Appendix B: Treasury climate change mitigation modelling — assumptions

1.1 Introduction

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

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

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

1.2 Policy and design features

1.2.1 Global carbon price

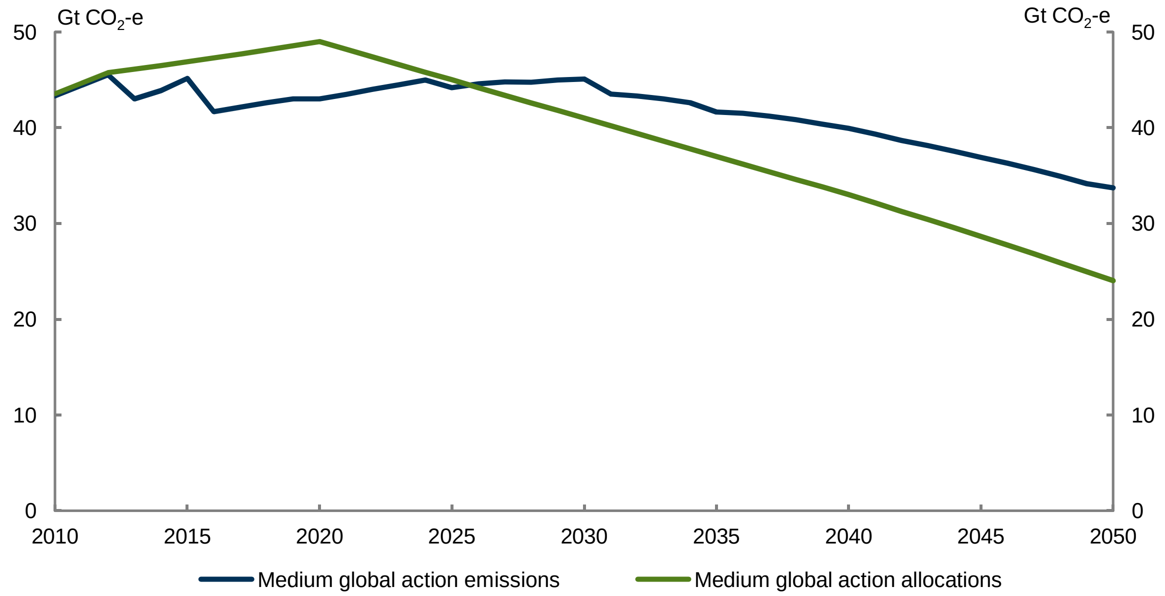
A Hotelling rule is used to construct a global emissions pathway for each scenario within the global model (GTEM). The starting carbon price for each scenario is set so global emissions give the desired path for concentrations of the modelled greenhouse gases using the MAGICC model. The real carbon price grows from a specified starting level at the real interest rate, assumed to be 4 per cent per year, which represents the rate of increase in comparable financial assets. This rate of return embodies the commercial risks of holding permits and investing in emissions-related activities. It is calibrated as a risk-free real rate of 2 per cent and a risk premium in markets for permits of 2 per cent. A similar method has been applied in other recent modelling exercises (EMF, 2011).

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

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

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

Chart B1: Allocations and emissions
Medium global action scenario



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

Table B1: Global allocations, emissions and banked permits

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

Source: Treasury estimates from GTEM.

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

1.2.2 Australian assumptions

Summary of domestic policy assumptions

The Australian policy scenarios considered assume Australia introduces a domestic carbon price with a fixed price scheme from 1 July 2012. The price rising each year, before the Government establishes a flexible price cap and trade scheme in 2015-16.

Table B2: Key carbon price design features

	Core scenario	High price scenario
Nominal domestic price in 2012-13	$20, $23 for household impact modelling	$30
Nominal world price in 2015-16, A$	Projected to commence at $29	Projected to commence at $61
World stabilisation target	550 ppm	450 ppm
Australian emission reduction target	5 per cent below 2000 levels by 2020; 80 per cent below 2000 levels by 2050	25 per cent below 2000 levels by 2020; 80 per cent below 2000 levels by 2050

Table B3: Implementation of policy scenario assumptions

Issue	Policy setting	Implementation in MMRF
Australia's emission trajectory	Set as a straight line from the end of the Kyoto commitment period (2008-2012) to 2020 and again as a straight line from 2020 to 2050.	
Coverage	All emission sources covered, except: * activity emissions from agriculture and forestry ; * forestry (in terms of mandatory liability for emissions); * decommissioned mines; * land-use change; * legacy waste; and * existing synthetic gases.	Agriculture comprises sheep and cattle, dairy, other animal and grains.
Emission-intensive trade-exposed activities (EITE)	EITE activities are shielded from the carbon price for direct emissions and for upstream emissions from electricity use. Assistance is based on allocative baselines reflecting historical industry average levels of carbon pollution per unit of production. Definitions of EITE activities and rates of assistance by activity (either 94.5 or 66 per cent) are consistent with the CPRS package as at 24 November 2009. The rate of assistance — the number of permits per unit of output — is reduced by 1.3 per cent per year, before being assumed to phased out in five annual steps starting in 2022.	EITE activities are allocated to MMRF industries. Calculations use 2007-08 data provided by the Department of Climate Change and Energy Efficiency.
International linkage	No international linking during the fixed carbon price period and only quality restrictions from 2015-16.	
Treatment of transport fuels	In the core policy scenario, an effective carbon price is applied to: businesses' combustion of liquid fuels from 2012-13 (except light vehicles, agriculture, forestry and fishing) and heavy on-road vehicles from 2014-15, through the fuel tax credit system; and aviation fuel from 2012-13 through the domestic aviation excise system. Off-road transport use and non-transport use of gaseous fuels face an effective carbon price through	In the core policy scenario, liquid fuel combustion is subject to a carbon price except: combustion by the road freight industry for the first 2 years; and combustion by service industries (except transport, but including road passenger transport), households and agriculture, forestry and fishing permanently. In the high price scenario, liquid fuel combustion is subject to a carbon price except:

Issue	Policy setting	Implementation in MMRF
	reductions in fuel tax credits or automatic excise remission. On-road transport use of gaseous fuels does not face a fuel tax credit reduction due to imposing the Road User Charge. In the high price scenario, all fuel combustion is subject to a carbon price. However, this effect is offset by permanent fuel excise reductions in the first 3 years for households and light on-road vehicles. Fuel credits offset the effect of the carbon price for the first year for heavy on-road vehicles, and for the first 3 years for agriculture, forestry and fishing.	combustion by the road freight industry for the first year; combustion by agriculture, forestry and fishing for the first three year; combustion by service industries (except transport, but including road passenger transport) and households is subject to the incremental increase in the carbon price beyond its level in 2014-15.
Use of permit revenue	Assistance will be provided through increases in Family Tax Benefit, pensions and allowances as well as tax cuts.	Net revenue from the scheme is allocated to households as lump sum payments.
PRISMOD assumptions	Assistance to EITE activities is allocated to the 109 industries in PRISMOD. Transport fuels are treated as described for the core policy scenario. Synthetic gases are assumed to be subject to a levy on importation into Australia. All data are adjusted, where necessary, to be consistent with the 2005-06 input-output tables. No adjustment is made for redistribution of net permit revenue as household assistance payments.	

Existing Australian policy measures in different sectors

Modelling of the global action scenarios includes a number of pre-existing Australian policy measures across a number of sectors.

Electricity policy measures

The global action scenarios assume pre-existing policy measures remain in place, including the Large-scale Renewable Energy Target (LRET), the Small-scale Renewable Energy Scheme (SRES), the NSW and ACT Greenhouse Gas Abatement Scheme (GGAS), the voluntary market program Green Power and the Queensland Gas Scheme. The LRET and SRES targets are in line with those published on the Office of the Renewable Energy Regulators website. The modelling assumes that the Cleaner Power Stations Initiative requires new power stations to have emissions below 0.86 t CO_2-e/MWh, in line with announced government policy.

In the policy scenarios, the GGAS scheme is removed with the introduction of a carbon price, in line with announced NSW Government policy. All other policy measures are assumed to remain in place.

Transport policy measures

The global action scenario assumes existing emission reductions and tax policies continue. In addition, the global action scenario policies include the Government's election commitments to introduce emissions standards for all new light vehicles. Emissions Standards for Cars is the only additional policy assumed to start during the modelling period.

NSW Biofuels Act

The NSW Biofuels Act requires all regular grade unleaded petrol to be E10 from 1 July 2011. The Act establishes a volumetric biodiesel mandate of 2 per cent, increasing the mandate to 5 per cent from 1 January 2012.

Emissions Standards for Cars

The Australian Government has proposed a mandatory carbon dioxide emission standard for all new light vehicles, including cars, from 2015. The policy and global action scenarios assume new vehicle emission standards limit emissions for new cars to 190g CO_2/km in 2015 and 155g CO_2/km in 2024. The mandatory standard sets a national fleet-wide target of average carbon dioxide emissions and each individual motor vehicle company contributes to this target. All new four-wheeled light vehicles with a gross vehicle mass of 3.5 tonnes or less – passenger cars, sports utility vehicles and light commercial vehicles sold in Australia, whether imported or manufactured locally – are included in the standards.

Fuel Excise

Methanol and the gaseous fuels, including liquefied petroleum gas (LPG), liquefied natural gas (LNG) and compressed natural gas (CNG), are currently outside the fuel tax system and thus excise free.

Excise tax for ethanol is phased in from 2010 to 2020. Domestic ethanol producers receive targeted assistance over ten years to manage the transition. The phase down in imported ethanol in excise-equivalent customs duty occurs over five years.

LPG Vehicle Scheme

The LPG vehicle scheme offers up to $2,000 in grants to either convert a private motor vehicle to LPG or purchase a new LPG vehicle. The scheme operates from 1 July 2009 to 30 June 2014.

Other policy measures

Both the global action and policy scenarios assume the Carbon Farming Initiative (CFI), which provides an incentive for additional permanent abatement from livestock, crops, avoided deforestation and managed regrowth, savannah fire management, legacy waste and carbon plantations, remains in place.

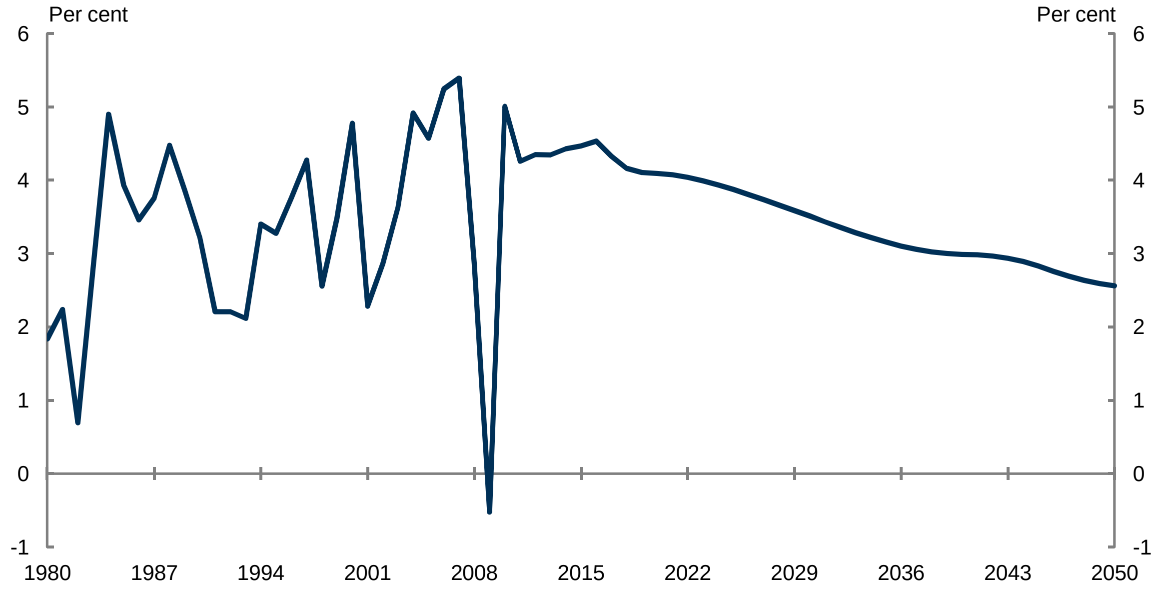
The CFI enables the sectors listed to generate abatement credits to sell internationally. It is assumed CFI credits are sold at the prevailing world carbon price and this price determines the level of abatement.

1.3 World economic assumptions

1.3.1 World gross domestic product

Gross world product (GWP) projections remain broadly similar to the previous climate change mitigation modelling (Australian Government, 2008). However, the balance of economic power is shifting towards developing economies. This is a result of the continued process of developing economies catching up to the per person income levels of developed economies. The recent downgrade to developed economy projections and upgrade to developing economy projections leaves overall GWP growth similar to previous estimates, at an average annual growth rate of 3.5 per cent to 2050, compared to the 3.9 per cent average over the past 50 years.

Chart B2: Real gross world product growth



Source: IMF, 2011; and Treasury.

Table 1.1: Table B4: World real GDP growth
Average annual growth (per cent)

	2010-2020	2020-2050
United States	2.5	1.9
European Union (25)	1.8	1.3
China	8.8	3.4
Former Soviet Union	4.3	2.7
Japan	1.2	0.4
India	8.1	6.2
Canada	2.2	1.9
Indonesia	6.8	5.1
South Africa	4.3	3.9
Other south and east Asia	4.4	3.4
OPEC	4.9	3.8
Rest of world	4.5	4.1

Source: Treasury, IMF, OECD and Consensus.

1.3.2 World population and participation

World population projections to 2050 are based on United Nations (UN) data (2011). The projections are interpolated to produce annual projections of population by country (both total and adult). These country projections are then aggregated into the country groups used in GTEM. The UN population projections have been revised up recently, although growth in some of the Asian countries is now lower.

Table B5: World population levels and growth GTEM regions (per cent)

	Population level (millions)			Average growth rate	
	2010	2020	2050	2010-2020	2020-2050
United States	313	340	406	0.8	0.6
European Union (25)	472	483	488	0.2	0.0
China	1358	1406	1314	0.3	-0.2
Former Soviet Union	284	287	277	0.1	-0.1
Japan	128	126	110	-0.1	-0.5
India	1188	1346	1642	1.3	0.7
Canada	34	37	44	0.9	0.5
Indonesia	236	258	288	0.9	0.4
South Africa	56	59	65	0.6	0.3
Other south and east Asia	429	473	547	1.0	0.5
OPEC	248	296	418	1.8	1.1
Rest of world	2124	2516	3677	1.7	1.3

Source: Treasury and United Nations, 2011.

1.3.3 World productivity and technological development

Aggregate productivity

Estimates of country-by-country growth in productivity (either output per worker or output per hour worked) use a conditional convergence framework. If a country's productivity level is below its 'potential' then, in the process of catching up, it gradually asymptotes to its potential. Baumol (1986) and Barro and Sala-i-Martin (1992) detail the economic framework for convergence. Convergence (sometimes called 'catch-up') is commonly assumed in long-term international growth projections, such as the *Special Report on Emission Scenarios* (IPCC, 2000), the OECD environmental outlook and IMF reports.

Productivity for OECD countries is based on per hour purchasing power parity (PPP) productivity from the Total Economy Database (The Conference Board/Gronningen) 2009 update. Non-OECD productivity is based on per working age population. GDP per person (in PPP terms) is from the World Bank International Comparison Project (ICP) (December 2007 update), and adjusted to a per working age population basis using the population assumptions. Where GDP data are unavailable from the ICP update, the most recent Maddison international PPP update (August 2007) is used. This is done for 50 countries, which collectively represent around 2 per cent of GWP.

US productivity growth is assumed to adjust gradually towards a long-term annual rate of 1.6 per cent. The long-term growth rate assumption is based on historical trends of productivity growth by industry and expected changes in the industry structure of the United States. Official projections of long-term productivity growth are somewhat higher at around 1.7 per cent (OASDI Trustees, 2011; and Congressional Budget Office, 2011), but do not take into account the likely shift towards industries with lower average rates of productivity growth.

Each country's potential productivity is modelled as a percentage of the productivity level of the technological leader, assumed to be the United States.

- High-income OECD countries with 70 per cent or more of US productivity levels converge to a productivity level relative to the US (equal of the average level of the last 5 years, to abstract from cyclical effects). This generally causes the country to grow at the same rate as the United States.

- High-income non-OECD countries converge to a productivity level relative to the US equal to their starting point. This generally has the causes the country to grow at the same rate as the United States.
- Non-OECD countries with a productivity level of less than 70 per cent of the US level are assumed to converge to a maximum of 70 per cent of the US productivity level, taking into account such things as their recent growth experience and measures of their current level of human development and governance.
  - For most countries, a common rate of convergence of 2 per cent per year is assumed (Sala-i-Martin, 1996). Many studies using climate change models assume this rate (Bagnoli et al, 1996; McKibbin et al, 2004; and more recent OECD work).
- Productivity growth is also smoothed, so that each country takes some time to go from its recent rate of growth to its long-term convergence path.

Convergence and GDP calculations are performed at a country, not regional level. OPEC, in particular, shows seemingly less convergence than other regions as a result. OPEC is a mix of countries with high productivity (such as Qatar) that do not converge, mid income countries (such as Saudi Arabia) that converge more slowly, and low income countries (such as Yemen).

Table B6: Productivity level relative to the United States by GTEM region
Level

	Productivity level		
	2010	2020	2050
United States	100	100	100
European Union (25)	67	67	69
China	13	25	53
Former Soviet Union	20	26	41
Japan	76	77	71
India	7	10	31
Canada	81	79	82
Indonesia	8	12	32
South Africa	20	23	40
Other south and east Asia	16	18	29
OPEC	26	28	39
Rest of world	14	15	20

Note: GDP per adult population, US=100.
Source: Treasury, OECD and United Nations.

Sectoral labour productivity

The productivity and population assumptions indicate the total change in output for the economy. To implement these in GTEM, Treasury assumes this increase in productivity (or efficiency) is distributed across industries. Capital stock accumulates endogenously and the model indicates the supply of other primary factors. It then calculates the value of a productivity variable, so that it is consistent with the exogenous trajectory of regional outputs.

The distribution of labour productivity across industries in each country is based on historical performance. Sectoral productivity growth rates are based on historical averages from the Groningen Growth and Development Centre database and the OECD. Different sectors have different relative growth rates in the GTEM model.

Table B7: Relative sectoral labour productivity growth rates
Base year values

	USA	EU(25)	China	FSU	Japan	India
Coal mining	1.00	1.00	1.30	0.50	0.50	1.50
Oil mining	1.00	1.00	1.00	0.50	0.50	1.00
Gas mining	1.00	1.00	1.00	0.50	0.50	1.00
Petroleum and coal	1.00	1.00	1.00	0.50	0.50	1.00
Electricity	1.25	1.00	1.00	0.50	0.50	0.50
Mining and chemicals	1.25	1.00	1.00	1.00	1.50	1.00
Manufacturing	1.25	1.50	1.00	1.00	1.50	1.00
Road transport	1.50	2.00	2.00	1.00	2.00	2.00
Water and air transport	0.75	1.00	1.00	0.50	1.00	0.50
Crops	0.75	1.50	1.00	1.00	0.50	0.50
Livestock	0.75	1.50	1.00	1.00	0.50	0.50
Fishing and forestry	0.75	1.50	1.00	1.00	0.50	0.50
Food	1.40	1.50	1.00	1.00	1.00	1.00
Services	1.00	1.00	1.00	0.75	1.00	0.75

	Canada	Indonesia	Sth Africa	Other Asia	OPEC	ROW
Coal mining	1.00	1.40	1.00	1.00	1.00	1.00
Oil mining	1.00	0.75	1.00	0.75	1.00	1.00
Gas mining	1.00	0.75	1.00	0.75	1.00	1.00
Petroleum and coal	1.00	0.75	1.00	0.75	1.00	1.00
Electricity	1.25	0.75	1.00	0.75	1.00	1.00
Mining and chemicals	1.25	1.00	1.00	1.00	1.00	1.00
Manufacturing	1.25	1.00	1.00	1.00	1.00	1.00
Road transport	1.50	2.00	2.00	2.00	2.00	2.00
Water and air transport	0.75	0.50	1.00	0.50	1.00	1.00
Crops	0.75	0.75	1.00	0.50	1.00	1.00
Livestock	0.75	0.50	1.00	0.50	1.00	1.00
Fishing and forestry	0.75	0.50	1.00	0.50	1.00	1.00
Food	1.40	0.50	1.00	0.50	1.00	1.00
Services	1.00	0.75	1.00	0.75	1.00	1.00

Note: GTEM industries have been aggregated where distribution of sectoral productivity is the same.
Source: Treasury.

The data indicate that, for instance, road transport labour productivity in China will grow twice as quickly as labour productivity in the coal sector. These numbers do not directly compare sector productivity across regions. For example, mining and chemicals productivity growth in China and India are not equal because growth rates are relative to the individual country or regions' aggregate labour productivity growth.

Intermediate input assumptions

The assumption in GTEM is that industries' efficiency in using intermediate inputs changes over time. Rates of improvement differ between regions and sectors.

Table B8: Improvement in intermediate input efficiency in GTEM
Average annual rate of improvement (per cent, 2001 to 2050)

	Annual average
United States	0.3
European Union (25)	0.2
China	0.4
Former Soviet Union	0.7
Japan	0.2
India	1.0
Canada	0.2
Indonesia	0.5
South Africa	0.7
Other south and east Asia	0.3
OPEC	0.5
Rest of world	0.5

Source: Treasury.

Economy-wide energy efficiency

Energy efficiency increases when the same amount of output is produced using less energy. This can occur when: energy prices rise relative to other inputs; existing technology is used more efficiently; upgrading existing technology; or when new technology is developed through research and development and learning by doing.

Assumptions about energy efficiency improvements affect the level of energy use and hence emissions. GTEM and MMRF have different treatments of energy efficiency due to the different structures of the models.

In the baseline scenario, GTEM assumes a rate of improvement in energy efficiency of 0.5 per cent per year, except for specific sectors such as transport, iron and steel, non-metallic minerals, non-ferrous metals, chemicals, rubber and plastics.

Sector-specific energy efficiency

Transport

Energy efficiency in the transport sector is assumed to improve over time. Rates of improvement are based on ABARE (Matysek et al, 2006).

Table B9: Improvement in energy efficiency: transport
Average annual rate of improvement (per cent, 2010 to 2050)

	Rail	ICE	Advanced ICE	Hybrid	Non-fossil fuel
United States	0.6	0.2	0.4	0.7	0.7
European Union (25)	0.6	0.2	0.3	0.5	0.5
China	0.6	1.0	1.2	1.8	1.8
Former Soviet Union	0.6	0.5	0.7	0.9	0.9
Japan	0.6	0.2	0.3	0.5	0.5
India	0.6	1.1	1.4	1.7	1.7
Canada	0.6	0.2	0.4	0.7	0.7
Indonesia	0.6	0.2	0.3	0.5	0.5
South Africa	0.6	0.6	0.7	0.9	0.9
Other south and east Asia	0.6	1.0	1.2	1.5	1.5
OPEC	0.6	0.5	0.7	0.9	0.9
Rest of world	0.6	1.0	1.1	1.1	1.1

Note: ICE refers to internal combustion engines. Non-fossil fuel vehicles include electric and hydrogen cars.
Source: ABARES and Treasury.

Other sectors

Energy efficiency improvement projections in other sectors are assumed to be in line with those in previous Treasury modelling. The efficiency improvement for the non-ferrous metal sector is projected to vary significantly across regions. The improvement is mainly due to the increase of the use of scrap aluminium rather than technological advancement (Fisher et al, 2006). Higher scrap availability in a country leads to greater efficiency improvement projections. Composition shifts within the sector also contribute to the overall efficiency.

Table B10: Improvement in energy efficiency: non-ferrous metals
Average annual rate of improvement (per cent)

	2010-2050
United States	1.7
European Union (25)	1.7
China	1.1
Former Soviet Union	0.7
Japan	0.6
India	0.8
Canada	0.7
Indonesia	1.5
South Africa	0.8
Other south and east Asia	0.7
OPEC	0.7
Rest of world	0.8

Source: ABARES and Treasury.

The efficiency improvement projections for the chemical, rubber and plastics sector are assumed to be almost uniform across regions, reflecting the uniform accessibility of the energy-saving processes for the sector.

Table B11: Improvement in energy efficiency: chemical, rubber and plastics
Average annual rate of improvement (per cent)

	2010-2020	2020-2030	2030-2050
United States	0.5	0.5	0.6
European Union (25)	0.5	0.5	0.5
China	0.5	0.5	0.5
Former Soviet Union	0.4	0.4	0.5
Japan	0.5	0.5	0.5
India	0.6	0.5	0.5
Canada	0.5	0.5	0.5
Indonesia	0.4	0.5	0.5
South Africa	0.5	0.5	0.5
Other south and east Asia	0.4	0.5	0.6
OPEC	0.4	0.5	0.5
Rest of world	0.5	0.5	0.6

Source: ABARES and Treasury.

Energy efficiency in the iron and steel industry, and annual average efficiency improvements, are based on the US Energy Information Administration National Energy Modelling System (NEMS), which underlies the EIA's Annual Energy Outlook. GTEM represents iron and steel as a bundle with two discrete technologies — blast furnace and electric arc furnace (recycled steel from scrap).

Table B12: Improvement in energy efficiency: blast furnace production
Average annual rate of improvement (per cent)

	2010-2020	2020-2030	2030-2050
United States	0.3	0.3	0.8
European Union (25)	0.3	0.3	0.4
China	1.0	1.0	0.7
Former Soviet Union	0.9	0.9	0.7
Japan	0.3	0.3	0.5
India	0.9	0.8	1.0
Canada	0.3	0.3	0.5
Indonesia	0.0	0.0	0.5
South Africa	0.8	0.8	1.2
Other south and east Asia	0.5	0.5	0.4
OPEC	0.3	0.3	0.9
Rest of world	0.8	0.8	0.9

Source: ABARES and Treasury.

Table B13: Improvement in energy efficiency: electric arc production
Average annual rate of improvement (per cent)

	2010-2020	2020-2030	2030-2050
United States	0.7	0.7	0.9
European Union (25)	0.6	0.6	0.7
China	1.3	1.3	1.0
Former Soviet Union	1.3	1.4	0.8
Japan	0.6	0.6	0.8
India	1.3	1.3	1.3
Canada	0.7	0.7	0.6
Indonesia	1.2	1.2	1.4
South Africa	1.3	1.3	1.5
Other south and east Asia	0.7	0.8	1.2
OPEC	0.9	0.9	1.0
Rest of world	1.2	1.3	1.2

Source: ABARES and Treasury.

Electricity technology assumptions

Thermal efficiency

The thermal efficiency of a fossil fuel power plant is the ratio of electricity generated to energy input. Thermal efficiencies are greatest when plants operate at maximum capacity; as plants do not always operate at maximum capacity, the average thermal efficiency is typically lower than shown.

Table B14: Thermal efficiency of new power plants in GTEM

	Coal			Gas		
	2002	2020	2050	2002	2020	2050
United States	36	40	46	40	52	61
European Union (25)	35	37	40	48	51	54
China	32	38	43	46	57	63
Former Soviet Union	31	33	33	38	39	41
Japan	37	39	42	45	51	60
India	28	41	48	42	55	64
Canada	38	39	45	46	53	57
Indonesia	28	41	46	33	51	63
South Africa	38	42	47	39	54	65
Other south and east Asia	34	41	46	37	51	62
OPEC	39	43	48	32	51	63
Rest of world	33	40	47	41	53	61

Source: ABARES, ACIL Tasman (2008) and SKM MMA.

Carbon capture and storage (CCS)

CCS technology, combined with coal and gas electricity generation, is assumed to be available on a commercial scale only after 2021. This is later than earlier modelling because of the technology's slower assumed development and deployment. In addition, its commercial scale of uptake is also assumed to depend on the level of the carbon price in place, to allow for gains in cost competitiveness compared to other technologies.[2]

In GTEM, the capture efficiency rate is fixed at 90 per cent of produced emissions, imposed as an increased auxiliary use component (increased consumption of electricity necessary for generation, resulting from the CCS technology).

A sensitivity scenario was also run to test the implications of carbon capture and storage being unavailable (see Chapter 3).

Nuclear

Nuclear is assumed to continue to be available in regions where it is currently deployed, but not elsewhere. No specific constraints are imposed: nuclear resources and emerging technology are assumed to be able to meet demand for nuclear electricity. Japan's recent experience with its nuclear electricity plants may result in uncertainty about the extent of future expansion of the technology. Sensitivity analysis examines the impacts of no new nuclear capacity installed beyond 2020 (see Chapter 3). Nuclear is assumed to remain unavailable in Australia.

Marginal abatement cost curves

Carbon pricing provides an incentive for industries to reduce the emission intensity of their production. A common way to represent and model this reduction, especially when the models do not allow for substitution between intermediate inputs of production, is with marginal abatement cost (MAC) curves.

In the current modelling, MAC curves have the functional form:

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

where:

Λ is an emissions factor relative to the reference year;

τ is the carbon price;

min Λ is the minimum emissions factor possible; and

α and γ sets the extent of adjustment of emission intensity in response to a carbon price with higher values providing larger changes. α is set to 0.03 unless otherwise noted.

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2 In GTEM, the threshold carbon price for the uptake is assumed to be $31 for coal CCS and $38.5 for gas CCS technology (all in 2010 US dollars), reflecting the costs of transporting and storing the captured emissions.

The parameters γ and min Λ are chosen for each industry based on sector-specific information on technology and production possibilities. The MAC curves are non-linear and results can be sensitive to the solution methods used by the models.

The MAC curve parameters used in GTEM were chosen to fit global data from the EMF-21 data set by Weyant and Chesnaye (2006). The MAC curves in GTEM are applied only to fugitive and industrial process emissions; that is, only to emissions that are not the consequence of fuel combustion.

Table B15: GTEM fugitive/industrial process emission MAC curve parameters

	CO_2		CH_4		N_2O		
	α	γ	α	γ	α	γ	min Λ
Coal	-	-	0.03-0.07	0.90	-	-	0.02-0.1
Oil	0.03	0.60	0.03	0.75	-	-	0.01-0.1
Gas	0.03	0.60	0.03	0.80	-	-	0.02-0.1
Petroleum and coal products	0.03	0.60	-	-	-	-	0.02-0.1
Non-ferrous metals	0.05	0.99	-	-	-	-	0.01-0.1
Chemicals, rubber and plastic	-	-	-	-	0.09	0.99	0.02-0.1
Non-metallic minerals	0.03	0.60	-	-	-	-	0.01-0.1
Crops	-	-	0.03	0.50	-	-	0.00-0.1
Livestock	-	-	0.03	0.60	0.03	0.60	0.02-0.1
Fertiliser use	-	-	-	-	0.03	0.40	0.3
Waste(a)	-	-	0.05	0.70	-	-	0.1

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 B16: Change in non-combustion emission intensity in GTEM
Average annual growth (per cent, 2010 to 2050)

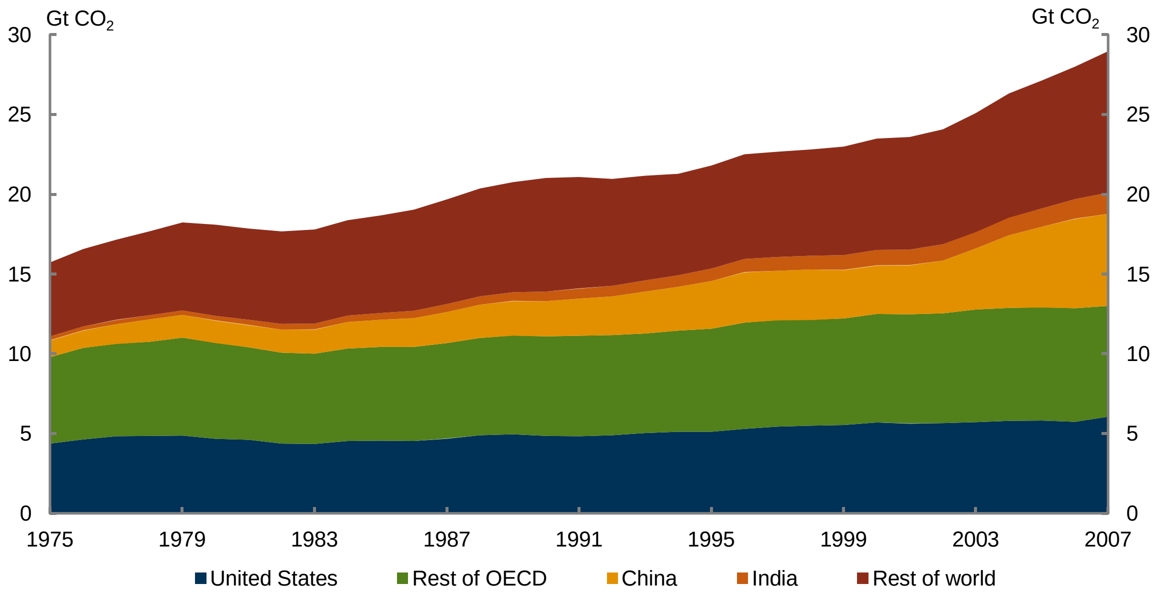
	Coal CH_4	Non-metallic minerals, CO_2	Livestock CH_4/N_2O	Crops N_2O	Gas CH_4	Oil CH_4
United States	-1.4	-0.2	-0.8	-0.8	0.0	0.0
European Union (25)	-1.7	-0.2	-0.8	-0.5	-0.6	0.0
China	-0.7	-0.3	-0.8	-0.3	-1.3	-3.6
Former Soviet Union	-1.0	-0.2	-0.8	-1.2	-2.8	-1.0
Japan	0.0	-0.2	-0.8	-0.5	-1.6	-5.1
India	-3.6	-0.3	-0.8	-0.3	-1.5	-4.6
Canada	0.0	-0.2	-1.1	-2.0	0.0	0.0
Indonesia	-0.7	0.0	-1.1	-1.5	0.0	0.0
South Africa	-3.6	-0.2	-0.8	-0.4	-1.6	-4.8
Other south and east Asia	-1.0	-0.2	-0.8	-0.5	-1.9	-5.1
OPEC	-3.6	-0.2	-0.8	-0.4	-1.7	-4.6
Rest of world	-3.8	-0.2	-0.8	-0.2	-0.2	-3.6

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

1.3.4 World emissions

Much of the world's economic activity depends, and will continue to depend, on emission-intensive energy. Despite an overall fall in the energy intensity of world output, total primary energy demand grew more than 60 per cent from 1980 to 2008, with most energy coming from fossil fuels (IEA, 2010a).

Chart B3: Fuel combustion emissions



Source: OECD/IEA, 2008; and WRI, 2011.

In the baseline scenario, where the world does not undertake any further abatement action than was in place in 2008, the world economy continues to rely on fossil fuel combustion to power growth, which in turn leads to increased greenhouse gas emissions, despite there being considerable declines in the expected emission intensity of growth.

With the world economy projected to grow strongly this century, annual greenhouse gas emissions more than double between 2010 and 2050. The annual rate of growth of emissions is expected to slow from around 2.5 per cent now to around 1.3 per cent by 2050.

These emissions are mostly carbon dioxide from energy use and deforestation, and methane and nitrous oxide from agriculture. Other gases such as hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) maintain a small share of around 1.5 per cent.

Table B17: Baseline global emissions

Emissions by region

	2010 CO_2-e	2020 CO_2-e	2050 CO_2-e
United States	6.9	6.9	8.2
European Union (25)	4.7	4.5	4.7
China	10.3	17.9	31.0
Former Soviet Union	3.9	4.6	6.2
Japan	1.3	1.2	1.0
India	2.2	3.5	12.6
Canada	0.8	0.8	1.0
Indonesia	0.9	1.0	2.4
South Africa	0.5	0.6	1.2
Other South and East Asia	1.7	1.7	3.1
OPEC	2.1	2.7	5.6
Rest of world	7.8	9.0	16.1
World	43.5	55.0	94.3

Emissions by gas and type

	2010 CO_2-e	2020 CO_2-e	2050 CO_2-e
Carbon dioxide	34.4	43.5	77.1
Combustion	30.6	39.7	70.9
Fugitive/Industrial process	1.5	2.4	5.7
Waste	0.04	0.04	0.04
LUCF	2.2	1.4	0.5
Methane	5.9	7.4	10.6
Combustion	0.5	0.6	0.9
Fugitive/Industrial process	4.1	5.3	7.9
Waste	1.3	1.5	1.8
Nitrous oxide	2.7	3.4	5.3
Combustion	1.6	2.0	3.0
Fugitive/Industrial process	1.0	1.3	2.2
Waste	0.03	0.03	0.04
Other gases	0.5	0.7	1.3
Total	43.5	55.0	94.3

Note: LUCF means land use change and forestry
Source: Treasury estimates from GTEM.

The emission intensity of the world economy falls by more than 45 per cent by 2050 compared with 2010. The emission intensity of output varies significantly across regions, although these differences are expected to narrow over time. Nevertheless, variations in key factors, such as consumer preferences, geographical location, resource endowments and comparative advantage, cause some differences in emission intensity to remain.

While emissions per unit of output are projected to decline, global emissions per person are projected to almost double between 2010 and 2050 in the baseline. Differences in per person emission levels are projected to narrow as incomes in developing regions rise, flowing through to increased consumption of energy and other emission-intensive goods. China's emissions per person triple to 2050 and overtake the level of the United States. India's emissions per person remain below the world's average by 2050, despite strong growth. Emissions per person are projected to be relatively stable for developed economies, reflecting continued energy efficiency improvements, technological change and rising consumption of low-emission services.

Emissions per person and emissions intensity of output are both lower than in previous Treasury modelling. This reflects the updated United Nations projections of world population (United Nations, 2011) and higher projected prices of fossil fuel commodities (IEA, 2010a).

Table B18: Baseline emissions by region

Emission intensity of GDP	2010	2020	2050	Emissions per person	2010	2020	2050
	kg CO_2-e per US $				t CO_2-e per person		
United States	0.45	0.35	0.23	United States	22.1	20.2	20.1
European Union (25)	0.30	0.24	0.17	European Union (25)	10.1	9.3	9.7
Australia	0.66	0.56	0.38	Australia	27.4	27.1	27.4
Rest of annex B	0.66	0.58	0.43	Rest of annex B	13.3	14.7	19.1
China	1.06	0.79	0.50	China	7.6	12.7	23.6
India	0.58	0.43	0.26	India	1.8	2.6	7.7
Rest of world	0.62	0.46	0.27	Rest of world	4.2	4.2	5.7
World average	0.58	0.48	0.31	World average	6.3	7.2	10.1

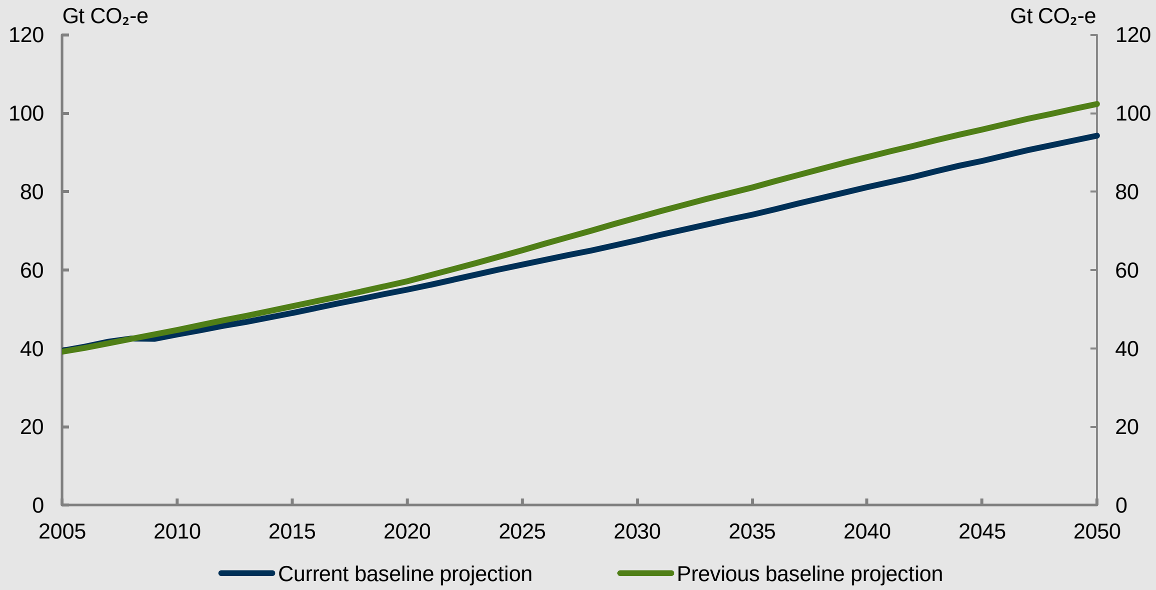
Note: GDP is in $ US 2010 using 2005 PPP weighting.
Source: Treasury estimates from GTEM.

Box 1.1: Baseline emissions comparison

The updated baseline scenario projects higher world population growth than previous modelling, but lower global production growth. Additionally, commodity price projections for fossil fuels are higher. Lower incomes and higher commodity prices leads to a decline in the demand for energy and other emission-intensive goods and services declines. Emissions from the two major emission-intensive sectors (electricity generation and transport) are significantly lower, contributing to lower level of world emissions than projected in the previous modelling.

Emissions growth is steady over the projection period, leading to total global emissions of 94 Gt CO_2-e in 2050. This projection is at the high end of the range compared to other studies (IPCC, 2007c; the EMF21 scenarios range from around 50 to 100 Gt CO_2-e in 2050), largely due to higher economic growth projections assumed in the current Treasury modelling. For example, global emissions in the baseline scenario of the current study are higher than those in OECD projections, which are around 70 Gt CO_2-e in 2050 (OECD, 2009). However, the emission intensity of the world economy is comparable, at around 0.29 kg CO_2-e per US dollar in 2050 in the OECD projection (based on calculations from results in OECD, 2009), compared to 0.31 kg CO_2-e per US dollar in 2050 in the current Treasury modelling.

Chart B4: Global greenhouse gas emissions



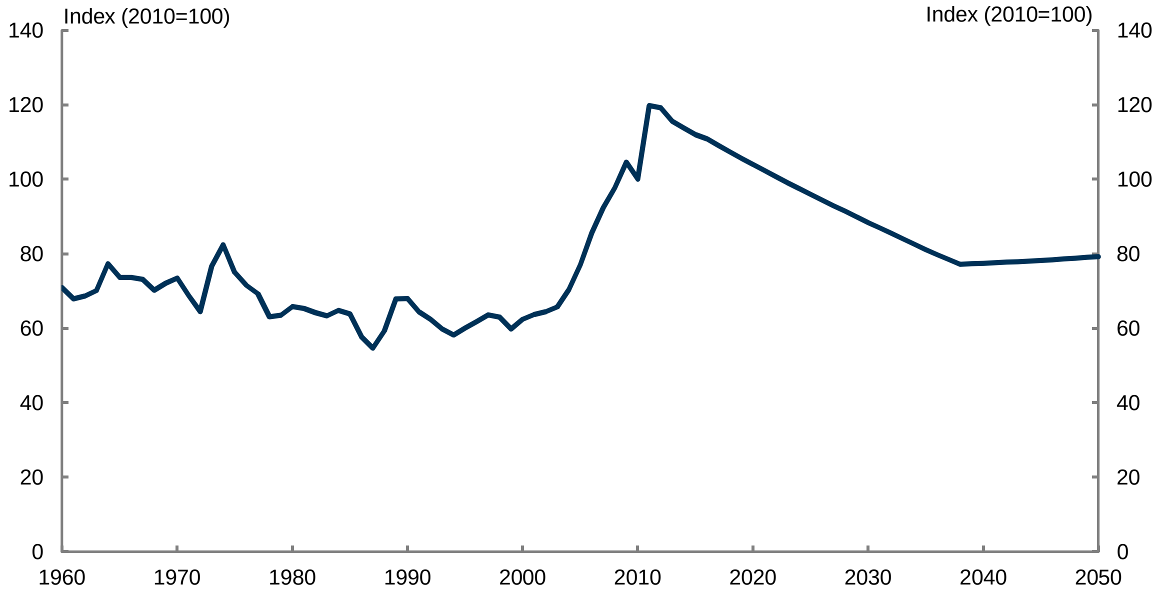
Source: Treasury estimates from GTEM.

1.4 Terms of trade and energy price assumptions

1.4.1 Terms of trade

The modelling uses the same medium-term path for the terms of trade as the Budget, a projected decline of around 20 per cent over a 15-year period. The terms of trade are then assumed to continue declining until 2037-38, when the level is in line with Treasury international modelling results. In later years, it grows modestly reflecting long-term expectations of world demand and supply of Australia's key exports, as modelled within GTEM.

Chart B5: Australia's terms of trade
Medium global action



Source: ABS and Treasury estimates from MMRF.

1.4.2 Energy commodity prices

Consistent with the previous modelling, assumed prices for oil and gas are based on projections from the International Energy Agency (IEA). Since previous modelling, the IEA has increased the projected growth rate and level of oil and gas prices out to 2030, reflecting rapidly increasing demand and the rising cost of extraction from marginal resources. As a result, prices in the current modelling are higher than in previous modelling. Prices in real terms are constant from around 2035.

Coal prices to 2028 are based on Treasury projections, after which they are held constant in real terms. For thermal coal, prices are based on information from individual companies, private sector forecasters, futures markets, ABARES and other industry sources, in addition to Treasury's analysis of bulk commodity prices.

In Australian dollar terms, coal, gas and oil prices in the ambitious global action scenario are the same as in the medium global action scenario until 2012. From 2012 to 2050, oil prices differ modestly between the two scenarios, with prices in the ambitious global action scenario, on average, higher by 0.3 per cent. Over the same period, coal and gas prices are both slightly lower in Australian dollar terms in the ambitious global action scenario: by 4.8 per cent and 3.7 per cent for coal and gas respectively, on average.

1.4.3 Fuel costs for Australian electricity generation

The detailed modelling by SKM MMA and ROAM employs similar assumptions about the fuel costs generators face.

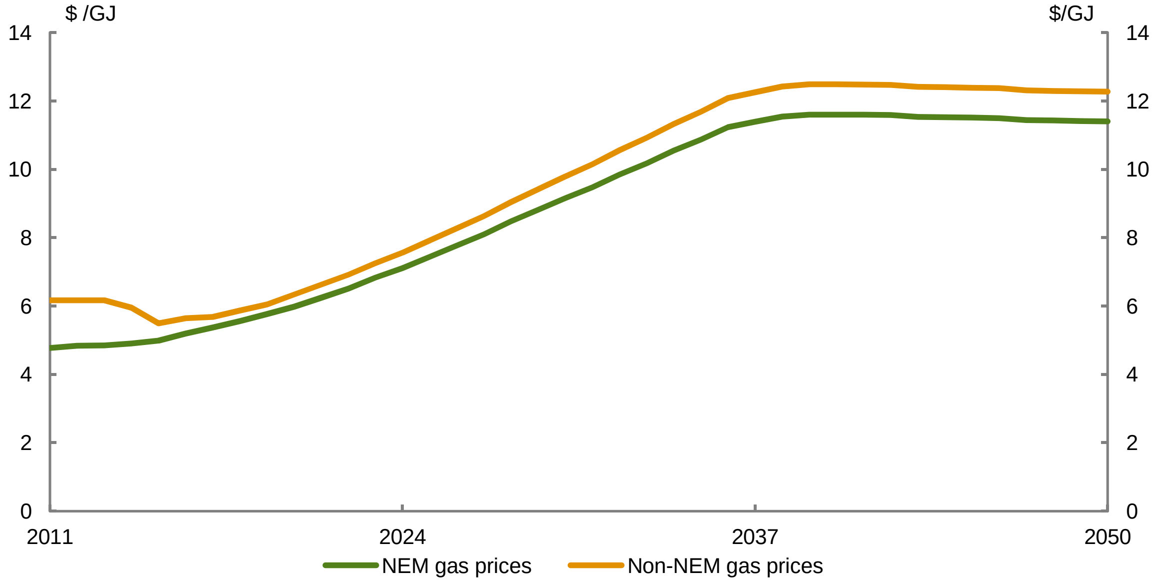
- Once existing contracts expire for black coal (non-mine mouth), world prices influence new contracts. Brown coal and mine mouth black coal prices are not affected by world energy price movements.

- The modellers were provided with assumptions about the path of world gas prices. These prices are used by the modellers to inform assumptions about the domestic prices for gas.

  – Western Australian gas prices are assumed to be at a domestic equivalent of the international price of gas, excluding export costs (such as for compression).

  – The significant investment plans in production and LNG export facilities in Queensland is assumed to result in the domestic gas price in the east coast being linked to changes in world gas prices by around 2020.

Chart B6: Domestic Australian gas prices
Medium global action scenario



Source: SKM MMA and ROAM.

1.5 Australian economic assumptions

1.5.1 Australian gross domestic product

Table B19: Australia's employment, productivity and GDP
Average annual growth (per cent)

Decade	Employment	Labour productivity	Real GDP
2010s	1.6	1.4	3.0
2020s	1.1	1.6	2.6
2030s	1.0	1.6	2.6
2040s	0.9	1.6	2.5

Note: Results from the medium global action scenario.
Source: Treasury and ABS.

Gross state product

Gross state product is a function of assumptions about the distribution of population and industry across states.

Table B20: Gross state product
Average annual growth (per cent)

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

Source: Treasury and ABS.

Table B21: State population growth
Average annual growth (per cent)

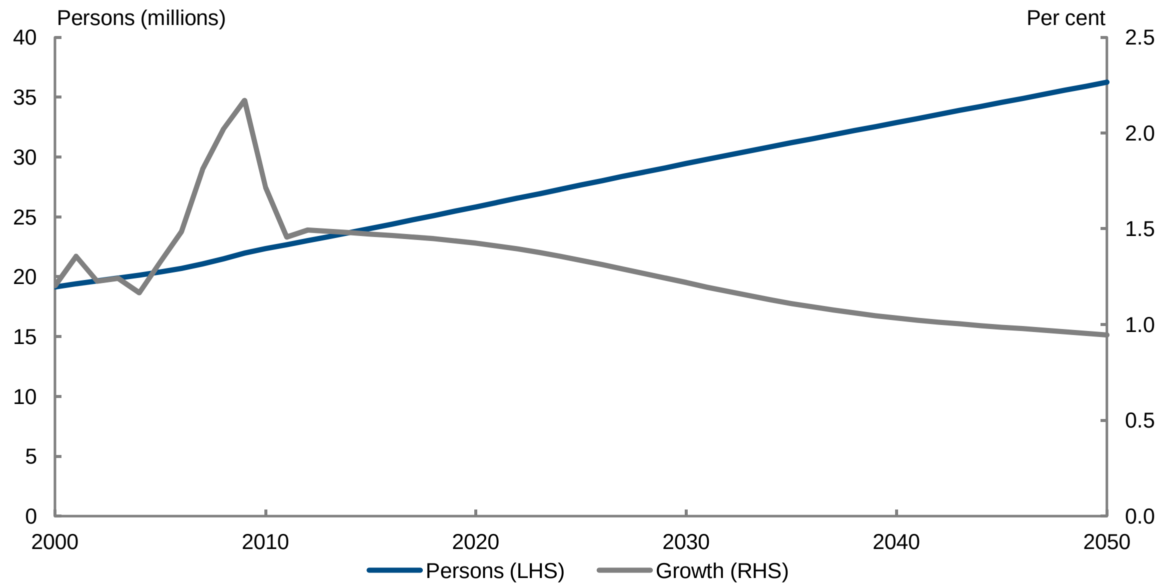
Decade	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
2010s	1.1	1.4	2.1	1.0	2.0	0.7	1.5	1.2
2020s	1.0	1.3	1.8	0.9	1.7	0.5	1.4	1.0
2030s	0.9	1.0	1.5	0.7	1.4	0.3	1.3	0.9
2040s	0.8	0.9	1.3	0.6	1.3	0.2	1.3	0.8

Source: Treasury and ABS.

1.5.2 Australian population and participation

Australian national population is based on Treasury projections updated since the 2010 Intergenerational Report (Australian Government, 2010). State population projections used in MMRF disaggregate the national population into the states by applying state population shares projected by the ABS.

Chart B7: Australia's population growth



Source: 2010 Intergenerational Report and Treasury projections.

1.5.3 Australian productivity and technological development

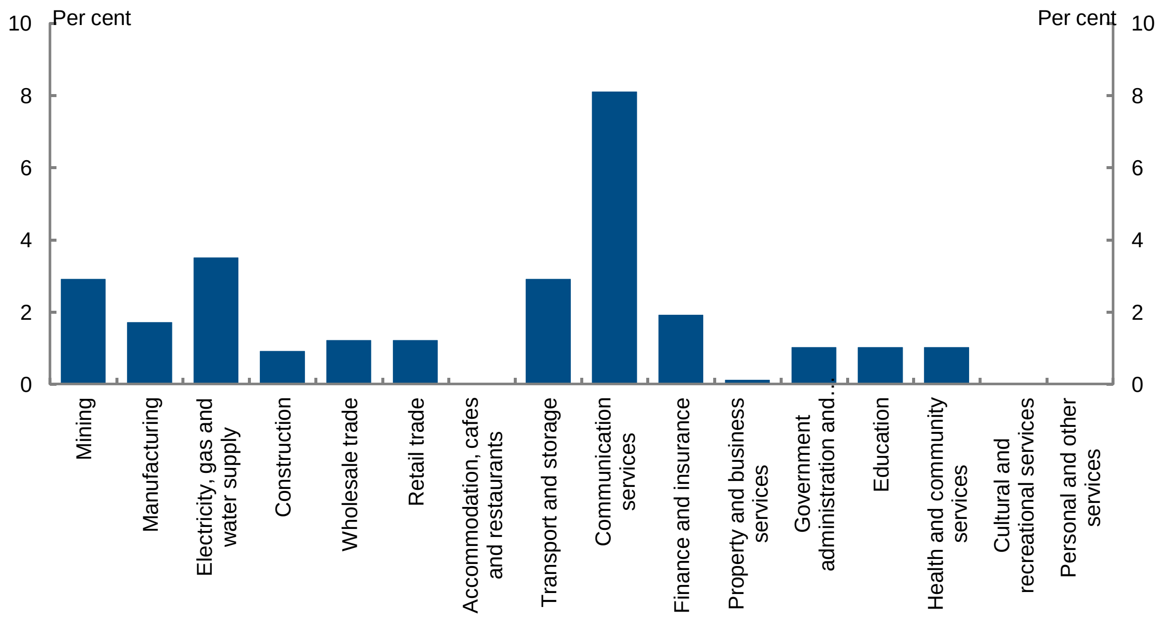
Labour productivity

The modelling uses Treasury forecasts and budget projections for aggregate labour productivity growth to 2014-15. Sector-specific labour productivity then gradually transitions to the assumed aggregate rate of 1.6 per cent per year. Australia's aggregate long-term labour productivity growth of 1.6 per cent is consistent with the US long-term labour productivity growth assumption.

MMRF uses an aggregate labour productivity assumption by adjusting its labour-augmenting technical change variable at an industry level, thereby dispersing technical change across industries, based on historical estimates.

The growth rates of labour-augmenting technical change across industries are not the same. The growth rates are estimated from the ABS National Accounts. They remove the effect of capital deepening on output by adjusting multifactor productivity estimates by industry-level labour income shares.

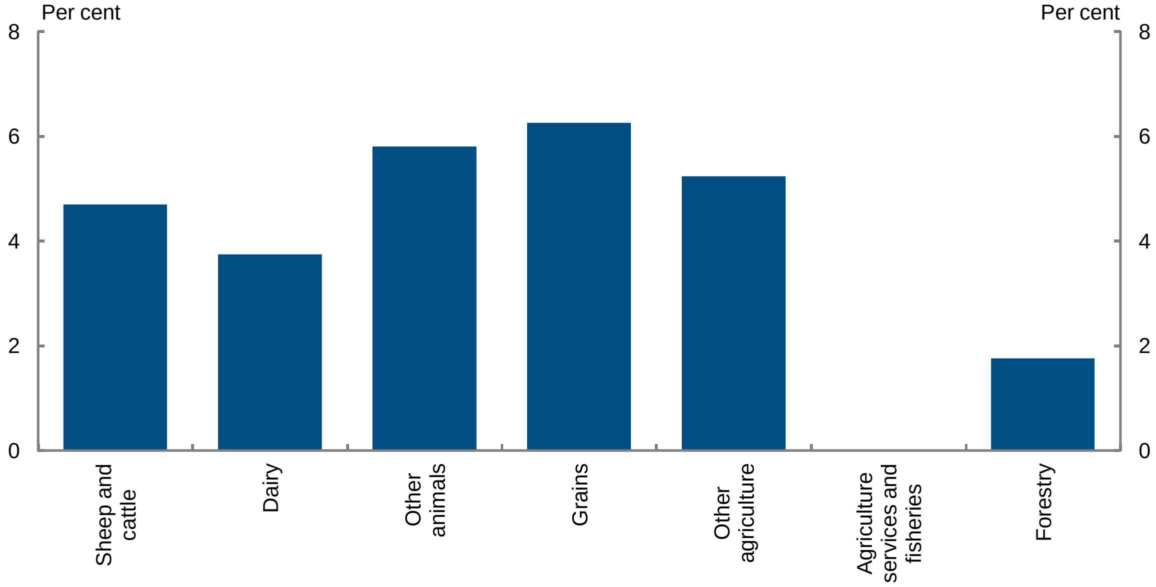
Chart B8: Industry labour-augmenting technical change
Average annual growth from 1976 to 2007



Source: Treasury and ABS.

The modelling uses a more detailed set of assumptions for the agricultural sector than the previous modelling. Technical change for each disaggregated sector is based on Centre for International Economics (2010) and ABARES (2011).

Chart B9: Agriculture, forestry and fishing labour-augmenting technical change
Average annual growth from 1976 to 2007



Source: Treasury, CIE and ABARES.

Intermediate input assumptions

The assumed changes in MMRF are based on a historical decomposition analysis by Giesecke (2004). Treasury validates intermediate input usage estimates in MMRF using a data set from the Centre for Integrated Sustainability Analysis at University of Sydney. Reflecting uncertainty about the persistence of historical trends over long timeframes, the intermediate input changes are assumed to decline linearly to zero between 2020 and 2050. MMRF implements the change in the intermediate input usage in a cost-neutral way, so total factor productivity remains unchanged.

Table B22: Intermediate input usage in MMRF

Average annual growth

Commodities	2010 to 2020	2020 to 2030	2030 to 2040	2040 to 2050
Sheep and cattle	-0.2	-0.2	-0.1	0.0
Dairy cattle	-0.2	-0.2	-0.1	0.0
Other animals	-0.2	-0.2	-0.1	0.0
Forestry	-0.5	-0.4	-0.3	-0.1
Coal mining	-0.5	-0.5	-0.5	-0.5
Gas mining	-0.5	-0.5	-0.5	-0.5
Other mining	-1.5	-1.2	-0.8	-0.3
Meat products	0.5	0.4	0.2	0.1
Textiles, clothing and footwear	-2.0	-1.6	-1.0	-0.4
Wood products	-0.2	-0.2	-0.1	0.0
Paper products	-0.2	-0.2	-0.1	0.0
Printing	-0.4	-0.3	-0.2	-0.1
Gasoline	-0.5	-0.5	-0.5	-0.5
Diesel	-0.5	-0.5	-0.5	-0.5
LPG	-0.5	-0.5	-0.5	-0.5
Air fuel	-1.0	-1.0	-1.0	-1.0
Other fuel	-0.5	-0.5	-0.5	-0.5
Chemicals	-0.7	-0.6	-0.4	-0.1
Rubber & plastic products	0.5	0.4	0.2	0.1
Non-metal construction products	-0.5	-0.4	-0.3	-0.1
Cement	-0.3	-0.2	-0.2	-0.1
Iron and steel	-1.0	-0.8	-0.5	-0.2
Aluminium	-1.0	-0.8	-0.5	-0.2
Other metals manufacturing	-0.1	-0.1	-0.1	0.0
Metal products	-0.1	-0.1	-0.1	0.0
Other manufacturing	-0.5	-0.4	-0.3	-0.1
Electricity supply	-0.8	-0.6	-0.5	-0.5
Water supply	-1.0	-0.8	-0.5	-0.2
Construction	0.5	0.4	0.2	0.1
Trade	0.5	0.4	0.2	0.1
Accomodation and hotels	-1.5	-1.2	-0.8	-0.3
Road transport: passenger	0.7	0.6	0.3	0.1
Road transport: freight	0.7	0.6	0.3	0.1
Rail transport: passenger	0.4	0.3	0.2	0.1
Rail transport: freight	0.4	0.3	0.2	0.1
Air transport	0.5	0.4	0.2	0.1
Communication services	1.0	0.8	0.5	0.2
Financial services	0.5	0.4	0.2	0.1
Business services	1.5	1.2	0.7	0.3

Note: Annual rate of change of use of the commodity identified per unit of output of all industries. Energy commodities have economy-wide energy efficiency term applied.Excluded commodities have no intermediate input efficiency shocks applied.
Source: Treasury.

Household taste shifts

Additional changes in consumption, apart from changes in incomes and prices, are due to shifts in household tastes. The assumptions are based on a historical decomposition analysis by the Centre of Policy Studies (Adams et al, 1994; Dixon and Rimmer, 2002; and Giesecke, 2004). In addition, Treasury uses the National Accounts consumption categories in its decomposition analysis in the MMRF model.

The projected household taste shifts imply long-term trends continue towards services and away from basic commodities. The assumption reflects uncertainty about how persistent household trends are over long timeframes, with taste shifts declining to zero between 2020 and 2050.

Table B23: Household taste shocks in MMRF
Average annual growth, per cent

Commodities	2010 to 2020	2020 to 2030	2030 to 2040	2040 to 2050
Biofuels	1.0	0.8	0.5	0.2
Forestry	-1.5	-1.2	-0.8	-0.3
Coal mining	-0.6	-0.5	-0.3	-0.1
Paper Products	-1.0	-0.8	-0.5	-0.2
Printing	-1.0	-0.8	-0.5	-0.2
Chemicals	0.8	0.7	0.4	0.1
Water supply	-0.5	-0.4	-0.3	-0.1
Trade	0.5	0.4	0.2	0.1
Accomodation and hotels	0.5	0.4	0.2	0.1
Air transport	1.5	1.2	0.8	0.3
Communication services	3.0	2.5	1.5	0.5
Financial services	0.5	0.4	0.2	0.1
Business services	1.0	0.8	0.5	0.2
Public services	2.3	1.9	1.1	0.4
Other services	1.0	0.8	0.5	0.2
Private transport	-0.2	0.0	0.0	0.0
Private electricity	0.5	0.4	0.2	0.1

Note: Excluded commodities have no taste shocks applied.
Source: Treasury and Centre of Policy Studies.

Economy-wide energy efficiency

CGE models can internally capture price-induced improvements in energy efficiency through consumption and production substitution choices. When the models cannot capture fully these substitution opportunities, a simple autonomous energy efficiency improvement (AEEI) parameter incorporates underlying energy efficiency improvements. The AEEI parameter specifies the rate of annual energy efficiency improvement, not the source of it.

Calibrating the AEEI is difficult, given the uncertainty about energy efficiency over very long timeframes. While history provides a guide, available data often are aggregated, obscuring trends in energy efficiency with other factors such as structural changes in the economy.

In MMRF, the AEEI parameter incorporates the range of policies, of both the Australian Government and the States that drive improvements in energy efficiency. The parameter is higher in the near term, averaging 0.8 per cent per year to 2025, before declining to 0.5 per cent per year for the remainder of the period.

Elasticity of Australian electricity demand

The MMRF model allows for substitution between production and consumption inputs at both the firm and household levels. The aggregate response of electricity demand to electricity prices depends on several factors, including: the assumed constant partial elasticities; and the induced changes in the industrial and consumption structure of the economy.

The constant partial equilibrium elasticities (expenditure and implied own-price elasticities) reflect only part of the response to electricity prices. They indicate the expected change in demand for electricity, given a change in price or expenditure, assuming nothing else in the economy changes. They are deliberately not presented here to avoid any misinterpretation.

As MMRF is a general equilibrium model, important second round effects to electricity demand should be included in any estimate of the total price elasticity of demand. Higher costs reduce profitability and return on capital in electricity and emission-intensive industries. This reduces resources flowing to these sectors and reduces the overall demand for electricity in the economy at industry and household levels.

The modelled outcomes also change depending on the size of the price shift and the impact of electricity and other prices in the economy.

Analysis of the scenarios contained in this modelling suggests a total price elasticity of demand of around -0.3. That is, a 10 per cent increase in wholesale electricity prices leads to a 3 per cent decrease in electricity demand across the economy, in the medium term.

A recent review of domestic and international literature concluded a 10 per cent increase in prices leads to a fall in demand of between 2 and 4 per cent in the short term and 5 and 7 per cent in the long term.[3]

Sector-specific assumptions

Electricity technology assumptions

Electricity generation sector assumptions are particularly important as the sector is a significant source of Australia's emissions. In developing the assumptions, the views of the Department of Resources, Energy and Tourism Stakeholder Reference Group on the cost and performance of Australian electricity generation technologies were considered.

The bottom-up modelling focuses on the main inputs into technology development in the electricity sector: thermal efficiency, capital costs and learning rates. SKM MMA provided the assumptions on thermal efficiency improvements for Australia.

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3 See Fan and Hyndman, 2010; and Productivity Commission, 2011.

Table B24: SKM MMA technology cost and performance assumptions

	Captial cost	Captial cost deescalator		Thermal efficiency	
	2010 $/kWh sent out	2010-20 (a) % pa	2021-30 (a) % pa	2010 % (b)	Efficiency improvement % pa
Black coal options					
Supercritical coal (dry-cooling)	2,357	0.5	0.5	40	0.5
Ultra-supercritical coal (wet cooled)	2,235	0.5	0.5	41	0.5
IGCC	3,643	1.0	1.0	46	1.2
IGCC with CCS	5,418	1.0	1.0	36	1.3
Ultra-supercritical with CC and oxy-firing	5,676	1.0	1.0	30	0.6
USC with post- combustion capture (wet cooled)	3,828	1.0	1.0	31	0.6
Brown coal options					
Supercritical coal with drying	2,900	0.5	0.5	31	0.5
Supercritical coal	2,900	0.5	0.5	29	0.5
Ultra supercritical coal with drying	3,000	1.0	0.5	32	0.5
IGCC with drying	6,601	1.0	1.0	35	1.2
IGCC with CCS	9,816	1.0	1.0	26	1.3
Natural gas options					
CCGT - small	1,850	0.5	0.5	43	0.6
CCGT - medium	1,400	0.5	0.5	46	0.6
CCGT - large	1,300	0.5	0.5	51	0.6
Cogeneration (large)	1,900	0.5	0.5	69	0.6
CCGT with CCS (wet cooled)	2,755	1.0	0.5	45	0.7
Renewable options					
Wind	2,400	1.0	0.5		0.2
Biomass - Steam (woodwaste used)	6,382	0.5	0.5	25	0.1
Biomass - Gasification (woodwaste used)	5,361	1.5	1.0	25	0.1
Concentrated Solar thermal plant - without storage	6,500	2.5	1.5		0.2
Concentrated Solar thermal plant - with storage	9,500	2.5	1.5		0.2
Geothermal - HSA	6,500	1.0	1.0	28	0.1
Geothermal - Hot Rocks	7,000	1.5	0.5	26	0.1
Concentrating PV	6,175	2.5	1.5		0.1
Hydro	3,500	1.0	0.5		0.1

Note: (a) The deescalater assumptions reflect factors such as learning-by-doing and efficiency improvements in the production of capital. They are largely influenced by global supply and demand factors. As such, these deescalater rates will be influenced by global climate change mitigation action. These assumptions reflect global mitigation action to achieve stabilisation of greenhouse gas concentration levels at around 550ppm CO_2-e around 2100.
(b) GJ of output (electricity) over GJ of input (fuel).

Australian capital costs decline over time, informed by in-house expertise and GTEM global learning rates. The main factors driving capital costs over time in SKM MMA modelling are technological progress, metal prices and movements in the exchange rate. SKM MMA assumptions about the proportion of capital costs reflect commodity price forecasts from the MMRF model.

Table B25: ROAM technology cost and performance assumptions

	Captial cost	Captial cost deescalator		Thermal efficiency	
	2010 $/kWh sent out	2010-20 (a) % pa	2021-30 (a) % pa	2010 % (b)	Efficiency improvement % pa
Black coal options					
IGCC - black coal	4,768	0.8	1.7	47	0.8
IGCC - black coal with CCS	6,396	0.7	1.6	38	1.2
Supercritical PC - black coal	2,774	0.3	0.7	42	1.3
Supercritical PC - black coal with CCS	5,476	0.5	1.0	37	1.8
Supercritical PC - black coal oxy-combustion CCS	5,877	0.5	1.1	44	1.5
Brown coal options					
IGCC - brown coal	6,191	1.4	3.3	38	1.9
IGCC - brown coal with CCS	8,365	1.2	2.7	29	2.5
Supercritical PC - brown coal	3,722	0.3	0.7	39	1.7
Supercritical PC - brown coal with CCS	6,880	0.4	0.9	33	2.6
Natural gas options					
CCGT - without CCS	1,317	0.5	1.0	51	0.8
CCGT - with CCS	2,607	0.6	1.4	48	1.0
OCGT - without CCS	931	0.4	0.8	33	1.1
Small CCGT - without CCS (non NEM)	1,449	0.5	1.0	51	0.8
Small CCGT - with CCS (non NEM)	2,867	0.6	1.4	48	1.0
Renewable options					
Solar thermal - parabolic trough w 6hrs storage	8,182	1.0	2.3		0.0
Solar thermal - parabolic trough w/out storage	5,308	1.2	2.7		0.0
Solar thermal - central receiver w 6hrs storage	6,054	1.2	2.7		0.0
Solar thermal - central receiver w/out storage	4,262	1.3	3.2		0.0
Photovoltaic - PV fixed flat plate	4,348	1.0	2.3		0.0
Photovoltaic - PV single axis tracking	4,769	1.0	2.3		0.0
Photovoltaic - PV two axis tracking	5,283	1.0	2.3		0.0
Wind	2,699	0.7	1.4		0.0
Geothermal - EGS	7,586	0.2	0.5		0.0
Geothermal - HSA	7,260	0.3	0.7		0.0
Biomass	4,675	0.0	0.0	30	0.0

Note: (a) The deescalator assumptions reflect factors such as learning-by-doing and efficiency improvements in the production of capital. They are largely influenced by global supply and demand factors. As such, these deescalator rates will be influenced by global climate change mitigation action. These assumptions reflect global mitigation action to achieve stabilisation of greenhouse gas concentration levels at around 550ppm CO_2-e around 2100. ROAM only apply deescalator rates after 2015.
(b) GJ of output (electricity) over GJ of input (fuel)

Capital costs in ROAM are based on Electric Power Research Institute (EPRI) as reviewed by ACIL Tasman (2010). These estimates were based on an exchange rate around US 81c = AU 1. Given the current level of the exchange rate, the DRET estimates were adjusted to remove the currency cost factors previously used by EPRI. ROAM's deescalators were also informed by GTEM global learning rates.

Technology constraints

Exogenous assumptions and constraints in the SKM MMA and ROAM include:

- constraints on new power plant entry in the near term, especially where planning has not started, to allow sufficient time for planning and construction
- limits on the rate of growth in deploying and totally developing renewable energy capacity, reflecting resource availability, and engineering and technical constraints.

Carbon capture and storage

SKM MMA's, ROAM's and GTEM's approach to modelling CCS differ, reflecting the level of detail in the models and the inherent uncertainty surrounding the technology. The timing of CCS technology deployment depends on current and expected future electricity demand, carbon prices, capital costs, the running costs of CCS technologies and that of competing low emission technologies. ROAM and MMA have assumed CO_2 storage and transport costs of between \$7/t CO_2 and \$38 /t CO_2 depending on the plant location.

Australian transport

CSIRO provided detailed modelling of the effects of a carbon price on the road transport sector. This bottom-up modelling was an input into MMRF. The assumption in CSIRO modelling is that, from 2006 to 2050, vehicles equipped with petrol engines will become 25 per cent more efficient and diesel engines 14 per cent more efficient. This will occur independently of changes to fuel type and hybrid drivetrain (Graham et al, 2008).

Table B26: CSIRO fuel efficiency improvements from 2010 to 2050
Average annual rate of improvement (per cent)

	2010-20	2020-30	2030-40	2040-50
Medium global action	0.8	1.3	1.0	0.4
Ambitious global action	0.8	1.3	1.0	0.4
Core policy	0.7	1.5	1.4	0.5
High price	0.8	2.4	2.5	6.3

Source: CSIRO.

Marginal abatement cost curves

Carbon pricing provides an incentive for industries to reduce the emission intensity of their production. A common way to represent and model this reduction, especially in models that allow only limited substitution between intermediate inputs of production, is with marginal abatement cost (MAC) curves.

In the current modelling, MAC curves have the functional form:

$$\Lambda = \begin{cases} e^{-a(t+1)^g} & \textbf{if } \Lambda > \textbf{min}\,\Lambda, \\ \textbf{min}\,\Lambda; & \end{cases}$$

where:

Λ is an emissions factor relative to the reference year;

τ is the carbon price;

min Λ is the minimum emissions factor possible; and

α and γ sets the extent of adjustment of emission intensity in response to a carbon price with higher values providing larger changes. α is set to 0.03 unless otherwise noted.

The parameters γ and min Λ are chosen for each industry based on sector-specific information on technology and production possibilities. The MAC curves are non-linear and results can be sensitive to the solution methods used by the models.

In MMRF, marginal abatement cost curves represent opportunities, in the long-term, for cost-effective abatement, but take up of these opportunities takes time. There is a gradual dynamic adjustment of emissions factor towards the potential MAC curve. This gradual adjustment mechanism accounts for the time required for a firm to transform its production process towards less emission-intensive technologies. In MMRF this is represented by:

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

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 by the earlier MAC curve equation; and

β is the speed of adjustment parameter.

A higher β parameter represents a faster speed of adjustment towards the potential emissions factor. The speed of adjustment parameter β is set to 0.3 in most years. This means that the emissions factor changes each year to close 30 per cent of the gap with the potential emissions factor. This parameter is lower in the earlier years of carbon pricing, reflecting an assumption of slower adjustment during this initial period.

The take up of new abatement opportunities involves a cost to industries. These costs offset some of the savings in carbon costs.

Fugitive and industrial process emission MAC curves

The MAC curves for fugitive emissions used in MMRF were constructed using a combination of the EMF-21 data set by Weyant and Chesnaye (2006), consultation with McLennan Magasanik Associates and information provided by industry stakeholders. This process yielded a set of MAC curves tailored to Australian industries.

Table B27: MMRF fugitive/industrial process emission MAC curve parameters

Sector	γ	minΛ
Coal	0.70	0.1
Oil	0.55	0.1
Gas	0.63	0.1
Non-Ferrous Ore Mining	0.50	0.1
Paper Products	0.50	0.1
Refinery	0.55	0.1
Chemicals	0.90	0.1
Non-Metal Construction	0.50	0.1
Cement	0.89	0.1
Steel	0.70	0.1
Aluminium	0.70	0.1
Other Manufacturing	0.70	0.1
Gas Supply	0.64	0.1
Trade	0.99	0.1
Accomodation and Hotels	0.99	0.1
Road Transport: Passenger	0.99	0.1
Other Services	0.99	0.1
Private Transport	0.99	0.1
Private Electricity	0.99	0.1

Source: Treasury; Weyant and Chesnaye (2006); MMA SKM; and information provided by industry.

Table B28: Change in non-combustion emission intensity in MMRF
Average annual growth

Sectors	2010 to 2020	2020 to 2050
	Per cent	Per cent
High enteric livestock	-0.3	-0.5
Other animals	0.0	-0.4
Grains	-0.9	-0.1
Other agriculture	-0.3	-0.4
Agriculture services and fishing	-0.8	-0.6
Forestry	-10.9	-1.6
Coal mining	0.2	0.2
Gas mining	0.8	0.3
Iron ore mining	-1.1	-0.8
Non-Ferrous ore mining	-0.6	-0.5
Other mining	-1.3	-1.0
Textiles, clothing, footwear and leather	-0.9	-0.6
Refinery	-0.5	-0.5
Chemicals	-0.1	-0.4
Non-metal construction products	-0.5	-0.3
Cement	-0.1	-0.1
Iron and steel	-0.9	-0.5
Alumina	-1.2	-0.7
Aluminium	0.0	0.0
Gas supply	-0.7	-0.1
Trade services	0.0	-1.6
Other services	-3.1	-1.1

Note: Negative numbers denote improvements in emission intensity.
Source: Treasury and DCCEE, 2011c.

Combustion MAC curves

The MMRF model does not currently capture the potential for fuel switching, that is, substitution between say coal and gas within each sector. In the MMRF model, MAC curves were applied to combustion emissions in the industrial (non-transport) sectors, allowing industrial combustion emissions to decline in response to carbon pricing.

The MAC curve for each fuel type is calibrated to reflect possible use of CCS technology (as in the electricity generation sector) or decarbonisation of the transport sector through the electrification of transport.

Table B29: MMRF combustion emission MAC curve parameters

Fuel	α	γ	minΛ
Coal	0.000001	2.55	0.1
Gas	0.000001	2.35	0.1
Gasoline	0.000015	2.20	0.1
Diesel	0.000015	2.30	0.1
LPG	0.000015	2.20	0.1
Air Fuels	0.000015	2.20	0.1
Other Fuels	0.000015	2.20	0.1

Source: Treasury.

Resource constraints

The MMRF model incorporates assumptions about energy resource supply constraints, drawing on Geoscience Australia and ABARE (2010). It is assumed that oil production in Australia ceases around 2030; and gas production ceases in South Australia around 2020 and in Victoria around 2030. No constraints on coal production are imposed: Geoscience Australia and ABARE report Australia has about 90 years of black coal reserves and around 490 years of brown coal reserves, at current production rates.

1.5.4 Land use, land use change and forestry assumptions

Forestry

Detailed modelling of the forestry sector can be problematic within CGE models. Due to the importance of this sector ABARES provided more detailed bottom-up modelling of the forestry sector.

The Australian estimates are based on the Kyoto Protocol Article 3.3 emissions accounting framework but are less consistent with the United Nations Framework Convention on Climate Change (UNFCCC) than the global estimates. The differences largely reflect the availability of data. The main differences between the carbon accounting in the international forestry modelling and the reporting adopted for Australia are:

- including all identified managed native forests and plantations (even if cleared after 1990)
- reporting all carbon including harvested wood products
- not including short rotation harvests.

For Australia, the supply of land available for use in the agricultural and forestry sectors is assumed to be fixed. ABARES models this land using a spatial modelling framework.

ABARES modelling examines the reforestation component of the CFI in Australian. The ABARES modelling incorporates assumptions on water inception and pricing, implications of native vegetations laws, timber processing capacity, reforestation establishment costs, carbon sequestration rates and others. These assumptions are provided in Burns et al (2011).

The assumed percentage changes each year to the returns to agriculture and timber are based on MMRF global action scenario projections. These changes are applied to both agricultural land values, and the returns and costs associated with timber plantations.

Three types of forestry activity are assumed to be available — softwood and hardwood timber plantations and environmental (carbon sequestration) plantations. All types have establishment costs, but environmental plantings do not have transport or harvesting costs and are assumed not to incur ongoing management costs.

ABARES modelling is supplemented by estimates of net carbon sequestration for plantations planted between 1990 and 2009 provided by the DCCEE, and adjustments to account for site quality.

Land use and land use change

There is no long-term economic modelling of emissions from Australian land use and land use change. Emissions from this sector are exogenously imposed in the models. Land use emissions for Australia are from clearing regrowth as part of agricultural management, as well as clearing new land. In the global action scenario in the absence of the CFI, emissions from land clearing are assumed to remain at 49 Mt CO_2-e per year throughout the modelling period, based on a simple extrapolation consistent with DCCEE projections in the most recent national emission projections (DCCEE, 2011c).