Government revenue by the carbon price.

In general, the effects on gross national income may be expected to be larger than the carbon price because the increase in foreign income outflows tends to lower the Australian terms of trade, and replacing forgone carbon revenue from alternative sources will typically carry additional welfare costs. These two effects are described in more detail below. Taken together, they suggest a rough rule of thumb that the welfare cost of reducing the level of the scheme cap by one tonne CO_2-e and replacing the forgone revenue with other taxes is around 1.55 times the carbon price.

Foreign income flows

A reduction in the level of the scheme cap will increase foreign income outflows.[2] These payments overseas will affect the balance of payments. Exports must be higher to generate the additional foreign currency and Australian firms will generally need to lower export prices in order to increase their share of world markets. This will tend to reduce the terms of trade, which flows through to an additional reduction in the real value of gross national income and welfare.

The decline in the terms of trade will also increase the price of tradable capital goods relative to the price of domestic production. This will tend to lower the rate of return on investment in the near term and lead to lower capital stocks and lower production in the long term, which further reduces incomes.

Revenue

The sale of carbon permits is a source of revenue for the Australian Government and reduction in the level of the scheme cap will reduce that revenue. One way to consider the economic costs of replacing lower permit sales revenue is to look at the typical costs associated with other general sources of revenue. An alternative response to lower revenue may be a reduction in spending or an increase in debt issuance that permits the revenue or expenditure response to be delayed; consideration of the economic effects of those options is, however, more difficult to quantify within economic models.

Taxes fund public services and transfer payments to improve the wellbeing of the Australian people as a whole, but by themselves generally result in some loss of economic efficiency. For example, a tax may reduce incentives for people to work or invest or induce them to alter their consumption patterns. This leads to losses in consumer welfare — an 'excess burden' of taxation — which can be expressed relative to the amount of revenue raised. An efficient tax system involves taxes that result in relatively low losses in consumer welfare per dollar of revenue raised.

There is a range of uncertainty around the size of the excess burden of individual taxes and there are also likely to be significant differences between different taxes. Reasonable estimates suggest that the marginal excess burden of taxation is typically around 25 per cent. This is broadly in line with the estimates by KPMG-Econtech (2010), in work commissioned in support of the Australia's Future Tax System Review, of the marginal excess burden of labour income tax, the single largest source of revenue. It is also consistent with the weighted average of the estimated marginal excess burdens across all Australian taxes that KPMG-Econtech modelled, though the estimates for individual taxes range from -8 per cent to +92 per cent. Such an assumption is also consistent with advice in the Department of Finance and Administration's (2006) *Handbook of Cost Benefit Analysis*.

3.7.2 Modelling of alternative targets

This section presents estimates of the welfare effects, measured by real gross national income, of changing scheme caps based on MMRF model simulations that incorporate general equilibrium

2 As the ABS has not finalised its accounting treatment of the purchase by Australians of foreign permits; the treatment here is the same as that used in Australian Government (2008, 2011).

effects of higher foreign income outflows, but not the excess burden associated with alternative revenue sources.

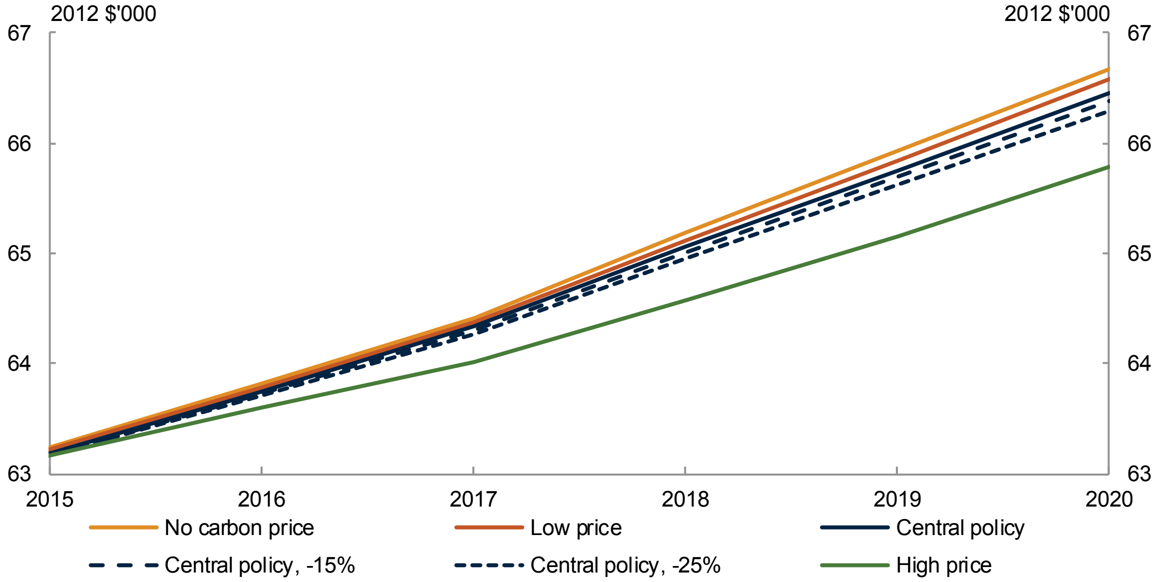
Regarding revenue, a standard modelling assumption is maintained that differences in government revenue associated with higher or lower carbon prices, or tighter or looser national trajectories, are returned to households as lump sum transfers. An alternative modelling approach would have been to assume the change in revenue is made up through changes in some other taxes, in which case the welfare costs associated with revenue collection would also have been modelled; this approach was not taken because such an assumption would necessarily have been arbitrary. The assumed marginal excess burden of taxation of 25 per cent would be in addition to the effects on GNI modelled here.

Under the central policy scenario, scheme cap levels that are consistent with abatement targets in 2020 of 5, 15, and 25 per cent below 2000 levels were modelled. Modelling results are consistent with a linear relationship between abatement targets and real GNI impacts throughout the period of 2015 to 2020. They suggest that reducing the cap by an additional tonne is associated with a change in GNI of around 1.3 times the carbon price.

These estimates reflect the production and trade structure of the MMRF model. Alternative models produce different estimates—with lower (or higher) estimates coming from models that have more (or less) elastic export demand and supply, and the elasticity of substitution between labour and capital also plays a role. Equivalent simulations within other models such as GTEM, the International Monetary Fund's Global Integrated Monetary and Fiscal Model (GIMF) and Independent Economics' Computable General Equilibrium Model suggest a range of estimates between 1.15 and 1.75.

Modelling results also suggest a small impact on industry composition. Reducing the cap lowers the exchange rate and terms of trade, thereby supporting output growth in export-oriented and import-competing industries, such as agriculture, mining and manufacturing. On the other hand, more domestically-focused industries, such as construction and services, grow more slowly with tighter caps. The impact is relatively small with changes in sector output levels in 2020 being less than 0.4 percentage points across the alternative caps in the central policy scenario.

Chart 3.40: GNI per person under various caps and carbon prices



Source: Estimates from MMRF.

Appendix A: Modelling framework and assumptions

Introduction

The report uses a suite of models because no one model adequately captures global, national and sectoral dimensions. The suite of models used is largely the same as described in previous modelling reports (Australian Government 2008, 2011). This appendix supplements those descriptions by focusing on the changes made to the modelling suite for the current exercise, and by restating the key parameters that determine emissions trajectories and abatement. These changes include:

- integration of Commonwealth Scientific and Industrial Research Organisation (CSIRO) modelling of fuel switching and abatement opportunities in rail, domestic water and domestic air transport, in addition to revisions of their previous estimates for road transport;
- integration of Centre for International Economics (CIE) projections for emissions-intensive segments of agriculture;
- integration of Bureau of Infrastructure, Transport and Regional Economics (BITRE) projections for transport activity;
- drawing on updated projections by the Bureau of Resources and Energy Economics (BREE), Wood Mackenzie and IBISWorld for mining and emissions-intensive segments of industrial processes;
- upgrading the database underpinning the international modelling to ABARES' database constructed from GTAP 8.1 with a base year of 2007; and
- implementation of AR4 Global Warming Potentials for the projections of international and domestic emissions.

Much of the data underpinning the analysis has been updated to draw on the latest available sources, including re-benchmarking the MMRF emissions matrix to match the 2010-11 NGGI and more recent quarterly releases, and updating domestic and international economic and demographic projections, and aligning projections for a range of emission-intensive industries to updated third-party sources.

Economy-wide modelling

GTEM global model

The version of Global Trade and Environment Model (GTEM) used in this exercise is similar to that used in previous Treasury modelling. However, modifications have been made to:

- provide a more detailed representation of emissions trading, including linking the EU and Australian schemes and their import of offsets at a lower carbon price than available domestically;
- update global warming potentials for non-carbon dioxide greenhouse gases based on AR4 parameters;
- cost the Marginal Abatement Cost (MAC) curves based on the cost-neutrality approach (that is, while pricing carbon involves additional production costs, firms respond to carbon liabilities by undertaking investment in abatement at the margin equivalent to the carbon price); and
- update the global economic, demographic and emissions data to a 2007 base year, with corresponding recalibration of some of the model parameters.

The modelling by GTEM for this exercise makes use of the latest database from the Global Trade Analysis Project (GTAP version 8.1). The new database is a snapshot of the world economy in 2007. World trade flows are reflected more accurately in the new database, better capturing the significance of China and India in the global economy and global trade. A consequence of the database update is that these countries are projected to have larger effects from global carbon pricing due to stronger trade linkages with the rest of the world than were represented in previous modelling. The new database also better represents technological costs based on the latest information. Emissions and emissions-intensities draw on more recent data in the new database, which improves the estimated economic costs of mitigation.

GTEM represents the global economy grouped into 13 regions: USA; EU25; Japan; China; India; Indonesia; Other South and East Asia; Former Soviet Union; OPEC; Canada; Australia; South Africa; and Rest of world.

MMRF Australian model

The Monash Multi-Regional Forecasting (MMRF) model was employed for the domestic modelling in this exercise. Developed as a detailed model of the Australian economy by Monash University's Centre of Policy Studies (CoPS), the version of MMRF used for this exercise is similar to that used for previous Treasury modelling (Adams *et al* 2010 and Australian Government 2008, 2011).

MMRF has been modified to cost abatement from activities covered under the Carbon Farming Initiative (CFI) based on the cost-neutrality approach, as applied to other sources of reductions in emissions intensity in the model.

Sector-specific modelling

A series of sector-specific models for electricity generation, transport, agriculture and forestry were employed to complement the CGE models. The main change from the previous modelling exercise was the integration of CSIRO modelling of fuel switching and abatement opportunities in rail, domestic water and domestic air transport. The consultants' detailed reports will also be published on the Climate Change Authority website.

Electricity

ACIL Allen Consulting (ACIL) provided detailed modelling of the Australian electricity generation sector. Projections are provided for levels of generation (on a sent out basis), total capacity (installed), emissions, 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.

The modelling is highly detailed and aims to represent actual market conditions as closely as possible. The model incorporates economic relationships between individual generating plants in the system and their technical and cost profiles. A range of fuel types are incorporated, including brown coal, black coal, natural gas and renewables (including hydro, biomass, solar, wind and geothermal). Details on the modelled new entrant technology and abatement measures are included in the ACIL report.

The modelling also incorporates technologies like carbon capture and storage, and differences between natural gas technologies (such as combined-cycle gas turbines and open-cycle gas turbines). The ACIL model uses a 100-point sequential representation of demand in each year to provide a realistic representation of aggregated electricity demand, capturing daily and seasonal fluctuations in energy use.

MMRF was linked with the electricity modelling from ACIL through a series of iterations. Using electricity demand data supplied by ACIL, MMRF was calibrated to match actual final electricity demand for the period 2010-11 to 2012-13. For the period 2013-14 to 2029-30, demand for electricity was modelled in MMRF, with the ACIL modelling providing the supply-side detail. MMRF electricity demand was provided to ACIL, together with the carbon price and commodity prices. ACIL then projected the response of the electricity sector to meet that demand. This was integrated into MMRF by calibrating the technology shares, fuel efficiency, and emissions-intensity of fuel use, transmission losses, wholesale prices and retail prices by industry. The iteration process continued until there was broad convergence.

Transport

The CSIRO modelled the Australian road and non-road (domestic air, water and rail) transport sectors.

The road transport sector was modelled using a partial-equilibrium model of the Australian energy sector, the Energy Sector Model (ESM), with a detailed transport sector representation. This model has an economic decision-making framework, based on the cost of alternative fuels and technologies. The 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 transport stocks in each state; lead times in new transport modes or plant availability; and the degree of flexibility in the existing fleet.

To capture dynamics in the non-road transport sectors, future fuel efficiency estimates were taken from the literature and imposed on each scenario. For domestic aviation, CSIRO's ESM was used to project the uptake of bio-derived jet fuels in aviation. Biofuel uptake in the domestic water and rail sector was imposed directly by CSIRO.

The transport sectors of MMRF were linked with the CSIRO modelling. Demand for individual fuels and vehicle types was determined using the ESM model. The outputs from ESM (fuel use and emissions) were then used as inputs back into MMRF. This iteration process continued until there was a broad convergence.

Transport activity levels for passenger transport (private cars, buses, rail and air) in the central scenario was set in accordance with projections from the Bureau of Infrastructure, Transport and Regional Economics (BITRE, 2010). This input was used to determine the emissions projections in the central scenario from CSIRO. The projected output paths of these passenger sectors were allowed to deviate from the central projection in the other scenarios, due in part to the impact of different carbon prices. The projections take into account saturation effects of passenger transport demand as incomes rise, contributing to declining output growth rates in the long run. The output growth rates for road and rail freight and water transport were determined endogenously within MMRF in the central case. As an example, the demand for road freight was determined in MMRF, taking into account the projected output of industries using road freight as an input, and changes in the costs faced by the road freight sector itself.

Table A1: Inputs and outputs to and from CSIRO

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

Agriculture and Land use, land-use-change and forestry (LULUCF) modelling

The emissions projections for the agriculture and LULUCF sector were prepared using separate models for each subsector.

International LULUCF modelling

The Generalized Comprehensive Mitigation Assessment Process (GCOMAP) model developed by Lawrence Berkeley National Laboratory (Sathaye *et al* 2006; Sathaye and Chan 2008) was used to project the LULUCF emissions responding to carbon pricing for the international modelling, by taking the carbon prices projected by GTEM as an input. These LULUCF emissions projections are incorporated into GTEM and added to emissions from other sources in GTEM. Negative LULUCF emissions represent a net sink of emissions which reduces the total emissions in GTEM.

Compared to previous modelling, GCOMAP projected a larger range of the cumulative net global sink from LULUCF till 2050 for this exercise between the two global action scenarios, due to the updated historical emissions in the model, larger carbon price differences between the two scenarios and the timing difference for harmonised international carbon prices.

Domestic agriculture

In the domestic modelling, emissions in the agriculture sector were aligned with the detailed modelling provided by the Centre for International Economics (CIE) and then calibrated to more recent data on base year emissions from the NGGI quarterly updates. The CIE's models incorporated the same global demographic projections and similar economic profiles as in the GTEM model, and land prices, the exchange rate and production costs were sourced from MMRF. The CIE then provided estimates for domestic production for the agriculture sector, which were incorporated into the MMRF central policy scenario, where the sector faces an incentive to abate through the CFI.

Domestic land use and land-use-change (LULUC) modelling

The emissions projections for deforestation, the largest component of emissions presented under the land use and land-use change category, were modelled from estimated relationships between areas of land clearing activity and movements in the farmers' terms of trade (FTOT). Projections of the FTOT were drawn from ABARES (2013).

Further details on the LULUC modelling assumptions and the other component parts, including grazing land management and cropland management, can be found at the end of this appendix.

DIICCSRTE modelled the abatement expected from the agriculture, LULUCF and legacy-waste components of the CFI. Estimates of abatement in agriculture were updated to reflect the policy parameters of the CFI and recent developments in the availability and costs of abatement opportunities. For more information on the modelling of CFI abatement, see Appendix C.

Domestic forestry modelling

FullCAM was used for the reforestation projections to estimate emissions and removals for the projected areas. The model utilises estimates of the associated living biomass (above and below ground), debris and soil carbon for the areas of land under reforestation. Further details on the Forestry modelling assumptions and the other component parts, including forest management, can be found at the end of this appendix.

MAGICC overview

The Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC v6) is used to estimate the atmospheric concentrations of the emission trajectories (Wigley and Raper

1992; Raper *et al* 1996; Wigley and Raper 2001; and Meinshausen *et al* 2009). MAGICC is calibrated against more complex climate models and was used in the IPCC's Fourth Assessment Report (IPCC 2007b). The latest version of MAGICC introduces several changes to better emulate these models.

GTEM models emissions of the main greenhouse gases including carbon dioxide, methane, nitrous oxide, sulfur hexafluoride as well as aggregated fluorocarbons (hydrofluorocarbons and perfluorocarbons). There are other greenhouse gases not modelled in GTEM but are required for MAGICC input. These greenhouse gases are taken from the representative carbon pathways RCP45 and RCP3-PD for the medium global action and ambitious global action scenarios, respectively. Both RCP scenarios include greenhouse gas concentration targets that stabilise around 2100. The global action scenarios modelled in GTEM only project emission paths of the main greenhouse gases to 2050. Projections of the main greenhouse gas emissions beyond 2050 are based on emissions projections from the Garnaut scenarios used in previous Treasury modelling (Australian Government 2008) as well as emission trends before 2051.

The medium global action scenario is defined by a stabilised concentration of 550ppm carbon dioxide equivalent around 2100, calculated in MAGICC. The ambitious global action scenario is defined by being consistent with a stabilised concentration of 450ppm carbon dioxide equivalent in the long term beyond 2100, also calculated in MAGICC. To ensure the ambitious global action scenario is consistent with a 50 per cent chance of limiting warming to 2 degrees Celsius or less, cumulative emissions were compared against the global emission budgets from the scientific literature, namely:

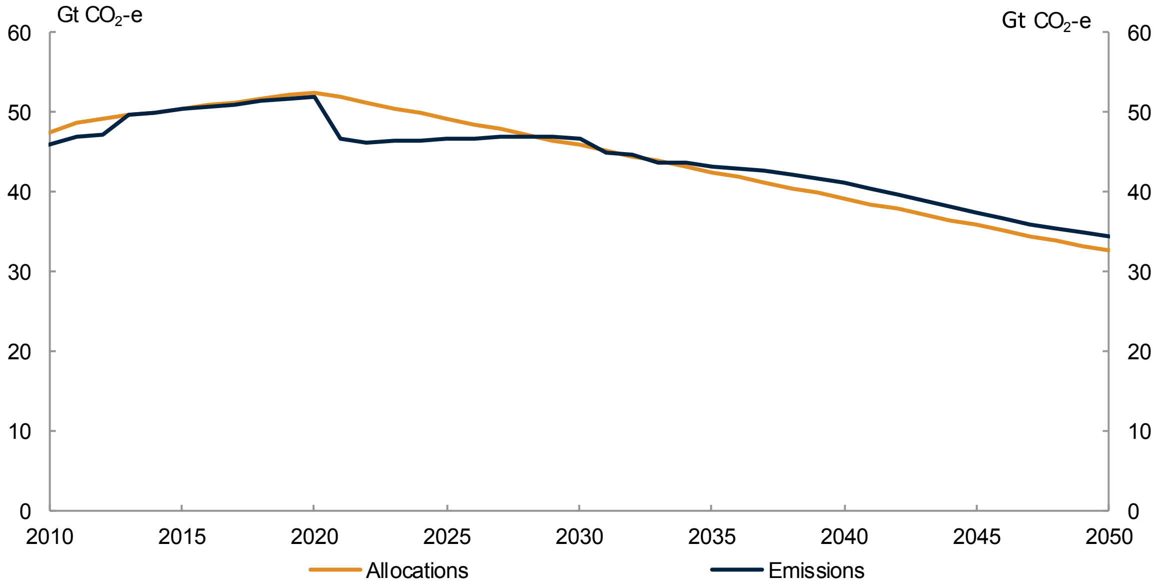
- cumulative fossil carbon dioxide emissions from 2011 to 2100 not to exceed 1679 Gt CO_2 (Raupach *et al* 2011); and
- cumulative carbon dioxide emissions from 2000 to 2049 not to exceed 1437 Gt CO_2 (Meinshausen *et al* 2009).

Policy and design features

International carbon price

The international carbon price was determined in largely the same manner as in previous Treasury modelling (Australian Government 2008, 2011), but with a harmonised international carbon price for 2021 and beyond. Each region achieves its 2020 pledge before transitioning to a harmonised international carbon price path (further regional action detail is outlined in Chapter 2). Global allocations in the medium global action scenario were chosen so that: advanced economies maintain a proportional effort to Australia in terms of percentage reduction from baseline emissions, with somewhat smaller percentage reductions for developing regions; and regional banking and borrowing nets out over the harmonised international carbon price period (2021 to 2050). The ambitious global action scenario made the technical modelling assumption that regions' allocations were equal to their emissions.

Chart A1: Global allocations and emissions
Medium global action scenario



Source: Estimates from GTEM.

Australian policy assumptions

All domestic scenarios include a number of pre-existing Australian policy measures across a number of sectors.

Electricity policy measures

All 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 Clean Energy Regulator website.

Transport policy measures

All scenarios assume existing transport polices remain in place. They include fuel excise (including excise equivalent customs duty) rates, the NSW Biofuels Act and the LPG Vehicle scheme.

Fuel excise rates and levies

Petrol and diesel have had a nominal dollar excise rate of 38.143 cents per litre (cpl) since indexation ceased in 2001. Heavy road vehicles are entitled to a fuel tax credit of 38.143 cpl. However, they are liable to pay a road user charge of 26.14 cpl from July 2013. The road user charge is reviewed each year.

The road excise rates that apply to alternative transport fuels were re-designed in 2011 and, like petrol and diesel, the rates are set in nominal dollar terms. Ethanol, renewable diesel and biodiesel are liable for excise of 38.143 cpl. However, under the Ethanol Production Grants Program, grants of 38.143 cpl are provided only for domestic production of ethanol. In addition, the Energy Grants (Cleaner Fuels) Scheme provides 38.143 cpl grants for both the domestic production and import of biodiesel and renewable diesel. These arrangements will continue until at least 30 June 2021; the modelling makes the technical assumption that they remain indefinitely.

LPG and natural gas face a gradual phase-in of excise rates based on energy content from 2011-12. As a result, the excise component of these alternative fuels has been increasing but will remain discounted relative to conventional fuels. The phase-in period is to 2015. Ethanol imports also attract a duty of 5 per cent. It is assumed that the level of excise remains constant in nominal terms from 2015 onwards. As a result, excise rates are assumed to decline in real terms.

Table A2: Fuel excise rates and levies

	LPG[(a)]	Natural Gas[(a)]	Biodiesel[(b)]	Ethanol[(b)]
	$ per litre	$ per kilogram	$ per litre	$ per litre
2011-2012	0.025	0.05224	0.38143	0.38143
2012-2013	0.050	0.10448	0.38143	0.38143
2013-2014	0.075	0.15673	0.38143	0.38143
2014-2015	0.100	0.20897	0.38143	0.38143
2015-2016	0.125	0.26122	0.38143	0.38143

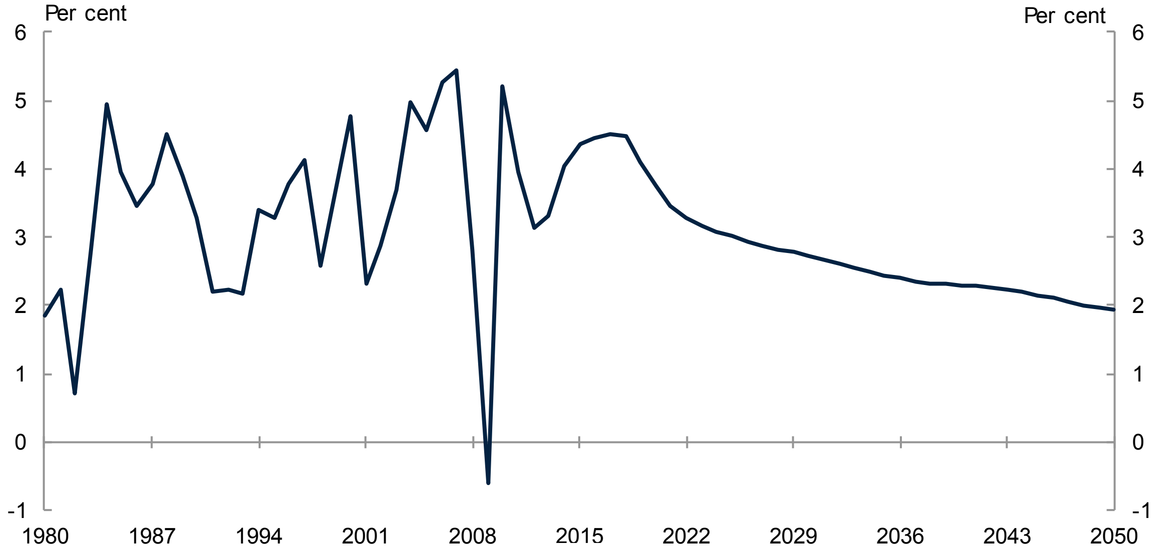
Note: (a) LPG and natural gas (CNG and LNG) rates introduced from 1 December in 2011. (b) Ethanol and biodiesel excise is in some cases offset by other grants. Under the Ethanol Production Grants Program, grants of 38.143 cpl are provided for domestic production of ethanol. The Energy Grants (Cleaner Fuels) Scheme provides 38.143 cpl grants for the domestic production and import of biodiesel and renewable diesel.
Source: Treasury and CSIRO.

International economic assumptions

World gross domestic product

World gross domestic product projections have been revised to incorporate data updates and a change to the conditional convergence methodology. Updated data sources include the World Economic Outlook (IMF 2013) and the Total Economy Database (Conference Board 2012). Methodological changes include updating the long-term US annual productivity growth assumption to 1.7 per cent, consistent with that used by the Congressional Budget Office (Shackleton 2013); and reworking the conditional convergence framework (Au-Yeung *et al* 2013), which is now based on global competitiveness index scores (World Economic Forum 2011).

Chart A2: Real gross world product
Annual growth rate, baseline scenario



Source: IMF 2013; and Treasury.

Table A3: International real GDP growth
Average annual growth, per cent, baseline scenario

	2010-2020	2020-2050
United States	2.7	2.1
European Union (25)	1.5	1.5
China	8.0	3.1
Former Soviet Union	3.7	1.4
Japan	1.2	0.7
India	6.5	4.5
Canada	2.3	2.1
Indonesia	6.5	4.1
South Africa	3.2	2.4
Other south and east Asia	4.2	1.9
OPEC	3.6	2.1
Rest of world	4.0	2.6

Source: Treasury, IMF, OECD and Consensus.

International population

International population projections to 2050 are based on United Nations (2013), aggregated to match GTEM regions.

Table A4: International population
GTEM regions

	Population level (millions)			Average annual growth rate (per cent)	
	2012	2020	2050	2012-2020	2020-2050
United States	318	338	401	0.8	0.6
European Union (25)	475	483	485	0.2	0.0
China	1384	1440	1393	0.5	-0.1
Former Soviet Union	282	283	267	0.1	-0.2
Japan	127	125	108	-0.2	-0.5
India	1237	1353	1620	1.1	0.6
Canada	35	38	45	1.0	0.6
Indonesia	247	269	321	1.1	0.6
South Africa	58	61	72	0.7	0.5
Other south and east Asia	435	469	536	0.9	0.4
OPEC	230	264	358	1.7	1.0
Rest of world	2087	2407	3695	1.8	1.4

Source: United Nations 2013.

International emissions

With the world economy projected to grow, annual greenhouse gas emissions are projected to increase by more than 80 per cent by 2050, compared to the current level. The annual rate of growth of emissions slows from now to 2050. Emissions are mostly carbon dioxide from fuel combustion and deforestation, and methane and nitrous oxide from agriculture. Other gases such as HFCs and PFCs maintain a small share of around 2 per cent of the global emissions over the simulation period.

Table A5: Baseline emissions

Emissions by region

	2012	2020	2050
		Gt CO_2-e	
United States	6.1	7.1	8.6
European Union (25)	4.6	5.0	5.6
China	12.3	18.8	30.0
Former Soviet Union	2.4	2.8	3.3
Japan	1.1	1.1	1.1
India	2.8	3.8	9.0
Canada	0.7	0.8	1.1
Indonesia	1.3	1.6	2.8
South Africa	0.5	0.6	0.9
Other South and East Asia	1.4	1.6	2.2
OPEC	2.6	3.1	4.7
Rest of world	12.8	14.3	18.6
World	49.2	61.4	89.0

Emissions by gas and type

	2012	2020	2050
		Gt CO_2-e	
Carbon dioxide	37.5	46.1	69.4
Combustion	29.9	38.1	58.7
Fugitive/Industrial process	3.2	4.4	8.7
Waste	0.1	0.1	0.1
LULUCF	4.3	3.6	1.9
Methane	7.7	10.3	12.3
Combustion	0.3	0.5	0.9
Fugitive/Industrial process	6.0	8.1	9.3
Waste	1.3	1.7	2.1
Nitrous oxide	3.1	3.6	5.5
Combustion	2.3	2.7	4.0
Fugitive/Industrial process	0.6	0.7	1.3
Waste	0.1	0.1	0.2
Other gases	1.1	1.4	1.8
Total	49.2	61.4	89.0

Note: LULUCF means land use, land-use-change and forestry.
Source: Estimates from GTEM.

Table A6: Baseline emissions intensity

Emission intensity of GDP	2012	2020	2050	Emissions per person	2012	2020	2050
	kg CO_2-e per GDP				t CO_2-e per person		
United States	0.39	0.37	0.24	United States	19.1	21.1	21.4
European Union (25)	0.29	0.27	0.19	European Union (25)	9.8	10.4	11.6
Rest of Annex B	0.42	0.40	0.31	Rest of Annex B	9.5	10.7	13.0
China	0.85	0.71	0.46	China	8.9	13.0	21.6
India	0.52	0.42	0.27	India	2.3	2.8	5.5
Rest of world	0.83	0.68	0.45	Rest of world	6.1	6.1	5.9
World Average	0.58	0.52	0.36	World Average	7.1	8.1	9.5

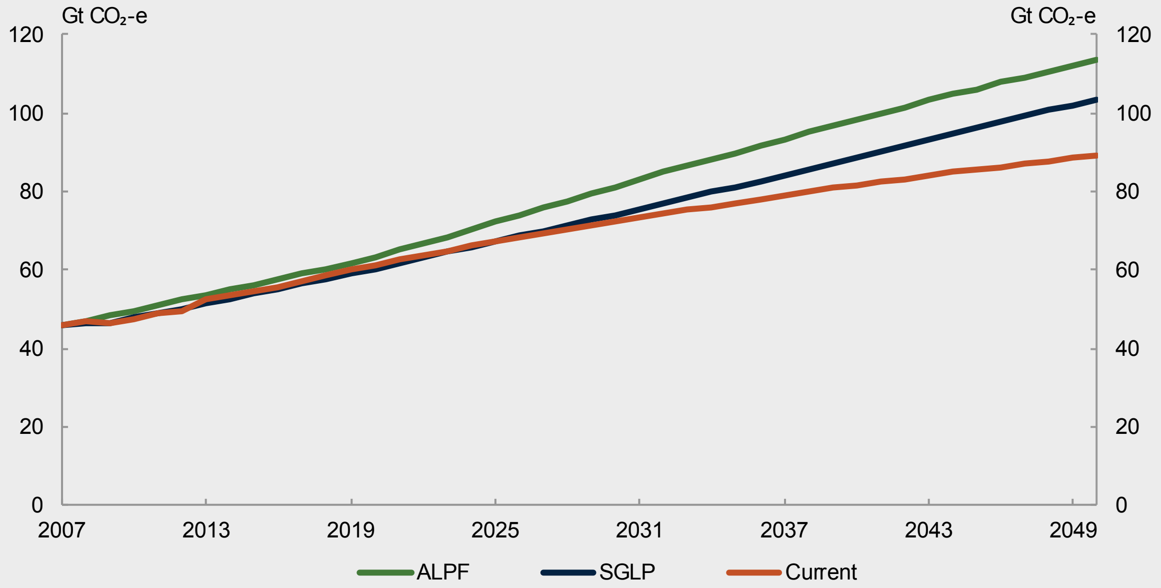
Note: GDP is in $US 2012 using 2005 PPP weighting.
Source: Estimates from GTEM.

The emissions intensity of the world economy falls by more than 35 per cent by 2050 compared to the current level even in the absence of carbon pricing, reflecting the move towards service-based economies as income levels rise. The emissions 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, mean that some differences in emissions intensity remain over time.

Box A.1: Baseline emissions comparison

The baseline scenario projects lower population growth than in previous Treasury modelling and slower growth in gross world product. Slower growth in world production implies slower overall growth in fuel combustion and production of other emissions-intensive goods and services. Emissions from the two major emissions-intensive sectors (electricity and transport) are significantly lower, contributing to a lower level of world emissions than projected in previous Treasury modelling.

Chart A3: Global emissions projections



Source: Estimates from GTEM. All emissions are indexed to 2007 historical levels. ALPF and SGLP refer to *Australia's low pollution future* and *Strong growth, low pollution* (Australian Government 2008, 2011).

Technological development

Electricity technology assumptions

Carbon capture and storage

Carbon capture and storage (CCS) technology in GTEM, combined with coal and gas electricity generation, is assumed to be unavailable on a commercial scale until after 2020. To allow for gains in cost competitiveness compared to other technologies, the scale of its commercial uptake is assumed to depend on the level of the carbon price in place at the time. The threshold carbon price for uptake is assumed to be $32 for coal CCS and $35 for gas CCS technology (in $US 2012), reflecting the costs of transporting and storing the captured emissions. In GTEM, the capture efficiency is assumed to be 90 per cent of produced emissions.

Nuclear

Nuclear power is assumed to continue to be available in regions where it is currently deployed, but not elsewhere. Nuclear power 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:

$$\Lambda = \begin{cases} e^{-\alpha(\tau+1)^{\gamma}} & \textbf{if } \Lambda > \min \Lambda, \\ \min \Lambda; & \end{cases} \qquad (1)$$

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 Energy Modelling Forum (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 A7: GTEM fugitive and 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	0.45	0.3
Waste(a)	-	-	0.05	0.70	-	-	0.1

Note: (a) Waste MAC curves apply only to USA, EU-25, China and the Former Soviet Union.
Source: Treasury; and Weyant and Chesnaye (2006).

Table A8: Change in non-combustion emissions-intensity in GTEM
Average annual growth (per cent, 2010 to 2050)

	Coal CH_4 Per cent	Non-metallic minerals, CO_2 Per cent	Livestock CH_4/N_2O Per cent	Crops N_2O Per cent	Gas CH_4 Per cent	Oil CH_4 Per cent
United States	-1.4	-0.2	-0.8	-0.8	0.0	0.0
European Union (25)	0.0	0.0	-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	-1.3	-2.8	-1.0
Japan	0.0	-0.2	-0.8	-0.5	-1.6	-5.1
India	-3.5	-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	-0.8	-0.8	0.0	0.0
South Africa	-3.5	-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	-3.5	-0.2	-0.8	-0.4	-1.7	-4.6
Rest of world	-3.8	-0.2	-0.8	-0.3	-0.2	-3.6

Note: Negative numbers denote improvements in emissions intensity.
Source: Treasury; DCC 2008; and Weyant and Chesnaye 2006.

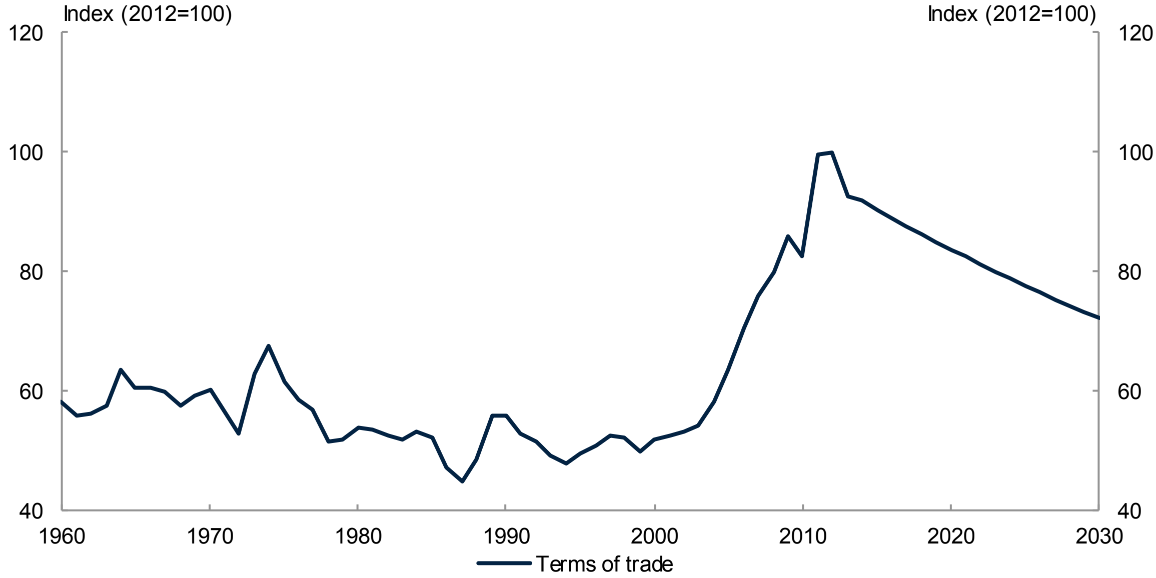
The version of GTEM used in this exercise uses a cost-neutrality methodology to cost marginal abatement of non-combustion and N_2O combustion emissions. This methodology involves the same mechanism for improvements in emissions intensity as previous Treasury modelling; however, while pricing carbon involves additional production costs, firms respond to carbon liabilities by undertaking investment in abatement at the margin equivalent to the carbon price.

Commodity price assumptions

Terms of trade

The modelling uses the same medium-term path for the terms of trade as the 2013-14 Budget and has not been adjusted for changes in the outlook presented in the Pre-Election Economic and Fiscal Outlook published in August 2013. This incorporates a projected decline of around 20 per cent over a 15-year period. The terms of trade are then assumed to continue declining until 2029-30.

Chart A4: Australia's terms of trade
Central policy scenario



Source: ABS, 2013-14 Budget and Treasury estimates.

Energy commodity prices

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. Coal prices to 2022 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 analysis of bulk commodity prices.

Fuel costs for Australian electricity generation

The detailed modelling by ACIL 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. ACIL's estimates of domestic gas prices are consistent with international assumptions: Western Australian gas prices reflect the domestic equivalent of the international price of gas, excluding export costs such as liquefaction; while east coast gas prices converge to this level by around 2020.

Australian economic assumptions

National population, employment and GDP growth are projected in a manner consistent with the 2013-14 Budget and the 2010 Intergenerational Report (Australian Government 2010). Gross state product is a function of assumptions about the distribution of population, based on shares projected by the ABS, and industry across states.

Table A9: Australian employment, productivity and GDP
Average annual growth, per cent, central policy scenario

Decade	Employment growth	Labour productivity growth	Real GDP growth
2010s	1.5	1.5	3.0
2020s	1.3	1.6	2.8

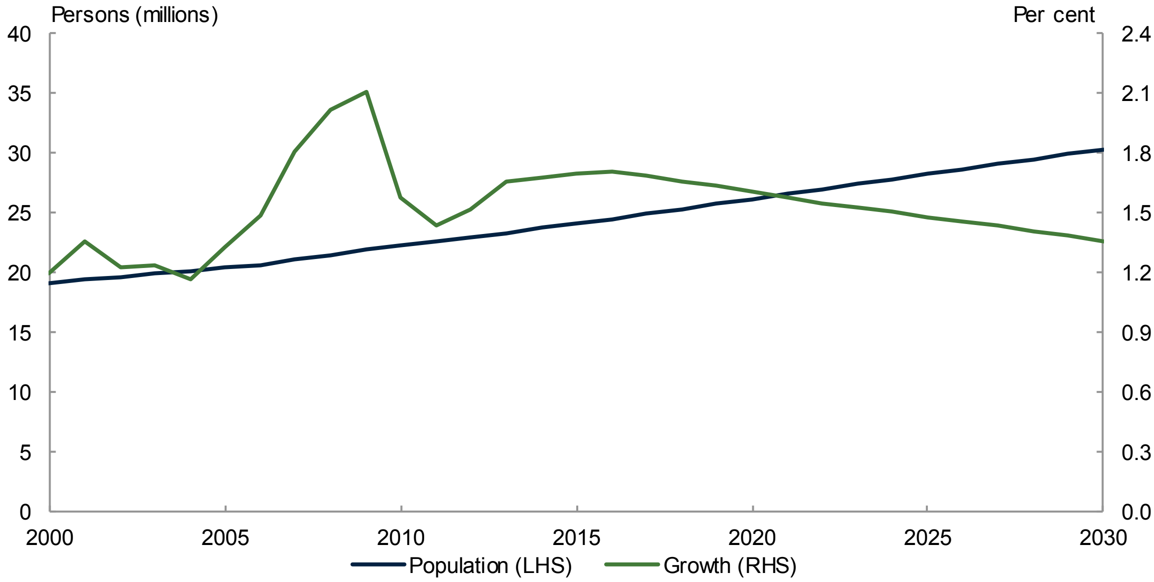
Source: Treasury and ABS.

Table A10: State population and gross state product
Average annual growth, per cent, central policy scenario

	2010s		2020s	
	Population	GSP	Population	GSP
NSW	1.3	2.5	1.2	2.9
VIC	1.6	2.5	1.4	3.0
QLD	2.2	3.5	2.0	3.1
SA	1.1	1.9	1.1	1.5
WA	2.2	4.9	1.9	2.7
TAS	0.8	1.3	0.7	2.2
NT	1.7	3.2	1.6	3.0
ACT	1.3	2.5	1.2	2.8

Source: Treasury and ABS.

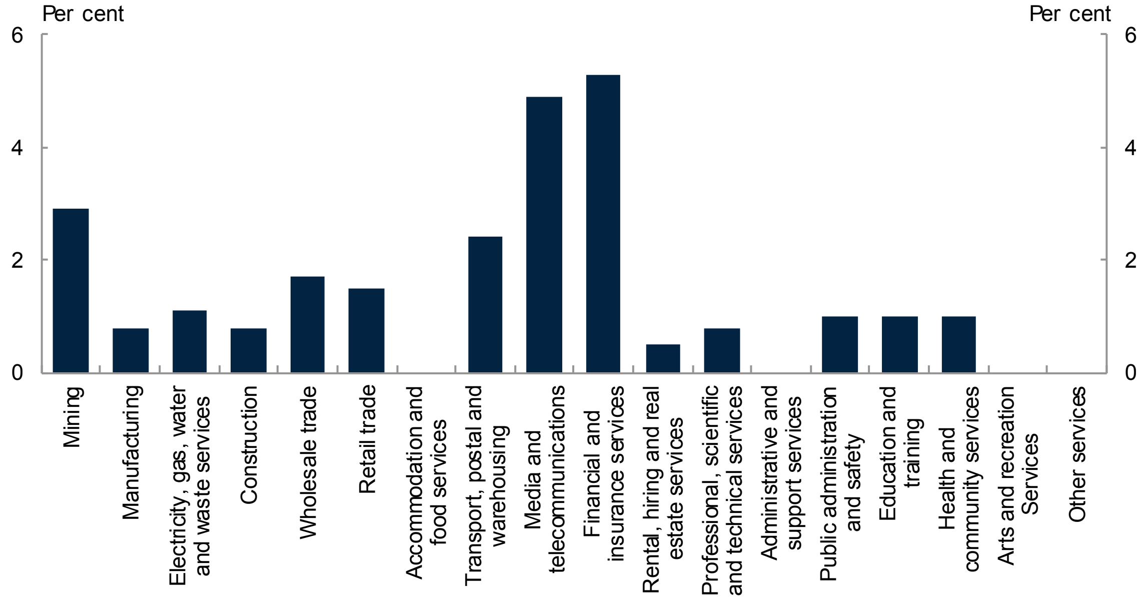
Chart A5: Australian population



Source: Treasury projections.

Labour-augmenting technical change at an industry level is initially based on historical estimates, converging over time to an assumed aggregate growth rate of 1.6 per cent per year. Initial growth rates are estimated from the national accounts. They remove the effect of capital deepening on output by adjusting multifactor productivity estimates by industry-level labour income shares.

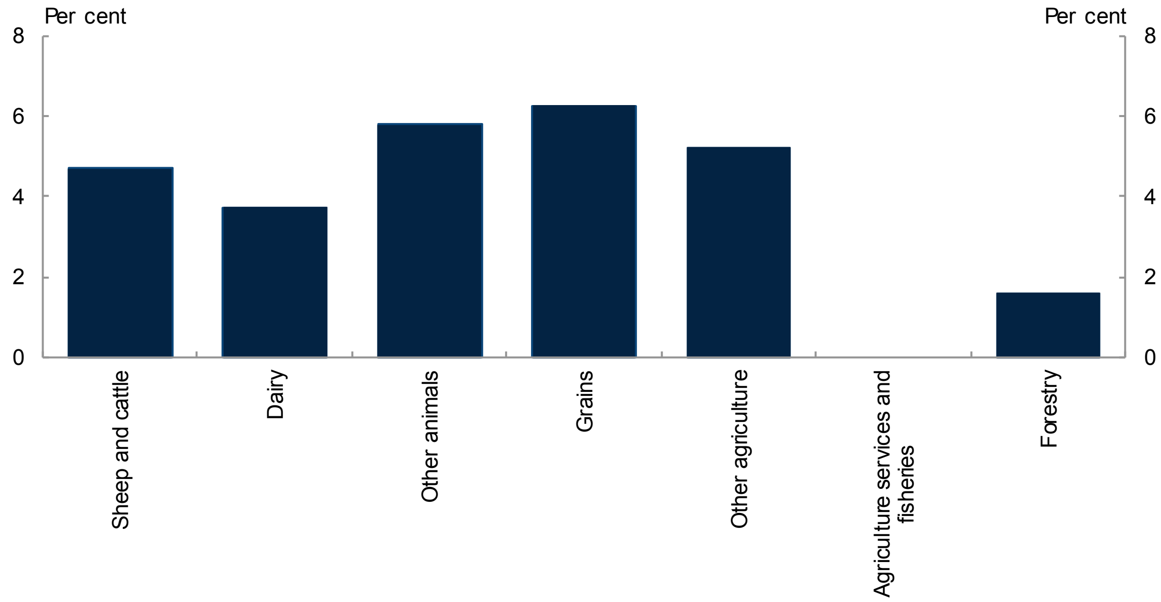
Chart A6: Industry labour-augmenting technical change
Average annual growth, 1982 to 2012



Source: Treasury and ABS.

The modelling uses a more detailed set of assumptions for the agricultural sector. Technical change for each disaggregated sector is based on CIE (2013) and ABARES (2011).

Chart A7: Agriculture, forestry and fishing labour-augmenting technical change
Average annual growth, central policy scenario



Source: Treasury, CIE and ABARES.

Economy-wide energy efficiency

The MMRF model incorporates an Autonomous Energy Efficiency Improvement (AEEI) parameter, which specifies the rate of annual energy efficiency improvement but not its source. In the long run, the AEEI parameter is assumed to be 0.5 per cent per year. The parameter is higher in the near term, averaging 0.8 per cent per year to 2025, to reflect a range of policies from the Australian and State Governments that drive improvements in energy efficiency.

Sector-specific assumptions

Electricity technology assumptions

Electricity generation sector assumptions are particularly important as the sector is a significant source of Australia's emissions. The electricity sector modelling focuses on the main inputs into technology development in the electricity sector: capital costs, thermal efficiency, and learning rates. ACIL capital costs tend to decline over time reflecting technological progress.

Table A11: ACIL technology cost and performance assumptions

	Capital cost	**Capital cost de-escalator**	**Thermal efficiency**
	2011-12 A$/kWh installed (a)	2012-30 per cent pa (b)	2011-12 % HHV sent out (c)
Black coal options			
Supercritical coal	2,974	0.27	41.9
Supercritical with CCS (post-combustion capture)	4,559	1.23	31.4
Supercritical with CCS (oxyfuel)	4,274	1.19	32.5
IGCC with CCS (d)	4,984	1.38	28.9
Brown coal options			
Supercritical coal	3,451	-0.40	32.3
Supercritical with CCS (post-combustion capture)	5,902	1.23	20.8
IGCC with CCS	5,083	1.38	25.5
Natural gas options			
CCGT (e)	1,100	-0.75	49.5
OCGT (f)	800	-0.69	32.0
CCGT with CCS	2,495	1.11	43.1
Renewable options			
Wind	2,300	1.01	
Solar PV	2,700	3.07	
Concentrated Solar Thermal (without storage)	4,526	4.10	
Geothermal - HSA (g)	6,300	-0.54	
Geothermal - Hot Rocks	9,646	-0.52	

Note: (a) 2011-12 Australian dollars (b) The de-escalator assumptions reflect factors such as foreign exchange rates and commodity prices provided to ACIL by Treasury. They also reflect variable AETA capital cost de-escalators. (c) High Heating Value. (d) Integrated Gasification Combined Cycle with Carbon Capture and Storage (CCS). (e) Combine-Cycle Gas Turbine. (f) Open Cycle Gas Turbine (OCGT). (g) Hot Sedimentary Aquifer.
Source: ACIL.

Exogenous assumptions and constraints in the ACIL model 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; and
- limits on the availability of carbon capture and storage technology.

Carbon capture and storage

ACIL'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 of competing low-emissions technologies. ACIL has assumed CO_2 storage and transport costs of between \$15/t CO_2 and \$30/t CO_2, depending on the plant location.

Australian transport

The assumption in CSIRO's transport modelling is that vehicle internal combustion engine fuel efficiency will improve by 25 per cent for petrol vehicles and 15 per cent for diesel vehicles by 2030. This will occur independently of changes to vehicle drivetrains, such that overall fuel efficiency improvements after vehicle electrification and/or hybridisation is adopted will be greater. The adoption of alternative drivetrains is endogenously determined within the model based on cost minimisation.

Table A12: CSIRO fuel efficiency improvements by decade
Average light vehicle fuel efficiency, annual growth, per cent

Scenario	2010s	2020s	2030s	2040s
No carbon price	1.5	1.7	1.3	0.6
Central policy	1.6	1.8	2.0	0.6
High price	1.7	1.9	2.7	0.6
Low price	1.7	1.4	1.5	0.8

Note: Improvements inclusive of uptake of alternative vehicle drivetrains.
Source: CSIRO.

Marginal abatement cost curves

In the current modelling, MMRF adopts the same functional form of the marginal cost curves as that used in the GTEM model (see equation 1 in the Technological development section).

These marginal 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 factors towards the potential MAC curve. This gradual adjustment mechanism accounts for the time required for a firm to transform its production process towards less emissions-intensive technologies. In MMRF, this is represented by:

$$\Lambda_t^* = (1-\beta)\Lambda_{t-1}^* + \beta\Lambda_t \qquad (2)$$

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 earlier in equation (1); 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 MAC curves for fugitive and industrial process emissions used in MMRF were constructed using a combination of the EMF-21 data set by Weyant and Chesnaye (2006), as well as drawing on previous consultations with McLennan Magasanik Associates and information provided by industry stakeholders. This process yielded a set of MAC curves tailored to Australian industries. MAC curves were not applied to fuel combustion emissions for the current report.

Table A13: 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
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.

Land use, land use change and forestry assumptions

There is no long-term economic modelling of emissions from Australian land use and land use change in MMRF. Emissions from this sector are exogenously imposed in the models using DIICCSRTE's FullCAM model. Further details on the FullCAM Model can be found on the DIICCSRTE website: http://www.climatechange.gov.au/climate-change/greenhouse-gas-measurement-and-reporting/tracking-australias-greenhouse-gas-emissions/land-sector-reporting.

Forestry

The Full Carbon Accounting Model (FullCAM) was used to estimate emissions and removals from the associated living biomass (above and below ground), debris and soil carbon for the projected areas of land under reforestation. Further details on the forestry subsectors are outlined below.

Afforestation/Reforestation

The supply of forest products grown in Australia responds to a range of demand factors including global economic growth, the international price of harvested wood products and the value of the Australian dollar as well as shifts in demand patterns, especially between Japan and China. Other factors influencing an ongoing decline in conditions for wood products production include:

- decline in structural timber demand;
- decline in demand for paper;
- increased production of paper, paperboard, plantation woodchips and pulp in developing countries; and
- paper recycling.

In the face of weakened demand for forest products grown in Australia the proposed base assumption for the 2013 reforestation projections is that wood supply in these forests remains at the current or near the current level. Over the coming decade an upward shift in wood availability is likely due to the age class of the forest, however, it is expected that supplies will be managed by changing the timing of harvest strategies.

This assumption was implemented in the model by maintaining the area of hardwood and softwood plantations at a constant level throughout the projections period. Establishment of new hardwood and softwood plantations as well as environmental plantings continues throughout the projection, with the new areas of hardwood and softwood plantings designed to replace areas of the estate that are not replanted. This assumption reflects the effect of plantations shifting out of unsuccessful or sub-optimal regions into new regions. Emissions due to the non-replanting of forests are reported in the deforestation projections.

Forest Management

Methods have been developed in the national inventory for the following sub-categories:

- Multiple-Use Forests — public native forests managed for multiple uses that include timber production;
- Plantations — plantations established prior to 1990;
- Private harvest native forests — privately owned forests that have been harvested since 1990;
- Other native forests; and
- Fuel wood consumed.

Sequestration from commercial forests, environmental plantings and managed native forests is dependent on the area of the forest estate, the contribution of forest growth in each year and the rate of harvesting. In all cases, projections rely on estimates of the amount of carbon sequestered in biomass, which differ by tree species and different climatic and geographical conditions.

Harvesting in multiple-use forests, private native forests and plantations is the key driver of human induced emissions and removals in these forests. Over recent years harvesting in the native forest sector has reached historically low levels. This decline has been associated with changes in supply factors such as from increasing supply from plantations (particularly those established after 1990). Demand factors such as the international price of harvested wood products, the value of the Australian dollar and shifts in demand patterns, especially between Japan and China, have also contributed to the decline in harvesting. The assumption for this projection is that harvesting in these forests remains at current levels. Given the large number of factors that influence harvest rates, this is an assumption that will need to be carefully reviewed over time as new information on demand and supply factors emerges.

Land use and land use change

The Full Carbon Accounting Model (FullCAM) was used to estimate emissions and removals from the associated living biomass (above and below ground), debris and soil carbon for the projected areas of cleared land.

Deforestation

Land use emissions for Australia are from clearing regrowth as part of agricultural management, as well as clearing new land and are modelled based on land clearing activity in response to movement in the farmer's terms of trade.

Cropland Management and Grazing land Management

Under the Kyoto Protocol rules, accounting for cropland management and grazing land management requires a comparison of net emissions/removals in 1990 against net emissions/removals in the commitment period. Cropland management and grazing land management will make a contribution towards meeting Australia's second commitment period target if, during the commitment period, net emissions are lower or net removals are higher than they were in the 1990 base year.

The estimates of net emissions from these activities provided here are based on activity data collated from ABS statistics, which provide data on changes in agricultural management practices since 1990.

The area of cropland under minimum tillage practice increased from 9 per cent of the total area in 1990 to 74 per cent in 2010 with a modest positive impact on soil carbon stocks. No additional change in practice is assumed after 2010. As a result, cropland management estimates are the result of the ongoing effect of management changes made between 1990 and 2010.

ABS statistics publications also provide evidence of changes in agricultural management practices since 1990 that impact net emissions from grazing lands. For example, there has been an increase in the area of improved pasture due to fertilizer since the mid-1980s. The impact of this on grazing land soil carbon stocks during the second commitment period is expected to be approximately equal to the abatement in the 1990 base year. Under the Kyoto Protocol accounting rules, net emissions from fires and changes in the area of woody vegetation are likely to be included in the accounting for the grazing land management activity. Annual activity data is collected for these sources from the inventory's remote sensing program.

Estimated abatement from these activities is projected to be modest given current policies and existing methods. New empirical data sources are expected to emerge for these activities over time. The methodologies and models necessary to fully implement these new activities in the national inventory system will be refined in future as this new scientific evidence becomes available.

Appendix B: Changes since the 2012 Projections

This appendix summarises major changes in modelling results since the *Australia's emissions projections 2012* publication. They include:

- incorporating updated National Greenhouse Gas Inventory data for the 2010-11 inventory year and preliminary emissions estimates for 2011-12 and 2012-13;
- moving from the global warming potentials published in the Intergovernmental Panel on Climate Change's (IPCC) Second Assessment Report (AR2) to those in its Fourth Assessment Report (AR4);
- expansion of coverage due to Australia's inclusion in the second commitment period under the Kyoto Protocol of additional human-induced activities related to forest management, cropland management, and grazing land management (under Article 3.4 of the Kyoto Protocol); and
- updating forecasts to take account of changes in the global and Australian economies.

Main changes since 2012 Projections

Updated information since the 2012 Projections

Australia releases official projections of its greenhouse gas emissions annually. On 1 November 2012, the Department of Climate Change and Energy Efficiency released *Australia's emissions projections 2012* (the '2012 Projections'). The projections in this report incorporate updated data that has become available since the release of the 2012 Projections including:

- updated emissions data from Australia's National Greenhouse Gas Inventory, released in April 2013 and emissions estimates for 2011-12 and 2012-13 based on new activity, fuel consumption and electricity generation data;
- updated macroeconomic parameters consistent with the 2013-14 Budget; and
- a central policy scenario that reflects the commencement of an emissions trading scheme from 1 July 2014.

The projections presented in this report also reflect detailed sectoral information on emissions-intensive commodities in the heavy manufacturing, agriculture and mining sectors from sectoral modelling. Output in industries such as metal production, petroleum refinery, liquefied natural gas (LNG) and coal production have been informed by projections from the Bureau of Resource and Energy Economics' *Resources and Energy Quarterly, March Quarter 2013*, IBISWorld industry analysis and the Wood Mackenzie coal and LNG supply services. Economic activity in agricultural industries was modelled by the Centre for International Economics (CIE) in the medium to long term and informed by forecasts from the Australian Bureau of Agriculture Resource Economics and Sciences (ABARES) in the short term.

Revisions to global warming potentials

Global warming potential factors represent how much heat a greenhouse gas traps in the atmosphere compared to carbon dioxide. The impact of each greenhouse gas varies in terms of its effectiveness in trapping solar radiation and, consequently, its contribution to global warming. Global warming potentials thus provide a means of combining the emissions of different greenhouse gases to calculate a total emissions figure expressed in terms of carbon dioxide equivalence (CO_2-e).

By international agreement, Australia currently uses global warming potentials published in the 1995 AR2 for national inventory reporting. These global warming potentials also form the basis for assessing liabilities under the carbon pricing mechanism.

At the United Nations Framework Convention on Climate Change (UNFCCC) meeting in November-December 2011 in Durban, South Africa, countries agreed to adopt updated global warming potentials. Countries also agreed to include the new greenhouse gases published in the 2007 AR4. These global warming potentials replace those used from the AR2.

To ensure consistency with the latest UNFCCC reporting requirements, emissions are reported here using the updated AR4 global warming potentials. This means that these projections are not directly comparable to the 2012 Projections. To allow comparison with previously published projections, a set of projections using AR2 global warming potentials is included in this appendix.

Overall, adopting revised global warming potentials increases Australia's total emissions in CO_2-e terms and also affects the split between covered and uncovered emissions. The most significant change for Australia's emissions profile is an increase in methane's global warming potential from 21 times that of carbon dioxide to 25 times; methane represents around one-fifth of Australia's emissions.

Table B1 below compares the sectoral emissions projections based on AR2 and AR4 in the central policy scenario.

Table B1: Emissions by sector, AR2 and AR4
Central policy scenario

	2010-11		2019-20	
	AR2	AR4	AR2	AR4
	Mt CO_2-e		Mt CO_2-e	
Waste	12.8	15.1	9.9	11.7
Electricity	198.8	198.8	185.0	185.0
Fugitives	41.3	47.7	57.0	65.5
Industrial processes	33.3	34.3	26.5	27.2
Transport	87.6	87.6	94.0	94.1
Other stationary	94.4	94.6	115.7	115.7
Agriculture	84.1	95.7	91.0	102.9
Forestry and land use change	10.7	10.7	18.2	18.2

Source: National Greenhouse Gas Inventory; and projections from MMRF.

Changes in Emissions Coverage

New accounting rules

The Kyoto Protocol and other international agreements set out the rules for which emissions must (and may) be included in the greenhouse gas accounts, and how to measure them. In December 2012, Australia joined the second commitment period under the Kyoto Protocol, to run from 2013 to 2020.

New accounting rules will apply for the second commitment period. Forest management has been added to the list of mandatory land sector activities, which also includes deforestation and afforestation/reforestation activities. Forest management became a mandatory activity facilitated by two new rules. Net emissions from forests are to be compared with net emissions from a forest management reference level, which takes account of the underlying growth dynamics of forests and policies in place as at 2009. Countries will also be able to exclude from their accounting the emissions, and subsequent sequestration, from natural disturbances like bushfire.

In addition, from 2013, emissions from the harvested wood product pool from forests will be included and estimated to reflect the use and degradation of products over time. The previous rules that applied to harvest wood products — known as the harvest sub-rule — applied for the first commitment period. Under this rule, debits resulting from harvesting during the first commitment period following afforestation and reforestation were offset against credits accounted for on that land.

Broadened coverage

The Government has decided to broaden coverage of the land sector for Australia's second commitment period target by including (or accounting for) the additional land-based activities of cropland management, grazing land management and revegetation.

The broadened coverage of the land sector improves opportunities for landholders to voluntarily participate in carbon markets through the CFI. Previously some important land sector activities — including enhancing soil carbon — were not able to generate Kyoto eligible credits as these activities were outside the coverage of Australia's Kyoto target. This decision removes that inefficiency and allows land managers to earn Kyoto-compliant credits from CFI projects for the full range of management activities on forest and agricultural lands.

The combined effect of the broadened coverage and new accounting rules has been to decrease emissions by a cumulative 126 Mt CO_2-e over the 2012-2020 period in the central policy scenario.

GreenPower

GreenPower is a voluntary government-accredited renewable energy program that enables energy providers to purchase renewable energy on behalf of customers. The scheme enables consumers to pay a premium for electricity generated from sources like mini-hydro, wind power and biomass, which produce no net greenhouse gas emissions.

As part of the Clean Energy Future Plan in 2011, the Government committed that emissions reductions from GreenPower purchases would be additional to meeting Australia's emissions reduction target. The projections in the current report incorporate an adjustment to the national trajectory to account for this commitment.

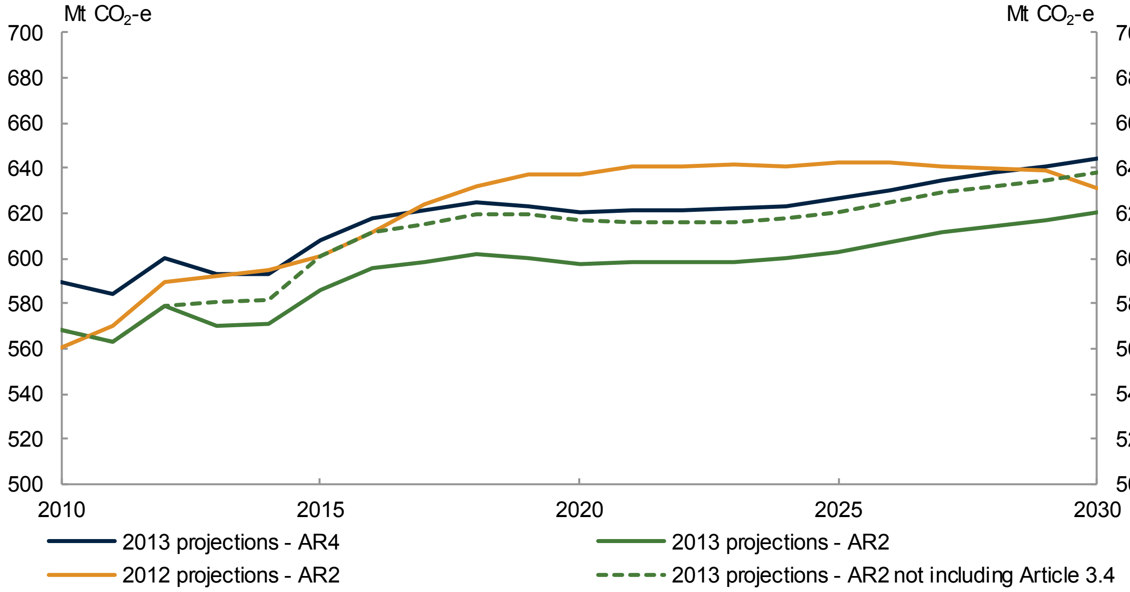
GreenPower forecasts used to adjust the national trajectory are based on 2011 audited data with the proportion of electricity demand sourced as a result of purchased GreenPower assumed to remain constant.

Main sectoral emissions projections changes

The emissions projections in the body of this report are based on the AR4 global warming potentials. Chart B1 compares the modelling results based on AR4, AR2 and AR2 net of the Article 3.4 scope change with the 2012 projections.

Chart B1: Comparison of emissions projections

Central policy scenario and 2012 Projections with carbon price and CFI scenario



Source: Treasury estimates from MMRF and *Australia's Emissions Projections 2012*.

In 2020, domestic emissions in the central policy scenario are projected to be 40 Mt CO_2-e lower than the 2012 Projections' with carbon price scenario, accounted on an AR2 basis. The majority of the difference can be attributed to the electricity, direct combustion and land use, land-use change and forestry (LULUCF) sectors.

Electricity emissions have been revised down 6 Mt CO_2-e in 2020 due to reduced industrial electricity demand and greater penetration of small scale renewables. Direct combustion emissions in 2020 are 11 Mt CO_2-e lower than in the 2012 Projections. Production forecasts for some trade-exposed industries have fallen, in large part due to the sustained high exchange rate in recent years. Industrial forecasts have been revised to account for this amended outlook. Some coal seam gas-to-LNG plants are also now assumed to use grid electricity in addition to direct gas combustion in their processing operations, which further contributes to the lower projections for direct combustion emissions.

The outlook for LULUCF has changed due to improved methodologies for deforestation and reforestation. Projections of deforestation emissions in 2020 have increased 1.3 Mt CO_2-e due to improvements in the inventory methodology for detecting deforestation activity on deforested lands. Projections of reforestation emissions have decreased 5.8 Mt CO_2-e in 2020 partly due to an increase in the area known to be currently under reforestation due to changes in remote sensing methodologies and data.

In addition, the incorporation of Article 3.4 activities, increased emissions coverage and CFI abatement from these new activities decreases emissions in 2020 by 20 Mt CO_2-e relative to the 2012 Projections in the central policy scenarios.

Appendix C: Carbon Farming Initiative

Overview

The Carbon Farming Initiative (CFI) allows farmers and land managers to earn carbon credits by storing carbon or reducing greenhouse gas emissions on the land using approved methodologies. These credits can then be sold to people and businesses wishing to offset their emissions under the Carbon Pricing Mechanism rather than purchasing units from other sources. The CFI also provides environmental benefits by encouraging sustainable farming practices and providing a source of funding for landscape restoration projects.

On 15 September 2011, the *Carbon Credits (Carbon Farming Initiative) Act 2011* (CFI Act) received royal assent. The program provides an incentive for carbon abatement. In some circumstances, projects can claim carbon credits for abatement achieved from 1 July 2010.

To support the environmental integrity of carbon offsets generated under the CFI, the independent Domestic Offsets Integrity Committee (DOIC) assesses methodology proposals and advises the Minister. If a methodology proposal is endorsed by the DOIC, the Minister will consider whether or not to make the proposal into a methodology determination in accordance with the DOIC's advice and the CFI Act.

Under the Carbon Pricing Mechanism, Australia's net emissions will be determined by the scheme cap in place. The link the CFI has to the Carbon Pricing Mechanism means that it does not lead to additional net abatement beyond what would be delivered by the Carbon Pricing Mechanism. However, the CFI does increase the amount of abatement achieved domestically, as distinct from the purchase of carbon credits from international sources, and lowers the cost of achieving Australia's abatement targets by providing liable entities the opportunity to purchase credits from low cost abatement occurring in land sectors.

Further information on the DOIC and the CFI is available at the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education's (DIICCSRTE) website: www.climatechange.gov.au/cfi.

Estimating CFI abatement

There is high uncertainty around the level of abatement that will be achieved by the CFI. This is due, in part, to the limited historical information available regarding the participation of the land use, land-use-change and forestry (LULUCF) and agriculture sector in abatement programs. More generally, the level of uncertainty is affected by the limited information regarding the drivers of abatement.

These drivers include:

- the cost of generating the abatement and receiving credits;
- the price at which the credits can be sold;

- levels of participation by the relevant sectors; and
- other relevant policies at all levels of Government.

Scope and coverage of the CFI

The Kyoto Protocol sets out the rules for what emissions must or may be included in Australia's greenhouse gas accounts, and how to measure them.

On 14 May 2013, the Australian Government announced its decision to broaden coverage of the land sector for Australia's second commitment period target by including (or 'accounting' for) the additional land-based activities of cropland management, grazing land management and revegetation. In addition, forest management has been added to the list of mandatory land sector activities for the second commitment period, along with deforestation and afforestation/reforestation.

This means that CFI credits generated from these activities will now become eligible for businesses with carbon price obligations to surrender against their liabilities. This increases abatement incentives for land sector abatement.

Crediting of CFI abatement

The CFI legislation sets out the rules for verifying and crediting abatement from CFI projects. These rules are likely to result in a lag between when abatement occurs and when it is credited.

Below are some of the assumptions that underpin the projected rate at which CFI abatement will be credited.

CFI Regulations

- Sequestration projects are subject to a 5 per cent risk of reversal buffer. This means that 5 per cent of abatement is not credited but retained by the Government to cover temporary losses of carbon, for example from bushfires.
- The CFI rules require that an offsets report, accompanied by an audit report, be delivered to the Clean Energy Regulator within three months of the end of the reporting period. The issuance of credits is, therefore, dependent on the time taken by a project operator to finalise and deliver the report.
- The Clean Energy Regulator has up to three months to conduct an assessment of the offsets and audit report to be satisfied actual abatement has occurred before issuing credits. The complexity of this assessment process and the necessity of ensuring the environmental integrity of the scheme could result in a further lag between abatement and crediting.
- The reporting and notification requirements in Part 6 of the CFI Act require that a reporting period must not be shorter than 12 months. This means that abatement from a project's first year cannot be reported and credited until the following year. It will also mean a gap of one year between each report.

Operational assumptions

- Project proponents can report and receive credits every 12 months but can delay reporting for up to five years. This allows proponents of small projects to minimise audit and reporting costs. Less frequent reporting is particularly likely in the case of sequestration projects because trees grow slowly initially and may be subject to drought or fire. In general, however, most project proponents are expected to report annually.

AR2 to AR4 global warming potential transition

- As noted elsewhere in this report, emissions are reported using AR4 global warming potentials. Abatement occurring before 2017-18 will still be credited using AR2 global warming potentials even if the credits are issued after 2017-18.

Table C1: Description of CFI abatement activities

Sector	Subsector	Abatement activity
Land-use, Land-use-change and Forestry		
	Deforestation	Avoidance of the direct, human-induced removal of forest cover and conversion to a non-forest land use. Also includes managed regrowth on deforested land.
	Afforestation/ Reforestation	Establishment of forests through direct human action on land that was not forest on 31 December 1989.
	Forest Management	Enhanced sequestration in forests due to changed forest management practices, including in managed native forests.
	Grazing Land Management	Enhanced sequestration and avoidance of carbon emissions in grazing land areas due to changed land management practices.
	Cropland Management	Enhanced sequestration and avoidance of carbon emissions in cropland areas due to changed land management practices.
Agriculture		
	Livestock, Crops, Fertiliser	Emissions avoidance of methane and nitrous oxide in the agriculture sector through changed management practices. For example: the application of nitrogen to soil; type of feedstock given to livestock; manure management practices; rice growing practices; and the combustion of plant material.
	Savanna Burning	Emissions avoidance through early-season burning of savanna/temperate grassland ecosystems that limits the severity and duration of fires.
Waste		
	Landfill/Solid Waste	Emissions avoidance through the capture and destruction of landfill gas or the alternative treatment of 'legacy waste'. The CFI only covers emissions from legacy waste.[a]

Note: (a) Legacy waste means waste physically accepted at a landfill, or onto the premises of a waste diversion facility, before 1 July 2012. Waste at a waste diversion facility must otherwise have entered landfill before 1 July 2012.

Abatement estimates: Central policy scenario

Overall results

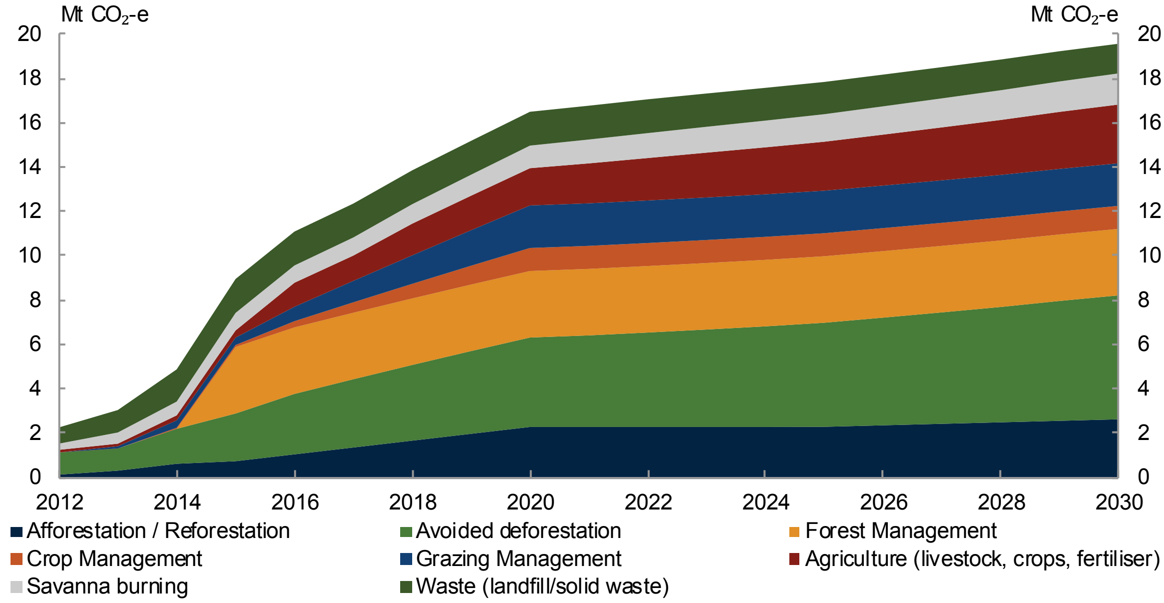
CFI abatement is projected to grow relatively rapidly in the early years of the scheme's operation, as some farmers and land managers enter the scheme quickly following its commencement. Experience over the first 18 months since the CFI's commencement supports this projection.

Abatement growth in the medium term (from around the middle of the decade) is estimated to slow, as opportunities for early moving farmers and land managers to undertake 'low-hanging' abatement activities decline and the offsets market matures. The steady but slower growth after this point reflects the ongoing entry of later moving operators and the ongoing expansion of the project types able to participate.

From around 2020, abatement is expected to increase steadily as a result of:

- projected increases in emissions from the LULUCF and agriculture sectors, which increases abatement potential;
- expansion of the project sectors able to participate;
- development of viable abatement technologies; and
- a rising carbon price.

Chart C1: CFI annual abatement by subsector, 2012 to 2030
Central policy scenario



Source: Projections from DIICCSRTE.

Table C2: Estimated annual abatement from the CFI, central policy scenario

	Mt CO_2-e			
	2012	2013	2020	2030
Total CFI abatement	2.3	3.0	16.5	19.6
LULUCF	1.1	1.4	12.3	14.2
Agriculture	0.4	0.6	2.7	4.1
Legacy waste	0.7	1.0	1.5	1.3

Source: Projections from DIICCSRTE.

Sectoral results

LULUCF

LULUCF abatement is driven largely by the implementation of projects under avoided deforestation, managed regrowth and forestry management methodologies. This focus reflects the low initial costs of project establishment in these areas as these projects generally relate to forgoing an action that would otherwise be undertaken for financial or other benefit, and that large areas of forest (particularly in Tasmania) are likely to become eligible to participate in the CFI in the near future.[1]

Box C.1: LULUCF CFI abatement drivers and activity levels

LULUCF abatement activities that reduce emissions will result in either avoidance or removal of greenhouse gas emissions into or from the atmosphere.

The abatement activities underpinning emissions avoidance or removals are stipulated in the abatement methodologies approved by the Domestic Offsets Integrity Committee and outlined in the relevant methodology determination. These activities include the protection of native forests through the reduction or cessation of logging in those forests. Other activities relate to the management practices applied to plantation forests that would not have otherwise occurred in the absence of the CFI (for example extended duration of harvesting cycles).

The magnitude and direction of abatement activities depends upon interactions between a range of factors. For example, movement in the farmers' terms of trade is one variable that effects land-holders' decisions to clear land. Other factors that influence the deforestation or reforestation decision include government land-clearing regulations, CFI eligibility rules, viable abatement methodologies, past rates of plantation establishment, commercial harvesting profiles, agriculture and timber commodity prices, the opportunity cost of land and the level of the carbon price.

Agriculture

The agriculture abatement estimates project a slow uptake based on an initially low carbon price before increasing on the expectation of higher prices.

1 This sector includes abatement from all LULUCF subsectors listed in Table C1, including those that were not included in Australia's accounts during the first commitment period of the Kyoto Protocol.

Box C.2: Agriculture CFI abatement drivers and activity levels

Agriculture abatement activities that reduce emissions will result in avoidance of greenhouse gas emissions into the atmosphere.

The abatement activities underpinning emissions avoidance or removals are stipulated in the abatement methodologies approved by the Domestic Offsets Integrity Committee and outlined in the relevant methodology determination. These activities include particular methods of applying fertilisers to soils in order to reduce nitrous oxide emissions. Other activities that avoid, reduce or remove greenhouse gas emissions include the capture and combustion of methane from manure lagoons and the enhancement and application of animal feedstock in order to reduce emissions from the enteric fermentation process.

The magnitude and direction of abatement activities depends upon interactions between a range of factors. For example, the productivity co-benefits arising from changed agriculture practices may incentivise project uptake. Other factors also influence the agriculture abatement decision, including climatic conditions (in the case of savanna burning), evolving farming practices, viable abatement methodologies, opportunity costs of resource allocation, technology availability, participation of project aggregators and the level of the carbon price.

Waste

After modest uptake during the early years of the CFI, uptake is projected to slow as the scheme matures, potential abatement of 'legacy' waste decreases and the carbon price experiences initial weakening after the fixed price period. Existing projects are assumed to continue as they are not price-sensitive once established. Abatement decreases over time as emissions from legacy waste also decrease with time.

Box C.3: Waste CFI abatement drivers and activity levels

Waste sector abatement activities that reduce emissions will result in avoidance of greenhouse gas emissions into the atmosphere.

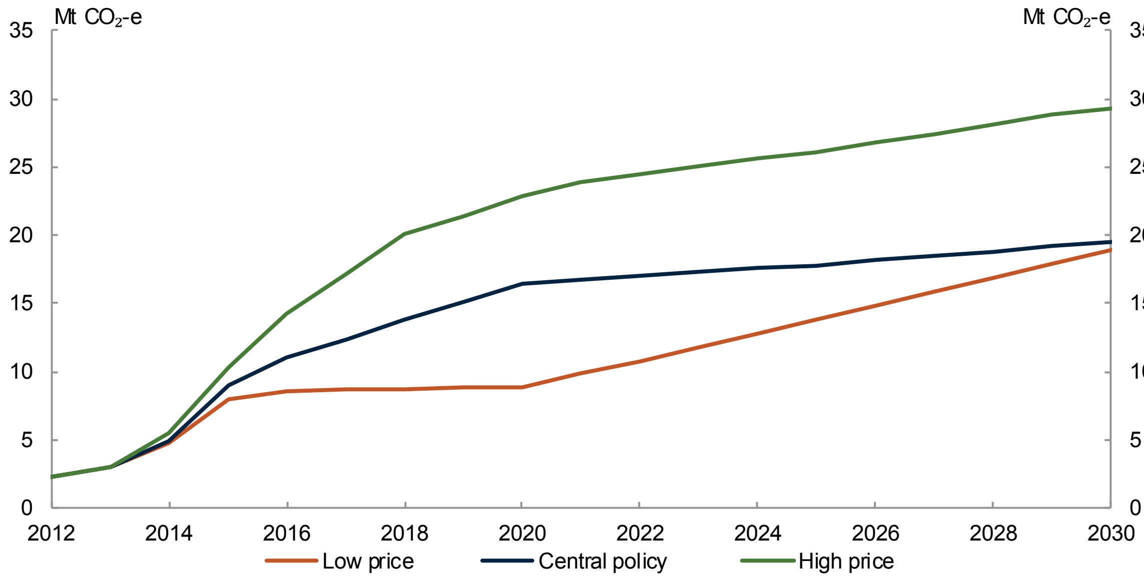
The abatement activities underpinning emissions avoidance includes alternate methods of collecting and treating waste under anaerobic conditions.

The magnitude and direction of abatement activities depends upon interactions between a range of factors. For example, government regulation on the management of landfill gas facilities which limits the scope of what is considered additional abatement is a key determinant of project uptake. Other factors also influence the waste sector abatement decision including the size of the waste facility, existence of a previously installed landfill gas system, the amount of legacy waste and the level of the carbon price.

Other scenarios

In addition to estimating CFI abatement in the central policy scenario, estimates were produced for the other two carbon price scenarios. Compared to the central policy scenario, a greater level of CFI abatement is projected in the high price scenario, and a smaller level in the low price scenario.

Chart C2: Total CFI abatement for alternate policy scenarios, 2012 to 2030



Source: Projections from DIICCSRTE.

High price scenario

CFI abatement in the high price scenario sees abatement continue to rise beyond the fixed price period. As the carbon price strengthens considerably, the level of abatement increases substantially. In particular, the high carbon price offers an economic incentive to convert land from agricultural use to forestry.

Table C3: Estimated annual abatement from the CFI in the high price scenario

	Mt CO_2-e			
	2012	**2013**	**2020**	**2030**
Total CFI abatement	2.3	3.0	22.8	29.3
LULUCF	1.1	1.4	17.8	22.6
Agriculture	0.4	0.6	3.4	5.4
Legacy waste	0.7	1.0	1.6	1.3

Source: Projections from DIICCSRTE.

The impact of the high carbon price on LULUCF abatement will be to incentivise development and implementation of CFI methodologies. As the price rises, marginal lands and plantations will become increasingly viable. This is particularly the case in the afforestation/reforestation and avoided deforestation subsectors.

As with LULUCF, abatement activity in the agriculture and waste sectors is projected to increase in response to the rising price signal. These effects are most pronounced through increased participation in savanna-burning projects, as well as a higher deployment of enhanced feedlot, manure management and waste treatment practices.

Low price scenario

CFI abatement in the low price scenario is incentivised during the fixed price period after which prior investment maintains abatement as the price falls. Abatement then increases as the carbon price recovers.

Table C4: Estimated annual abatement from the CFI in the low price scenario

	Mt CO_2-e			
	2012	2013	2020	2030
Total CFI abatement	2.3	3.0	8.9	18.9
LULUCF	1.1	1.4	6.1	14.2
Agriculture	0.4	0.6	1.4	3.4
Legacy waste	0.7	1.0	1.5	1.3

Source: Projections from DIICCSRTE.

As in the high and central scenarios, the relationship between the low carbon price and LULUCF abatement will be reflected in the changing profit incentive to develop and implement CFI methodologies. As the price falls, the viability of plantings and avoided deforestation on marginal lands (the most price sensitive LULUCF sub-sectors) is projected to decrease.

Similarly, abatement activity in the agriculture sector is projected to decrease in response to the declining price signal. Again, these effects are most pronounced in the savanna-burning manure management subsectors. Abatement from waste sector activities is projected to remain unchanged from the central scenario due to the low price sensitivity of the sector after abatement technologies become viable and are deployed.

Changes since last projections

Article 3.4 activities

Since the most recent CFI estimates, published in *Australian Emissions Projections 2012*, Australia has agreed to enter into a second commitment period under the Kyoto Protocol. The second commitment period is from 1 January 2013 to 31 December 2020 for the LULUCF sector and from 1 July 2012 to 30 June 2020 for the agriculture and waste sectors and provides the framework for reporting Australia's emissions reduction efforts over this period.

As part of the agreement to enter a second commitment period, Australia will now report emissions and removals from some additional activities outlined in Article 3.4 of the Kyoto Protocol. These activities are forest management, cropland management, grazing land management and revegetation. There is no net abatement anticipated from revegetation. The scope of abatement covered under the afforestation and reforestation subsector is also expanded for the second commitment period. CFI abatement estimates from these activities begin in 2013; they have not previously been included in Australia's Emissions Projections.

New information: revised carbon price, CFI regulations and emerging uptake information

The 2013–14 Budget included a revised carbon price estimate lower than anticipated in previous CFI projections. This downward revision of the carbon price reduces the level of abatement expected in the period out to 2020 due to a slower rate of CFI uptake.

New information reflecting developments in the CFI regulations and the rate of abatement uptake have also contributed to revised abatement estimates since the 2012 projections.

Early transition to an emissions trading scheme

The central policy scenario assumes a transition to an emissions trading scheme on 1 July 2014. Compared to a transition to an emissions trading scheme one year later, the impact on CFI abatement is limited. This is principally because farmers and land managers are assumed to take a longer-term view of carbon price trends in planning and implementing abatement action. Further, implementation of the announced change is not expected to significantly alter the expected long-term carbon price and is therefore unlikely to influence project planning and abatement activities already underway.

Methodology

These CFI abatement estimates were developed through a combination of bottom-up and top-down methods analysing abatement of emissions and sequestration from eligible activities. The abatement estimates appearing in this paper generally reflect a time series generated to be consistent with a bottom-up approach in the short term and the top-down approach in the long term. Individual estimates were developed for each CFI abatement subsector, which were then aggregated to determine the overall level of projected CFI abatement.

Where available, emerging information on uptake rates was used to construct a bottom-up estimate of CFI abatement for the short term. This was based on information relating to potential projects and methodologies under development.

In the long term, abatement is estimated using a top-down approach. This approach releases the estimates from bottom-up constraints regarding sunk capitals costs and allows for greater flexibility in abatement investments in response to broader global and domestic macroeconomic variables and changing marginal abatement cost (MAC) curves. These MAC curves were used for previous estimates of long-term CFI abatement and are consistent with earlier bottom-up estimates of 2020 ranges published by the former Department of Climate Change and Energy Efficiency.[2]

The methodology assumes that the cost of abatement increases more rapidly than the level of abatement (that is, the marginal cost of emissions reductions is an increasing, convex function of the proportional reduction in emissions). This method was used in the long term as detailed bottom-up information is not available for the longer term.

A smooth rate of transition was applied to harmonise the top-down and bottom-up approaches.

2 Further detail on the CFI projection methodologies relating to these MAC curves is included in the CFI estimates report produced for Australian Government (2011) and available on the Treasury website: http://archive.treasury.gov.au/carbonpricemodelling/content/consultantreports.asp

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