ANNEX B: TREASURY CLIMATE CHANGE MITIGATION POLICY MODELLING ASSUMPTIONS

B.1 INTRODUCTION

The main assumptions used for the modelling of climate change mitigation policy are included in this annex.

Treasury has engaged widely with government, industry and other non-government stakeholders on the methodological approach to the modelling to gather information about input assumptions. These discussions were very important in determining the modelling framework and in forming model-input assumptions. These model-input assumptions also drew on research, previous global and Australian studies, and consultation with government, industry and domestic and international experts. Many of the assumptions used in the modelling exercise are uncertain, especially over the long timeframes being examined.

Treasury, where possible, applied a harmonised set of assumptions across the suite of models to ensure that projections have a common basis. However, due to the different model structures and aggregation, it was not always possible to harmonise all assumptions. For example, the MMRF model has more industry disaggregation than GTEM and G-Cubed, and thus requires more industry specific assumptions.

B.2 POLICY AND DESIGN FEATURES

The main policy intervention modelled is a cap and trade emissions trading scheme. This scheme is assumed to apply globally. Features of the scheme differ across the CPRS and Garnaut scenarios (Table B.1).

Table B.1: Key emissions trading scheme design features, policy scenarios

	CPRS scenarios	Garnaut scenarios
Start	2010	2013
Coverage	Agriculture emissions excluded until 2015; Australian land-use change excluded.	All emissions in all sectors.
International permit trade	Limited until 2020, then unlimited.	Unlimited from 2013.
International participation	Annex B countries from 2010; China and high-income developing countries from 2015; India and middle-income countries from 2020; global coverage from 2025.	Global coverage.

B.2.1 International assumptions

The two main issues in modelling international emissions trading are the international permit allocation framework and treatment of offset credits. Specifications for each participating region are broadly consistent with the assumed Australian settings.

International permit allocation

Within the models, the approach to international permit allocation determines the national emission targets and trajectories. The CPRS scenarios used a multi-stage allocation approach; the Garnaut scenarios use a differentiated contraction and convergence approach (Garnaut, 2008).

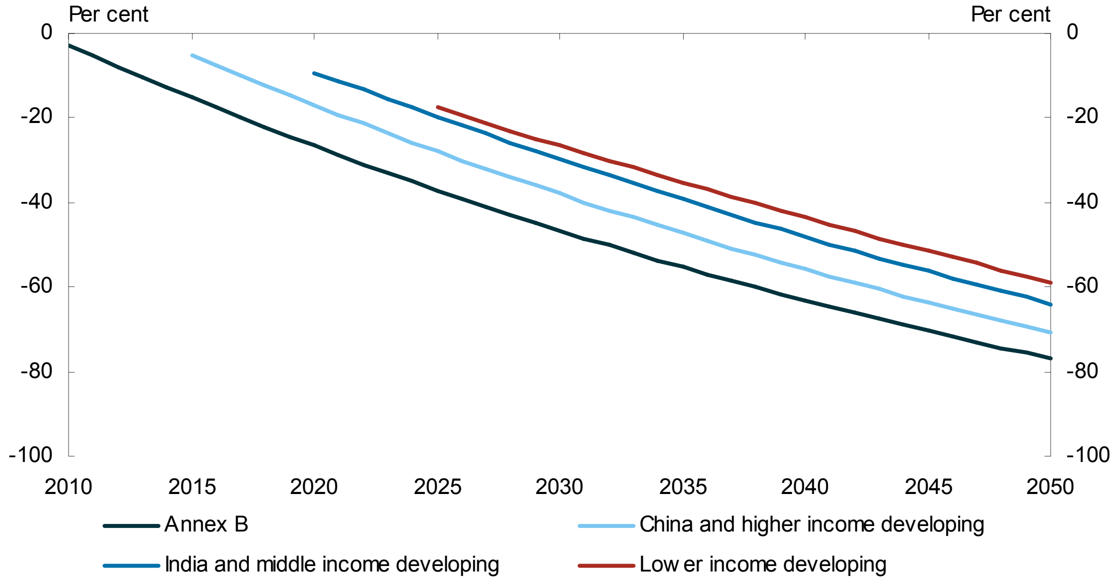
The multi-stage allocation approach

Under the multi-stage allocation approach, Australia's emission trajectory gradually diverges from the reference scenario, to be 5 per cent below 2000 levels in 2020 and 60 per cent below 2000 levels in 2050 in the CPRS -5 scenario; and 15 per cent below 2000 levels in 2020 and 60 per cent below 2000 levels in 2050 for the CPRS -15 scenario (Chart B.1). The same rate of divergence from reference scenario emissions is assumed for other regions. Emission allocations in Annex B countries start from their 2009 reference scenario emissions before diverging.

Emissions in non-Annex B countries diverge from their reference scenario levels in the year before they join the scheme. Emissions in economies not included in the trading scheme could theoretically diverge from their reference scenario levels through several mechanisms, including offset credits, positive spillovers from devolving low-emission technologies in Annex B countries; and relocation of emission-intensive trade-exposed sectors from Annex B countries. However, the modelling results suggest that the main difference between reference and policy scenario emissions for economies outside the scheme arises from the creation of offset credits. As a result, in the CPRS scenarios, allocations for non-Annex B countries start from reference scenario emissions levels, adjusted only for the assumed emission reductions from offset credits.

Chart B.1: Emission allocations by region

Per cent change from reference scenario, CPRS -5 scenario



Note: Non-Annex B regions start below reference scenario levels due to the effect of offset credits.
Source: Treasury.

Differentiation across regions was limited by the existing regional aggregation within the models. The regions corresponding to each group are shown in Table B.2.

Table B.2: Regional groupings in GTEM and G-Cubed

Multi-stage allocation approach

	GTEM	G-Cubed
Annex B	Australia, Canada, European Union, ormer Soviet Union, Japan, United States	Australia, European Union, former Soviet Union, Japan, other OECD, United States
China and higher income developing	China, OPEC, South Africa	China, OPEC
India and middle income developing	India, Indonesia, rest of South and East Asia	None
Lower income developing	Rest of world	Rest of world

The differentiated contraction and convergence approach

The differentiated contraction and convergence approach was developed for the Garnaut Climate Change Review, and used in the Garnaut scenarios. Under this approach, national allocations converge from current levels to an equal per capita allocation by 2050 (Chart B.2).

Fast growing non-Annex B countries are allowed 'head room' to increase their per capita emission allocations until they achieve a specified benchmark. The benchmark is based on the lowest per capita emissions over all Annex B countries. In implementing the allocation rule, however, the average of the European Union and Japan's allocation is used as the benchmark.

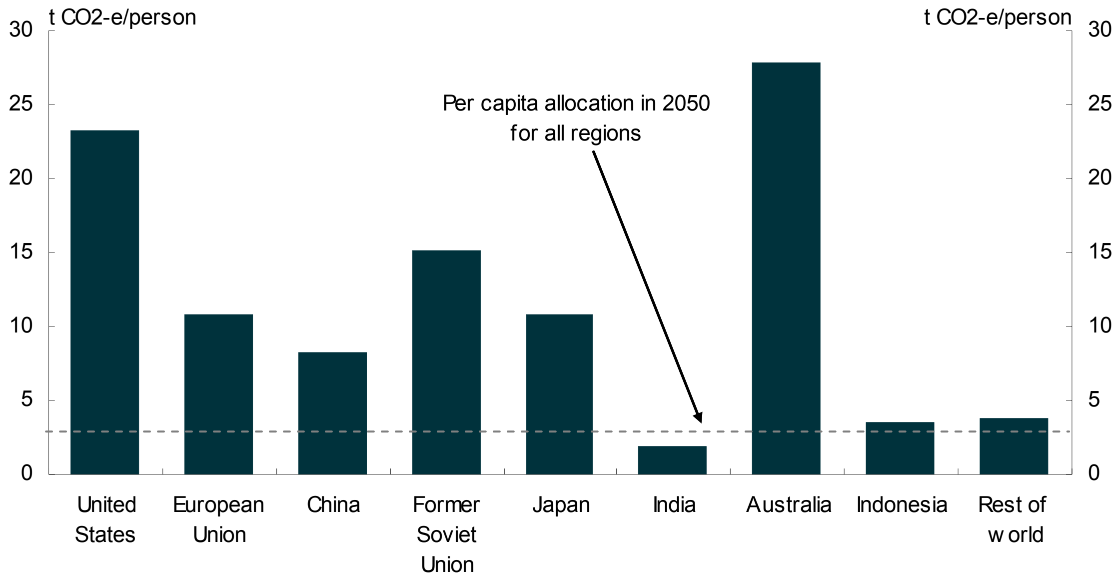
Other assumptions employed are:

- Annex B countries' allocations converge from their Kyoto targets; and

- the US allocation converges from reference scenario emissions, but is reduced at a more rapid rate; as a result, its cumulative allocation over the first 20 years is as if it had converged from its Kyoto target.

Chart B.2: Contraction and convergence approach

Per capita emissions in 2012, Garnaut -10 scenario



Source: GTEM; Treasury; Garnaut (2008a).

Offset credits

The CPRS scenarios assume economies outside the emissions trading scheme can generate offset credits for sale to Annex B countries, analogous to credits from Kyoto Protocol Clean Development Mechanism (CDM), but not necessarily restricted to this. This is not applied in Garnaut scenarios, as all economies take on national emission targets from 2013.

To implement offset credits in the global models GTEM and G-Cubed, assumptions were made about what the total quantity of credits was, where and how those credits were generated, and to whom those credits were sold (Table B.3).

In the short term, institutional capacity is likely to be an important determinant of where offset credits are generated. Credits from 2010 to 2014 therefore follow current patterns of CDM creation (UNEP, 2008). As the global emissions trading market and flexibility mechanisms evolve, credits are likely to be generated wherever low-cost mitigation is available. Credits from 2015 to 2019 therefore follow regional patterns of mitigation potential identified within the models.

Renewable energy and energy efficiency projects currently account for a large share of CDM credits, so these were used as the primary source of credits (UNEP, 2008). Mitigation from land-use change and forestry projects (including avoided deforestation) was not included until 2015, reflecting the institutional and accounting barriers to these projects in the short term.

Table B.3: Summary of offset credit assumptions

Year	2010 to 2014	2015 to 2019	2020 to 2024
Regions generating credits (GTEM)	China, OPEC, South Africa, India, Indonesia, other South and East Asia, rest of world	India, Indonesia, other South and East Asia, rest of world	Rest of world
Regions generating credits (G-Cubed)	China, OPEC, rest of world	Rest of world	Rest of world
Total credits generated (Mt CO_2e)	1,990	5,150	7,550
Source of credits	Renewable energy and energy efficiency projects	Renewable energy, energy efficiency and land use change and forestry projects	
Regions buying credits	All Annex B countries, allocated in proportion to their share of the aggregate abatement effort		
Price of credits	Prevailing global emission price		

B.2.2 Australian assumptions

Emission price

The global emission price for each of the four policy scenarios is estimated in the GTEM and G-Cubed models. The global price from GTEM is used as an exogenous assumption for the MMRF model, which estimates the Australian emission price given the global price and other assumptions. The Australian price from MMRF is used as an exogenous assumption for PRISMOD, which determines the distributional price impacts on households and industries.

Carbon pollution reduction scheme design

In the CPRS scenarios, the policy framework is based on the *Carbon Pollution Reduction Scheme Green Paper* (DCC, 2008b).

Table B.4: Carbon pollution reduction scheme design

Issue	Policy setting	Implementation in MMRF
Australia's emission trajectory	Determined by the international allocation assumptions.	
Coverage	All emission sources covered, except: * activity emissions from agriculture are excluded until 2015; and * emissions from land-use change are excluded (and remain subject to existing policies). Credit is available on a voluntary 'opt-in' basis for net increases in carbon stocks from forests on Kyoto-eligible land. Once in, credits can be generated from net increases, and permits must be acquitted for net losses in carbon stocks.	Agriculture comprises sheep and cattle, dairy, other animal and grains.
Banking and borrowing	Unlimited banking, no borrowing.	
Emission-intensive trade-exposed sectors (EITES)	EITES are shielded from the emission price for direct emissions and for emissions from electricity use ('CPRS costs'). From 2010 to 2019: * industries with an emission intensity of more than 2,000tCO_2e/$million revenue are shielded for 90 per cent of CPRS costs. * industries with an emission intensity of 1,500-2,000tCO_2e/$million revenue are shielded for 60 per cent of CPRS costs. Assistance per unit of output reduces by 3 per cent per year. Agricultural sectors are shielded from 2015, when they become covered by the scheme. From 2020 to 2024, assistance per unit of output phases out linearly. No shielding after 2025.	Industries over the 2,000 threshold are beef cattle, aluminium smelting, lime production, clinker production, sheep, dairy cattle, integrated steel manufacturing, and production of rice. Industries within the 1,500-2,000 group are production of pigs, ceramic product manufacturing, alumina refining, basic chemicals manufacturing, non-metallic mineral product manufacturing, pulp and paper manufacturing,

Issue	Policy setting	Implementation in MMRF
	Shielding is calculated according to the formula: $$A_{ia} = k_a\left[EI_{ia}^d \times O_{ia}\right] + k_a\left[EI_{ia}^e \times EF \times O_{ia}\right]$$ where A_{ia} is the allocation of permits to industry I for emissions associated with activity a; k_a is the assistance rate for activity a; EI_{ia}^d is the direct emission-intensity baseline for industry I conducting activity a (that is, baseline level of direct emissions per unit of output for the activity) EI_{ia}^e is the electricity-intensity baseline for indirect electricity emissions for industry i conducting activity a (that is, baseline level of electricity per unit of output for the activity); EF is the electricity factor, which reflects the impact of the emission price on the price of electricity; and O_{ia} is the output of activity a by industry i.	other non-ferrous metals smelting, and parts of oil and gas. Shielding is implemented as an implicit subsidy. Calculations use 2005 values as the baseline for emission and electricity intensity. The electricity factor is calculated taking account of both the direct and general equilibrium effects of the carbon price.
International linkage	No export of Australian permits until 2015, unlimited thereafter. Imports restricted to 50 per cent of the difference between reference scenario emissions and the national emission trajectory until 2020, unlimited thereafter.	CPRS -5 scenario: * from 2010 to 2014, imports restricted to 6 per cent of the CPRS cap. * from 2015 to 2019, imports restricted to 14 per cent of the CPRS cap. CRS -15 scenario: * from 2010 to 2014, imports restricted to 8 per cent of the CPRS cap. * from 2015 to 2019, imports restricted to 20 per cent of the CPRS cap.
Fuel tax offset	Rate of excise duty changed to offset CPRS impact on fuel prices for: * households, on-road business users, and agriculture and fishing from 2010 to 2012 (three years). * heavy vehicles in 2010 (one year). No offset for other fuel users.	
Use of permit revenue	All permits are assumed to be auctioned, with auction revenue (net of revenue allocated to firms for shielding purposes) recycled as lump-sum payments to households.	

Policy assumptions in PRISMOD

- Shielding arrangements use the definition of EITE industries to determine which industries in the ABS data will be shielded, and to what extent. These then are allocated a certain quantity of permits (based on their emission levels) at zero cost.
- Emissions from agricultural industries are excluded.
- The impact of the price increases on transport fuels is offset by a reduction in the excise tax. The excise tax is adjusted so that, after introducing the CPRS, the difference in the final purchaser's prices for liquid petroleum gas and gas and diesel fuels is zero. The excise tax on automotive petrol is adjusted by the same amount; this corresponds to a slight over-compensation for these fuels (so the increase in petroleum prices resulting from the CPRS is more than offset by the reduction in excise tax).

Electricity policy measures

The reference scenario assumes pre-existing policy measures remain in place, including the 9,500GWh/year Mandatory Renewable Energy Target (MRET), the Victorian Renewable Energy Target (VRET), the NSW and ACT Greenhouse Gas Abatement Scheme, and the Queensland 15 per cent Gas Scheme. No new mitigation policies, such as the planned increase in the Renewable Energy Target (RET) to 45,000GWh/year, the Carbon Pollution Reduction Scheme and the Australian Government's target to reduce emissions by 60 per cent from 2000 levels by 2050, have been included.

In the Garnaut scenarios, all pre-existing policy measures cease upon introduction of the emissions trading scheme.

In the CPRS scenarios, the expanded 45,000GWh RET is included. The target is assumed to increase linearly to 22,000 GWh in 2015, then linearly to 45,000GWh in 2020. The target is held constant at 45,000 until 2024, then phased out over the period to 2035. The Queensland 15 per cent Gas Scheme and the voluntary market program, Green Power, are assumed to remain in place. All other policy measures cease upon introduction of the CPRS.

B.3 ECONOMIC GROWTH

Gross domestic product (GDP) in the reference scenario is a function of assumptions about labour supply and productivity.

B.3.1 World gross domestic product

Published forecasts for GDP are used where available. Forecasts are imposed for 2006 to 2009 using outcomes and forecasts from the IMF (2008), OECD (2007) and Consensus Economics (2008a; 2008b). Where country specific forecasts are not available, regional forecasts have been used.

Table B.5: World GDP (GTEM regions)
Annual average growth

	2005 to 2050	2050 to 2100
	Per cent	Per cent
United States	2.0	1.7
European Union	1.3	1.3
China	5.4	1.5
Former Soviet Union	2.8	1.7
Japan	0.5	1.2
India	6.2	2.8
Canada	1.8	1.5
Indonesia	5.1	2.2
South Africa	4.0	2.0
Other South and East Asia	3.7	2.1
OPEC	4.1	2.4
Rest of w orld	4.9	3.1

Note: See also international population and productivity section.
Source: Treasury; IMF (2008); OECD (2007); Consensus Economics (2008a; 2008b).

B.3.2 Australian gross domestic product

Table B.6: Australia's population, productivity and GDP
Annual average growth rates

Decade	Employment	Labour productivity	Real GDP
	Per cent	Per cent	Per cent
2000s	2.3	1.1	3.4
2010s	1.1	1.6	2.8
2020s	0.8	1.5	2.3
2030s	0.7	1.5	2.2
2040s	0.6	1.5	2.1
2050s	0.6	1.5	2.1
2060s	0.7	1.5	2.1
2070s	0.7	1.5	2.2
2080s	0.6	1.5	2.1
2090s	0.6	1.5	2.1

Source: Treasury and ABS.

B.3.3 Gross state product

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

Table B.7: Gross state product
Annual average growth rates

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

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

B.4 Population and participation

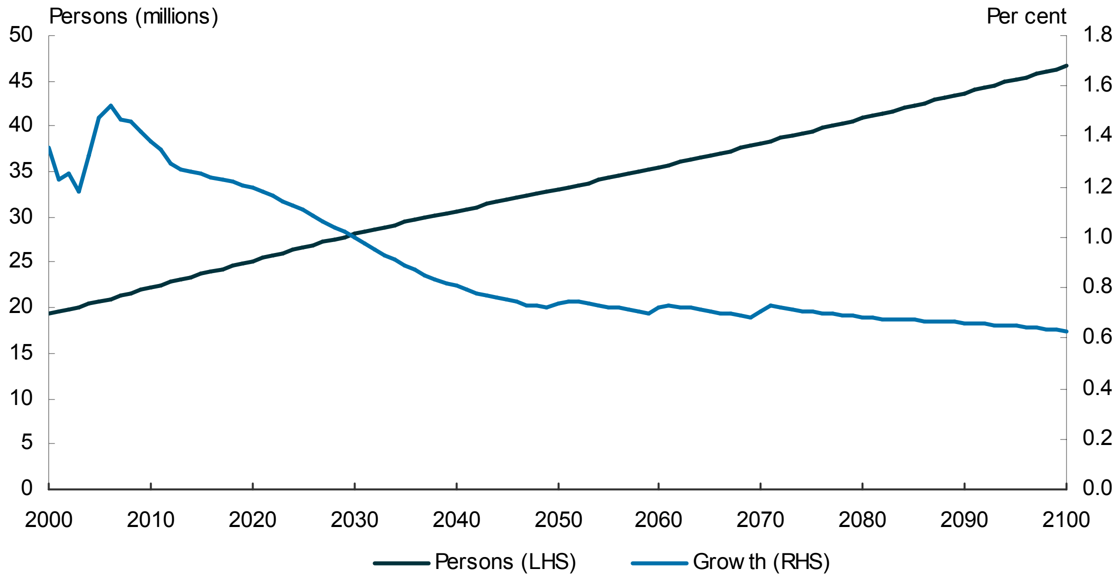
B.4.1 Australian population and labour force participation

Population projections are based on the framework used to develop the second *Intergenerational Report* — although input assumptions have been updated since the report's release in 2007. Since 2007 there has been additional information on future immigration trends. As a result, net overseas migration between 2012-13 and 2049-50 is assumed to be 150,000 people per year.

From 2050-51 to 2070-71 net migration is stepped up each decade to reach 200,000 people per year. Net migration is then kept constant at 200,000 to the 2100.

- A higher level of net migration beyond 2050 aims to reflect larger world and Australian populations, and increased requirements for skilled and unskilled workers as a result of the continued ageing of Australia's population.
- Labour force participation assumptions are consistent with the *Intergenerational Report* parameters; gender and age specific labour force participation rates remain stable from 2065.
- MMRF requires state population assumptions. State population ratios are taken from ABS projections (ABS cat. no. 3222.0 — *Population Projections, Australia, 2004 to 2101*, released on 14 June 2006) and scaled to be consistent with a higher estimated national aggregate population.
- The population estimates for Australia are higher than the UN projections for Australia, mainly due to recent changes in net migration assumptions not taken into account in the UN projections.

Chart B.3: Australian population



Source: Treasury and ABS.

Table B.8: State population

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

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

B.4.2 International population and participation

World population projections to 2050 are taken from the United Nations (2006). This report provides total population and working age (15-64) populations for each country in five year intervals from 1950 to 2050. The median projection variant is used.

After 2050, growth rates for population are taken from United Nations (2004). Country-by-country growth rates are used to project population levels over the 50 years to 2100.

Growth rates are interpolated to produce year-by-year projections of population by country (both total and working age). These country projections then are aggregated into the country groups used in GTEM and G-Cubed.

Table B.9: Global population level and growth rates (GTEM regions)

	2005	2050	2100	2005 to 2050	2050 to 2100
	Population (millions)			Per cent, growth	
United States	300	402	429	0.7	0.1
European Union	461	459	401	0.0	-0.3
China	1,320	1,418	1,202	0.2	-0.3
Former Soviet Union	279	243	200	-0.3	-0.4
Japan	128	103	84	-0.5	-0.4
India	1,134	1,658	1,577	0.8	-0.1
Canada	32	43	40	0.6	-0.1
Indonesia	226	297	275	0.6	-0.2
South Africa	53	62	60	0.4	-0.1
Other South and East Asia	380	513	493	0.7	-0.1
OPEC	219	399	452	1.3	0.2
Rest of world	1,961	3,564	4,056	1.3	0.3

Source: United Nations (2006); and Treasury.

International participation rates are assumed to remain constant over the projection period, so the growth of the labour force is projected using the growth of the working age population.

B.5 PRODUCTIVITY

B.5.1 Australian labour productivity

It is important for climate change mitigation modelling that the aggregate labour productivity assumption be built-up using sector productivity trends. Sectoral productivity trends are one of the principal determinants of the industry share of output. Industry shares of activity are an important determinant of the emissions intensity of the economy, and therefore, mitigation costs.

The mitigation modelling uses Treasury forecasts and budget projections for aggregate labour productivity growth until 2011-12 (Australian Government, 2008). Budget projections assume labour productivity growth of 1¾ per cent per year. This is based on 30-year trends from the ABS *National Accounts,* which indicate that aggregate labour productivity — expressed in terms of GDP per hour worked — for the Australian economy averaged around 1¾ per cent per year from 1975-76 to 2006-07.

The CGE modelling suggests, that over time, as the composition of the Australian economy continues to shift towards services, aggregate Australian productivity growth will gradually drift down, purely due to the composition effect. The service industries generally have lower levels and rates of growth of measured sector-specific labour productivity than the rest of the economy. In the reference scenario, aggregate Australian labour productivity growth is assumed to gradually slow from 1¾ per cent to 1½ per cent per year over the ten years to the mid-2020s. This outcome, of 1½ per cent for long-term aggregate Australian labour productivity growth, is consistent with the long-term labour productivity growth assumption for the United States.

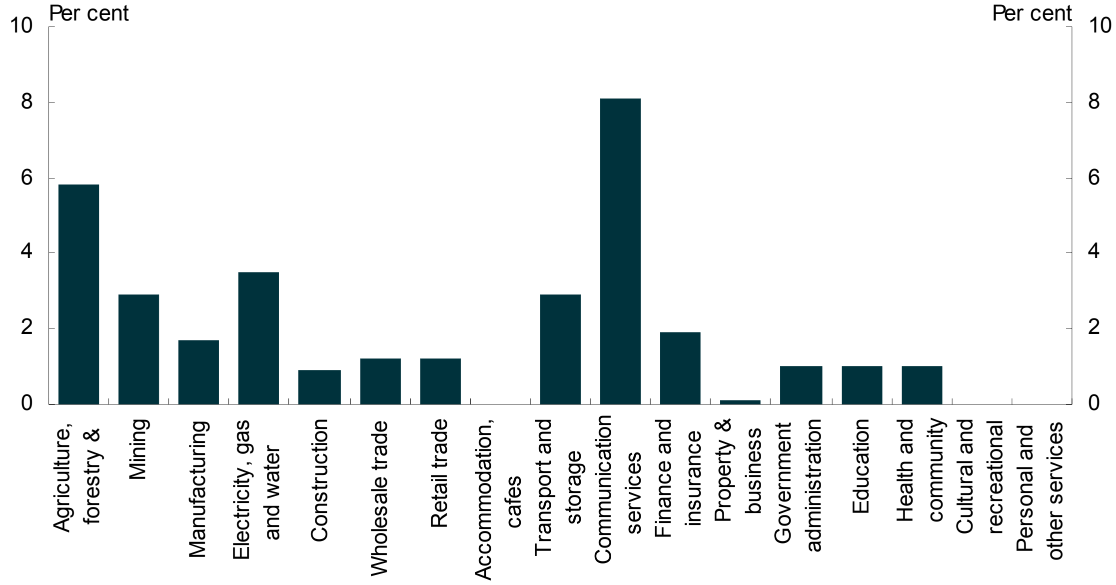
Aggregate labour productivity in MMRF is derived by adjusting the labour-augmenting technical change variable at an industry level. The dispersion of technical change across industry is based on historical estimates (Bagnoli, Chateau and Sahin, 2006).

The dispersion of labour-augmenting technical change across industry has not been uniform over the past 30 years. Chart B.4 shows the different growth rates by broad industry group from

1975-76 to 2006-07. These growth rates were estimated from ABS *National Accounts* and remove the effect of capital deepening on output. They were calculated by adjusting multifactor productivity (MFP) estimates by industry-level labour-income shares.

Chart B.4: Industry labour-augmenting technical change

Annual average growth from 1975-76 to 2006-07



Source: Treasury and ABS (2007).

Differences in industry growth rates imply changes in the level and composition of the Australian and state economies over time. Agriculture, manufacturing, communication, utilities, finance and insurance, wholesale, trade, transport and storage have historically grown faster than the national average over the last 30 years. Conversely, many service industries have grown more slowly than the national average. This pattern is similar across major developed economies.

After 2020, reflecting uncertainty about how persistent historical differences will be over the next century, the labour-augmenting technical change variable in market-sector industries converges to a constant rate by 2050. This constant rate is consistent with achieving aggregate labour productivity growth of 1½ per cent per year.

B.5.2 World productivity

Country-by-country growth in productivity (either output per worker or output per hour worked) is calculated using a conditional convergence framework. If a country has a productivity level below its 'potential', then it will have faster productivity growth as it catches up. Baumol (1986) and Barro and Sala-i-Martin (1992) discuss the economic framework for convergence in detail. Convergence (sometimes called 'catch-up') is a common assumption used for international growth in long-term projections, such as the *Special Report on Emission Scenarios* (IPCC, 2000).

The 'potential' for each country is assumed to be some percentage of the productivity level of the technological leader, assumed to be the United States. Productivity in the United States is assumed to adjust towards an assumed long-term growth rate (1½ per cent) in a gradual fashion from the end of history and GDP forecasts. The long-term growth rate assumption was selected after looking at the historical trends of productivity growth by industry, and the likely changes in the US industry structure. Official projections of long-term productivity growth are somewhat higher at 1.7 per cent (OASDI Trustees, 2008; Congressional Budget Office, 2008); but these projections do not take into account the likely shift towards industries with lower average rates of productivity growth.

The other key parameter for the world productivity projections is the rate of convergence. Given the lack of data for many non-OECD economies, trends that are commonly part of the development experience are assumed. The suggested rate in the literature is 2 per cent per year (Sala-i-Martin, 1996). Many studies using climate change models assume this rate, for example Bagnoli et al. (1996) and McKibbin et al. (2004).

- OECD productivity is calculated based on the per hour purchasing power parity (PPP) productivity from the Total Economy Database (The Conference Board/Groningen) January 2008 update. All OECD members as of January 2008 are included.
  - The US productivity growth rate is assumed to adjust towards its long-term growth rate of 1½ per cent in a gradual fashion, from the end of history and GDP forecasts. This gives a level of US productivity for all years.
- Non-OECD productivity is calculated based on the working age population. GDP per capita (in PPP terms) is taken from the December 2007 update of the World Bank International Comparison Project, and adjusted to per working age population using the population assumptions. Where data on the GDP level is unavailable from the International Comparison Project update, the most recent update of the Maddison international PPP data (August 2007) is used. This is done for 50 economies, making up around 4 per cent of world GDP.
- A conditional convergence framework is applied, with the conditional convergence level allowed to differ by country.
  - High-income OECD members (those with a productivity level of greater than 70 per cent of the US level) are assumed to converge to a level of productivity relative to the US equal to the average level over the last 5 years of history (to abstract from cyclical effects). This generally has the effect of causing the country to grow at the same rate as the United States.
  - High-income non-OECD economies (those with a productivity level of greater than 70 per cent of the US level) are assumed to converge to a level of productivity relative to the US equal to their starting point. This generally has the effect of causing the country to grow at the same rate as the United States.
  - Low-income economies (those with a productivity level of less than 70 per cent of the US level) are assumed to converge to 70 per cent of the US productivity level.
  - Productivity growth is smoothed, so each country takes some time to go from its recent rate of growth to its convergence path.
  - Growth in China up to 2030 has been further adjusted, based on judgements by the Garnaut Review of Climate Change of the likely growth path; see Garnaut (2008) and Garnaut et al. (2008).

Table B.10: Productivity level to the US level (GTEM regions)

	Productivity level relative to the United States		
	2005	2050	2100
United States	100	100	100
European Union	67	73	75
China	9	50	58
Former Soviet Union	18	39	52
Japan	74	76	76
India	5	24	45
Canada	82	83	84
Indonesia	7	26	47
South Africa	18	41	54
Other South and East Asia	15	30	49
OPEC	24	38	52
Rest of w orld	11	24	44

Note: GDP per adult population, US=100. Convergence and GDP calculations have been performed at a country, not regional level. OPEC in particular shows seemingly less convergence than other economies — this is a result of OPEC being a mix of economies with high productivity (for example, Qatar) that do not converge, mid-income economies (for example, Saudi Arabia) that converge more slowly, and low-income economies (for example, Yemen).

B.5.3 World sectoral labour productivity

The productivity and population assumptions give the total change in output for the economy. To implement these assumptions in the international models (G-Cubed and GTEM), some assumption has to be made about the way this increase in productivity (or efficiency) is distributed between industries. Since capital stock accumulates endogenously and the supply of other factors are given in the model, the model calculates the value of a productivity variable to be consistent with the exogenous trajectory of regional outputs.

Aggregate labour productivity has been distributed across industries in each economy on the basis of historical performance, consistent with the aggregate productivity. Productivity growth rates across sectors are based on historical averages calculated from the Groningen Growth and Development Centre database and the OECD. Table B.11 shows the relative growth rates of different sectors in key economies used in the GTEM model.

Table B.11: Sectoral labour productivity distribution

	Relative grow th rates betw een sectors						
Industry	United States	EU25	China	FSU(a)	Japan	India	Canada
Coal mining	1.00	1.00	1.30	0.50	0.50	1.50	1.00
Oil mining	1.00	1.00	0.75	0.50	0.50	1.00	1.00
Gas mining	1.00	1.00	0.75	0.50	0.50	1.00	1.00
Petroleum and coal	1.00	1.00	0.75	0.50	0.50	1.00	1.00
Electricity	1.25	1.00	0.75	0.50	0.50	0.50	1.25
Mining and chemicals	1.25	1.00	1.00	1.00	1.50	1.00	1.25
Manufacturing	1.25	1.50	1.00	1.00	1.50	1.00	1.25
Road transport	1.50	2.00	2.00	1.00	2.00	2.00	1.50
Water and air transport	0.75	1.00	0.50	0.50	1.00	0.50	0.75
Crops	0.75	1.50	1.00	1.00	0.50	0.50	0.75
Livestock	0.75	1.50	1.00	1.00	0.50	0.50	0.75
Fishing and forestry	0.75	1.50	1.00	1.00	0.50	0.50	0.75
Food	1.40	1.50	1.00	1.00	1.00	1.00	1.40
Services	1.00	1.00	0.75	0.75	1.00	0.75	1.00

(a) Former Soviet Union. GTEM industries have been aggregated where distribution of sectoral productivity is the same.
Source: Treasury.

Table B.11 (cont): Sectoral labour productivity distribution

Industry	Relative growth rates between sectors					
	Australia	Indonesia	Southern Africa	Other South East Asia	OPEC	Rest of world
Coal mining	1.00	1.40	1.00	1.00	1.00	1.00
Oil mining	1.00	0.75	1.00	0.75	1.00	1.00
Gas mining	1.40	0.75	1.00	0.75	1.00	1.00
Petroleum and coal	1.40	0.75	1.00	0.75	1.00	1.00
Electricity	1.40	0.75	1.00	0.75	1.00	1.00
Mining and chemicals	0.80	1.00	1.00	1.00	1.00	1.00
Manufacturing	1.00	1.00	1.00	1.00	1.00	1.00
Road transport	2.00	2.00	2.00	2.00	2.00	2.00
Water and air transport	1.40	0.50	1.00	0.50	1.00	1.00
Crops	1.00	0.75	1.00	0.50	1.00	1.00
Livestock	1.00	0.50	1.00	0.50	1.00	1.00
Fishing and forestry	2.00	0.50	1.00	0.50	1.00	1.00
Food	1.00	0.50	1.00	0.50	1.00	1.00
Services	1.00	0.75	1.00	0.75	1.00	1.00

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

As an example of how to interpret this data, note in the EU-25 road transport labour productivity grows twice as fast as coal sector labour productivity. The same comparison cannot be made between sectors, For example, mining and chemicals productivity in the EU-25 and China are not be equal; 'average growth' (that is, equal to 1.0) in each is determined by aggregate labour productivity.

Due to structures in the G-Cubed model, it was not possible to use differentiated labour productivity growth rates across economies, so the relative productivity pattern for Australia was used for all regions.

B.5.4 Weights used for gross world product

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

The MER/PPP debate in climate change modelling is about which exchange rate is more appropriate for converting different economies' GDP into a single currency (usually US dollars) to make economic comparisons and growth projections. It is argued that the choice of measurement could have significant impacts for the validity of economic growth projections and energy use, and hence, projections of future climate change (Castles and Henderson, 2003). The price levels expressed in common MER currency terms are typically higher in developed economies than in developing economies. Economic activity levels in the developing economies tend to appear lower than they actually are. As a result, current cross-country differences in income per capita levels tend to be over-estimated when MERs are used to convert GDP into a common currency. The use of MER exchange rates, together with the assumption of conditional convergence in relative per person income levels, could lead to over-stated economic growth in developing economies and consequently, excessive growth in energy demand and emission levels.

It is practical to use PPP data for this modelling report as the national and trade accounts in the CGE models used are specified using MER. However, the issues that arise from using MER data are lessened through careful analysis and implementation of assumptions. The initial productivity projections are derived using PPP exchange rates, and sector productivity growth rates are specified based on historical trends (Bagnoli, Chateau and Sahin, 2006). Using historic sector productivity assumptions tends to result in faster tradable sector productivity than non-tradable sector productivity. This difference, combined with the conditional convergence framework, typically lead to an appreciation of the real exchange rate over time, and a convergence between MER and PPP exchange rates ('Baumol-Balassa-Samuelson effect').

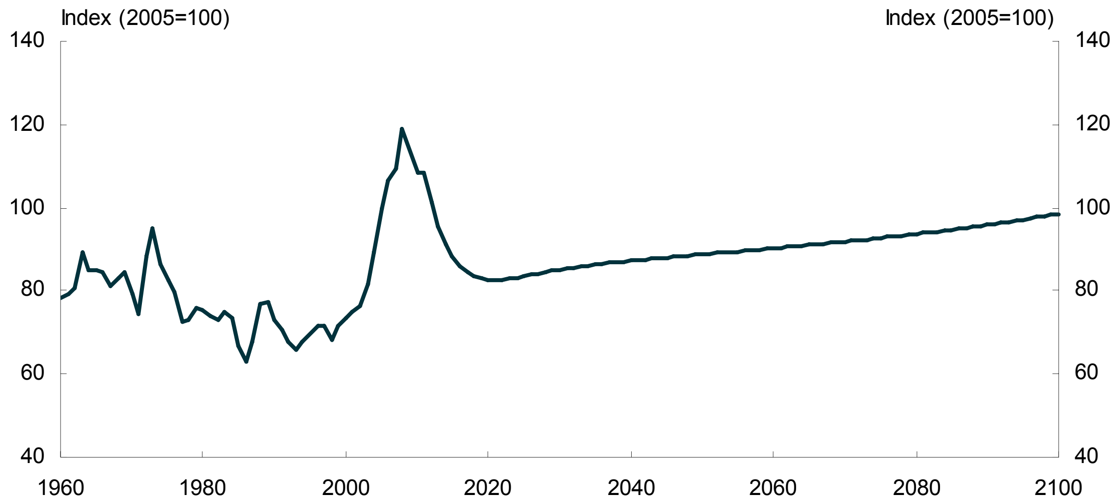
B.6 TERMS OF TRADE AND ENERGY PRICE ASSUMPTIONS

B.6.1 Australia's terms of trade

Australia's terms of trade (the ratio of export prices to import prices) are imposed on the MMRF model until 2020-21. In the short term, Treasury forecasts are used, then, in line with the methodology used in recent federal budgets, a two-year step down in the terms of trade is imposed. Beyond 2011-12, Australia's terms of trade are assumed to continue to decline gradually over the 10 years to 2021-22, as key commodity prices (coal, oil, gas, iron ore, non-iron ore, other mining, diesel, chemicals, rubber and plastic, steel and other metals) continue to fall towards levels that reflect longer term demand and supply conditions. After 2021-22, Australia's terms of trade are determined within the MMRF model.

In MMRF, export prices reflect the interaction of MMRF's industry supply schedules and the position of the world demand curves for Australia's exports. The position of the world demand curves for Australia's exports, which is exogenous in MMRF, is drawn from GTEM information.

Chart B.5: Australia's terms of trade



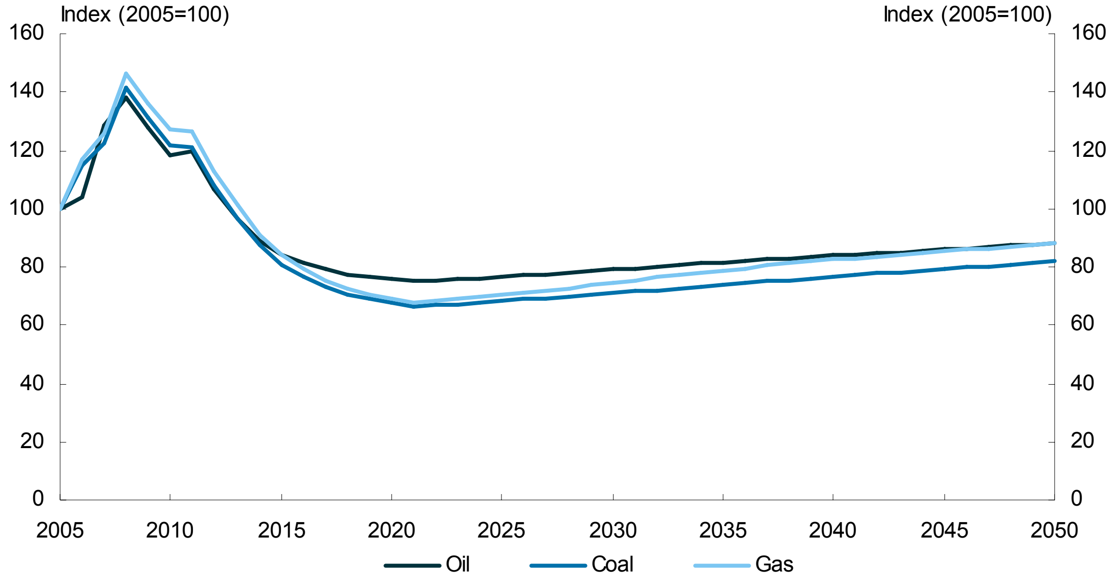
Source: Treasury.

B.6.2 Energy commodity price assumptions

Global energy prices are projected to rise gradually over time, consistent with International Energy Agency (IEA) projections, as in the *World Energy Outlook 2007*. As continued growth in demand forces the exploitation of more marginal resources, the rising marginal cost of extraction for these commodities pushes up their price.

Chart B.6: Energy commodity price assumptions

Foreign currency — 2005-06 dollars



Source: Treasury; IEA, 2007b.

Resource cost curves

In GTEM, movements in the international prices for key energy commodities, including oil, coal and gas, are assumed to broadly follow movements in IEA projections. Costs of extracting resources increase as output expands as low cost resource supplies are used up, requiring use of more primary factors (capital and labour) per unit of resource. Table B.12 shows the percentage decline in labour and capital efficiency in natural resource intensive sectors per doubling of cumulative extraction of the resources (resource depletion effect).

Table B.12: Change in factor efficiency per doubling in the level of extraction

	Coal	Oil	Gas	Other mining
	Per cent	Per cent	Per cent	Per cent
United States	2.9	12.8	10.6	3.2
EU-25	2.9	12.8	13.4	3.2
China	4.9	9.8	17.8	3.2
Former Soviet Union	1.7	9.8	17.8	3.2
Japan	11	24	46.2	3.2
India	4.9	3.4	2.6	3.2
Canada	5.7	9.8	16.2	3.2
Australia	5.7	12.8	6.4	3.2
Indonesia	0.7	18.6	25.5	3.2
South Africa	0.7	12.8	24	3.2
Other South East Asia	0.7	11	23	3.2
OPEC	0.7	10.4	14.6	3.2
Rest of w orld	3.3	6.6	12.9	3.2

Note: A positive number means that more factors are required per unit of extracted resource.
Source: Treasury and GTEM database.

B.6.3 Fuel costs for electricity generation

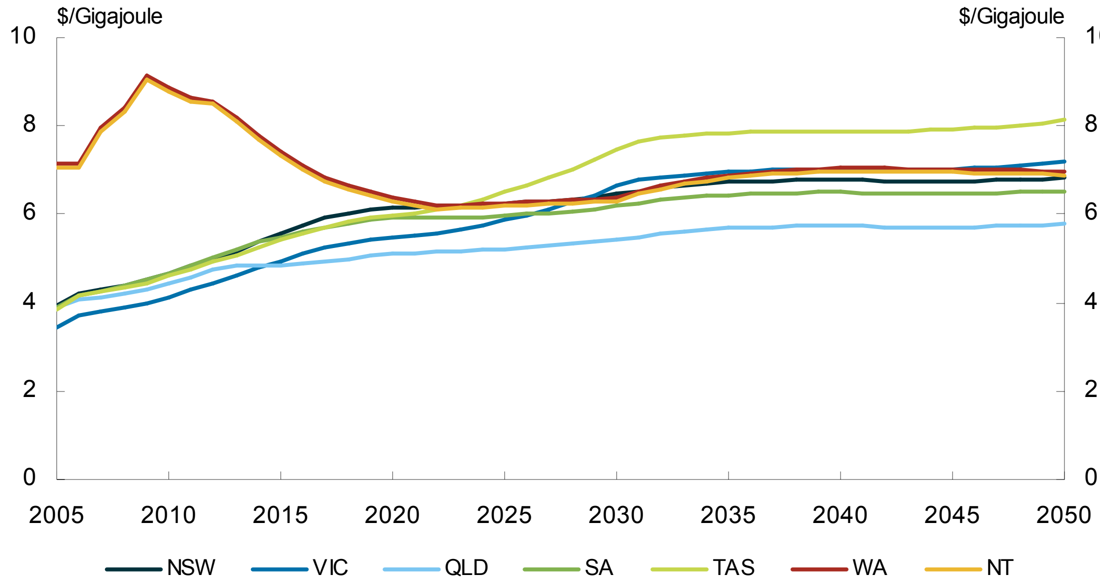
MMA combined Australian energy price assumptions with electricity industry-specific information to determine the fuel prices faced by Australian electricity generators.

- Once existing contracts expired for black coal (non-mine mouth), world energy price movements affected new coal contracts. Brown coal and mine mouth black coal prices were assumed to be unaffected by world energy price movements.

- South eastern gas supplies are assumed to be gradually depleted over the next 20 years, with gas increasingly sourced from Queensland. In addition, LNG facilities are assumed to be developed in Queensland, with a moderate degree of LNG penetration assumed, reaching 10 Mtpa LNG capacity. Consequently, east coast gas prices are assumed to converge to international gas prices in 2029-30. Differences in gas transmission costs amongst states, reflecting distance from fuel sources, mean that fuel prices are not equalised across states.

  – Domestic average gas prices are modelled by assuming that gas contracts turn over at a rate of 10 per cent of contracts per year, and that new contracts are influenced by world prices.

Chart B.7: Domestic Australian gas prices



Source: MMA.

B.6.4 Australian oil and gas supply constraints

The MMRF model incorporates assumptions about energy resource supply constraints, drawing on ABARE (2008), Geoscience Australia (2007 and 2008) and the BP statistical review of world energy (2007). No constraints have been imposed on the availability of energy resources in G-Cubed or GTEM.

It is assumed in MMRF that oil production in Australia ceases around 2030, and gas production ceases in South Australia around 2020, and in Victoria around 2030. Supply constraints in the model are imposed through scrapping existing capital.

ABARE reports that Australia has over 100 years worth of reserves of black coal and over 500 years worth of reserves of brown coal at current rates of production; therefore no constraints on coal production were imposed (ABARE, 2008).

B.7 Structural change

B.7.1 Intermediate input assumptions

Industry use of intermediate inputs in MMRF and GTEM is assumed to change over time.

The assumed changes in MMRF are based on historical decomposition analysis by Giesecke (2004). The estimates in MMRF were validated within Treasury, using a data set provided by the Centre for Integrated Sustainability Analysis at the University of Sydney. Reflecting uncertainty about the persistence of historical trends over the next century, the intermediate input change assumptions are assumed to decline linearly to zero between 2020 and 2050. The change in the intermediate input usage is implemented in MMRF in a cost-neutral manner, so total factor productivity remains unchanged.

As shown in Table B.13, the use of energy-intensive commodities is assumed to decline. This autonomous energy efficiency improvement (AEEI) reflects historical trends and analysis by the IEA and ABARE. In contrast, the intermediate use of services by business is assumed to continue to increase. For example, the demand for business services is assumed to increase by 1.5 per cent per year over the next 10 years.

Table B.13: Intermediate input usage in MMRF[(a)]

Annual average growth , per cent

Commodities	2006 to 2010	2011 to 2020	2021 to 2030	2031 to 2040	2041 to 2050	2051 to 2100
Sheep and cattle	-0.3	-0.2	-0.2	-0.1	0.0	0.0
Dairy cattle	-0.3	-0.2	-0.2	-0.1	0.0	0.0
Other animals	-0.3	-0.2	-0.2	-0.1	0.0	0.0
Forestry	-0.5	-0.5	-0.4	-0.2	-0.1	0.0
Coal mining(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Gas mining(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Other mining	-1.5	-1.5	-1.2	-0.7	-0.2	0.0
Meat products	0.5	0.5	0.4	0.2	0.1	0.0
Textiles, clothing and footw ear	-2.0	-2.0	-1.5	-0.9	-0.3	0.0
Wood products	-0.2	-0.2	-0.2	-0.1	0.0	0.0
Paper products	-0.2	-0.2	-0.2	-0.1	0.0	0.0
Printing	-0.4	-0.4	-0.3	-0.2	-0.1	0.0
Gasoline(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Diesel(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
LPG(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Air fuel	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Other fuel(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Chemicals	-0.7	-0.7	-0.5	-0.3	-0.1	0.0
Rubber and plastic products	0.5	0.5	0.4	0.2	0.1	0.0
Non-metal construction products	-0.5	-0.5	-0.4	-0.2	-0.1	0.0
Cement	-0.3	-0.3	-0.2	-0.1	0.0	0.0
Iron and steel	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Aluminium	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Other metals manufacturing	-0.1	-0.1	-0.1	0.0	0.0	0.0
Metal products	-0.1	-0.1	-0.1	0.0	0.0	0.0
Other manufacturing	-0.5	-0.5	-0.4	-0.2	-0.1	0.0
Electricity supply(b)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Water supply	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Construction	0.5	0.5	0.4	0.2	0.1	0.0
Trade	0.5	0.5	0.4	0.2	0.1	0.0
Accommodation and hotels	-1.5	-1.5	-1.2	-0.7	-0.2	0.0
Road transport: passenger	0.7	0.7	0.5	0.3	0.1	0.0
Road transport: freight	0.7	0.7	0.5	0.3	0.1	0.0
Rail transport: passenger	0.4	0.4	0.3	0.2	0.1	0.0
Rail transport: freight	0.4	0.4	0.3	0.2	0.1	0.0
Air transport	0.5	0.5	0.4	0.2	0.1	0.0
Communication services	1.0	1.0	0.8	0.5	0.1	0.0
Financial services	0.5	0.5	0.4	0.2	0.1	0.0
Business services	1.5	1.5	1.2	0.7	0.2	0.0

(a) Annual rate of change of use of the commodity identified per unit of output of all industries.
(b) Energy commodities have economy-wide energy-efficiency term applied. See energy efficiency section. Excluded commodities have no intermediate input efficiency shocks applied.
Source: Treasury and Centre of Policy Studies.

Table B.14: Intermediate input efficiency, GTEM
Annual average growth

	2002 to 2100
	Per cent
United States	0.3
EU-25	0.3
China	0.5
Former Soviet Union	0.6
Japan	0.3
India	0.7
Canada	0.2
Australia	0.4
Indonesia	0.3
South Africa	0.6
Other South East Asia	0.3
OPEC	0.4
Rest of w orld	0.7

Source: Treasury.

Table B.14 shows the average annual efficiency improvement across all intermediate inputs from 2002 to 2100. In the United States, intermediate input efficiency improves by around 0.31 per cent per year from 2002 to 2100.

B.7.2 Household taste shifts

Household taste shifts account for any additional change in consumption, after accounting for changes in incomes and relative prices. Projection assumptions are based on historical decomposition analysis by the Centre of Policy Studies (Adams et al., 1994; Dixon and Rimmer, 2002; Giesecke, 2004). In addition, Treasury has undertaken a decomposition analysis in the MMRF model, based on consumption categories in the national accounts.

The projected household taste shifts suggest a continuation of the long-term trends towards service commodities and away from basic commodities. Reflecting uncertainty about how persistent household trends will be over the next century, the taste shifts terms are assumed to decline to zero in a linear fashion between 2020 and 2050.

Table B.15: Household taste shocks in MMRF
Annual average growth, per cent

Commodities	2006 to 2010	2011 to 2020	2021 to 2030	2031 to 2040	2041 to 2050	2051 to 2100
Biofuels	1.0	1.0	0.8	0.5	0.1	0.0
Forestry	-1.5	-1.5	-1.2	-0.7	-0.2	0.0
Coal mining	-0.6	-0.6	-0.5	-0.3	-0.1	0.0
Paper products	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Printing	-1.0	-1.0	-0.8	-0.5	-0.1	0.0
Chemicals	0.8	0.8	0.6	0.4	0.1	0.0
Water supply	-0.5	-0.5	-0.4	-0.2	-0.1	0.0
Trade	0.5	0.5	0.4	0.2	0.1	0.0
Accommodation and hotels	0.5	0.5	0.4	0.2	0.1	0.0
Air transport	1.5	1.5	1.2	0.7	0.2	0.0
Communication services	3.0	3.0	2.3	1.4	0.4	0.0
Financial services	0.5	0.5	0.4	0.2	0.1	0.0
Business services	1.0	1.0	0.8	0.5	0.1	0.0
Public services	2.3	2.3	1.8	1.0	0.3	0.0
Other services	1.0	1.0	0.8	0.5	0.1	0.0
Private transport	-0.5	-0.1	0.0	0.0	0.0	0.0
Private electricity	0.5	0.5	0.4	0.2	0.1	0.0

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

B.8 ENERGY EFFICIENCY

Energy efficiency improves when less energy is required to produce the same amount of output. Energy efficiency can improve when the price of energy rises relative to other inputs or from technological improvements, including better use of existing technologies, the replacement of existing technologies with newer technologies, or improvements in new technology through research and development and learning by doing.

Assumed energy efficiency improvements in the modelling will affect the level of energy use and hence emissions. The three CGE models used by Treasury, GTEM, G-Cubed and MMRF treat energy efficiency differently depending on the model's structure.

B.8.1 Economy-wide energy efficiency

While CGE models can capture price-induced improvement in energy efficiency internally, if they allow for substitution in consumption and production choices, where they do not fully capture those substitution opportunities, they incorporate underlying energy efficiency improvements using a simple autonomous energy-efficiency improvement (AEEI) parameter. The AEEI parameter specifies the rate of annual energy-efficiency improvement, but not the source.

Arriving at estimates for the value of the AEEI is difficult given the uncertain evolution of energy efficiency over very long timeframes. While history provides a guide, available data is often aggregated, which obscures trends in energy efficiency with other factors such as structural changes in the economy. The reference scenario for Australia, assumes a constant economy-wide AEEI parameter of 0.5 per cent for all sectors outside the electricity and transport sectors, reflecting available estimates of historical energy efficiency by ABARE (2003) and the IEA (2004 and 2007a). For other regions, GTEM uses 0.5 per cent per year, except for some specific sectors such as: transport, iron and steel, non-metallic minerals, non-ferrous metals, and chemicals, rubber and plastics. These assumptions are outlined in Tables B.16 and B.18 to B.22. In its modelling of the Australian transport sector, the CSIRO also makes fuel efficiency assumptions (Table B.17).

B.8.2 Sector-specific energy efficiency

Transport energy-efficiency improvements

World transport efficiency assumptions

Transport energy-efficiency improvements in the 'other transport' sector in GTEM are based on ABARE (2006). The other transport sector includes rail and road transport technologies.

The fuel efficiencies of the different economies reflect a variety of trends. The increased uptake of variable valve controls and changes in fuel use (for example to diesel) tends to increase fuel efficiency. The improvement in fuel efficiency in North America is assumed to be slower than in some other developed regions as consumers prefer larger, less fuel efficient vehicles (ABARE, 2006). As discussed in Chapter 6, Australia is expected to see an increase the share of diesel fuel over the projection period.

Table B.16: Transport sector energy-efficiency assumptions
Annual average growth, 2005 to 2100

	Rail	ICE	Advanced ICE	Hybrid	Non-fossil fuel
	Per cent	Per cent	Per cent	Per cent	Per cent
United States	0.6	0.3	0.5	0.6	0.6
European Union	0.6	0.4	0.4	0.7	0.7
China	0.6	0.5	0.7	1.0	1.0
Former Soviet Union	0.6	0.5	0.7	0.7	0.7
Japan	0.6	0.3	0.4	0.6	0.6
India	0.6	0.8	0.9	1.2	1.2
Canada	0.6	0.3	0.5	0.6	0.6
Australia	0.6	0.7	0.8	0.9	0.9
Indonesia	0.6	0.6	0.8	0.7	0.7
South Africa	0.6	0.8	0.6	0.9	0.9
Other South and East Asia	0.6	0.9	1.2	1.1	1.1
OPEC	0.6	0.8	0.8	1.1	1.1
Rest of w orld	0.6	1.0	0.8	1.0	1.0

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

Australian transport energy efficiency assumptions

The CSIRO assumes petrol engine vehicles to be 25 per cent more efficient and diesel engines to be 14 per cent more efficient from 2006 to 2050, independently of changes related to fuel type and hybrid drivetrain, (CSIRO, 2008). Details of CSRIO's Australian road transport technology assumptions can be found in BITRE and CSIRO (2008).

Table B.17: CSIRO fuel efficiency improvements
Average annual growth, 2006 to 2050

	Petrol	Diesel	LPG	NG	B100	B20	E85	E10	H2	GTLD	CTLD
Passenger					Per cent						
Light	0.7	0.3	0.8	0.8	0.5	0.3	0.9	0.7	1.0	0.3	0.3
Medium	0.7	0.3	0.8	0.8	0.4	0.3	0.9	0.7	1.0	0.3	0.3
Heavy	0.7	0.4	0.8	0.8	0.4	0.3	0.9	0.7	1.0	0.3	0.3
LCVs											
Light	0.7	0.3	0.8	0.9	0.5	0.3	0.9	0.7	1.0	0.3	0.3
Medium	0.7	0.3	0.8	0.9	0.4	0.3	0.9	0.7	1.0	0.3	0.3
Heavy	0.7	0.4	0.8	0.9	0.5	0.3	0.9	0.7	1.0	0.3	0.3
Trucks											
Rigid	0.7	0.3	0.8	0.8	0.5	0.3	0.9	0.7	1.0	0.3	0.3
Articulated	0.7	0.3	0.5	0.5	0.5	0.3	0.6	0.7	0.6	0.3	0.3
Buses	0.7	0.3	0.8	0.9	0.5	0.3	0.9	0.7	1.0	0.3	0.3

Note: NG refers to compressed natural gas; B100 and B20 are different blends of biodiesel; E85 and E10 are different ethanol blends; H2 is hydrogen; GTLD is gas-to-liquid fuels; and CTLD are coal-to-liquid fuels.
Source: CSIRO, 2008.

Other sector energy efficiency assumptions

The non-ferrous metal sector includes aluminium, nickel, copper, lead and gold. Energy efficiency improvements for the aluminium sector are assumed to vary significantly between regions (Table B.18). The main determinant of efficiency improvements in the non-ferrous metals sector in GTEM is the assumed increase of scrap aluminium rather than technological advancement (Fisher et al., 2006). Early in the projection period, the United States is expected to shut down most of its primary aluminium smelting plants and produce aluminium solely from scrap. Australia and other major exporting regions, however, are assumed to have little scrap available. These regions are assumed to have significantly less efficiency improvements than the United States. Efficiency improvements in this sector largely reflect composition shifts within the sector, not uniform improvements over all sub-sectors within the aggregate sector.

Table B.18: Non-ferrous metals energy-efficiency shocks
Average annual growth

	2005 to 2100
	Per cent
United States	1.7
European Union	1.7
China	1.1
Former Soviet Union	0.7
Japan	0.6
India	0.8
Canada	0.7
Australia	0.5
Indonesia	1.5
South Africa	0.8
Other South and East Asia	0.7
OPEC	0.7
Rest of w orld	0.8

Source: ABARE and Treasury.

To test the sensitivity of the mitigation cost estimates to this assumption, a sensitivity scenario was undertaken. Non-ferrous metal energy-efficiency shocks were uniformly applied to all economies, at 0.5 per cent growth per year. Australia's exports of non-ferrous metals increased very slightly in the reference scenario as a result. However, this sensitivity scenario indicated changing this assumption had no material effect on the Australian and non-ferrous metal sector results under mitigation policy.

Table B.19: Non-metallic mineral energy-efficiency shocks
Average annual growth

	2005-2050
	Per cent
United States	0.7
European Union	0.6
China	1.0
Former Soviet Union	0.9
Japan	0.4
India	0.9
Canada	0.9
Australia	0.4
Indonesia	0.7
South Africa	0.4
Other South and East Asia	0.6
OPEC	0.6
Rest of w orld	0.5

Source: ABARE and Treasury.

Table B.20: Chemical, rubber and plastics energy efficiency shocks
Average annual growth

	2005 to 2010	2010 to 2020	2020 to 2030	2030 to 2100
	Per cent	Per cent	Per cent	Per cent
United States	0.5	0.5	0.5	0.6
European Union	0.5	0.5	0.5	0.5
China	0.5	0.5	0.5	0.5
Former Soviet Union	0.4	0.4	0.4	0.5
Japan	0.5	0.5	0.5	0.5
India	0.6	0.6	0.5	0.5
Canada	0.4	0.5	0.5	0.5
Australia	0.4	0.4	0.5	0.5
Indonesia	0.4	0.4	0.5	0.5
South Africa	0.4	0.5	0.5	0.5
Other South and East Asia	0.4	0.4	0.5	0.6
OPEC	0.4	0.4	0.5	0.5
Rest of w orld	0.5	0.5	0.5	0.6

Source: ABARE and Treasury.

Iron and steel energy efficiency (GTEM)

As part of the modelling in GTEM, assumptions have been made on improvements in energy efficiency in the iron and steel industry. Annual average efficiency improvements are based on the US Energy Information Administration National Energy Modelling System (NEMS), which underlies the EIA's Annual Energy Outlook. In GTEM, iron and steel is a technology bundle industry with two discrete technologies — blast furnace and electric arc furnace (recycled steel from scrap steel). The assumed improvements in energy efficiency for blast furnace and electric arc furnace processes are outlined in Tables B.21 and B.22 respectively.

Table B.21: Blast furnace
Average annual growth

	2005 to 2010	2010 to 2020	2020 to 2030	2030 to 2100
	Per cent	Per cent	Per cent	Per cent
United States	0.5	0.3	0.3	0.8
European Union	0.4	0.3	0.3	0.4
China	0.9	1.0	1.0	0.7
Former Soviet Union	0.5	0.9	0.9	0.7
Japan	0.3	0.3	0.3	0.5
India	1.1	0.9	0.8	1.0
Canada	0.2	0.3	0.3	0.5
Australia	0.4	0.3	0.3	0.7
Indonesia	0.0	0.0	0.0	0.5
South Africa	0.6	0.8	0.8	1.2
Other south and east Asia	0.3	0.5	0.5	0.4
OPEC	0.5	0.3	0.3	0.9
Rest of w orld	0.6	0.8	0.8	0.9

Source: ABARE and Treasury.

Table B.22: Electric Arc
Average annual growth

	2005 to 2010	2010 to 2020	2020 to 2030	2030 to 2100
	Per cent	Per cent	Per cent	Per cent
United States	0.9	0.7	0.7	0.9
European Union	0.8	0.6	0.6	0.7
China	1.0	1.3	1.3	1.0
Former Soviet Union	0.6	1.3	1.4	0.8
Japan	0.5	0.6	0.6	0.8
India	1.3	1.3	1.3	1.3
Canada	0.4	0.7	0.7	0.6
Australia	0.7	0.7	0.7	0.9
Indonesia	1.2	1.2	1.2	1.4
South Africa	0.7	1.3	1.3	1.5
Other South and East Asia	0.5	0.7	0.8	1.2
OPEC	1.0	0.9	0.9	1.0
Rest of w orld	0.6	1.2	1.3	1.2

Source: ABARE and Treasury.

B.9 TECHNOLOGY ASSUMPTIONS

B.9.1 Electricity technology assumptions

Table B.23 describes the key electricity sector input assumptions used by MMA.

Table B.23: Technology characteristics, MMA

	Thermal efficiency		Capital costs	Capital cost de-escalator	
Fuel/technology	2010 per cent	2011 to 2050 per cent per year	2010 $/kW sent out	2010 to 2020 per cent per year	2021 to 2050 per cent per year
Black Coal					
Supercritical coal (dry-cooling)	38	0.48	1,879	0.5	0.5
Ultrasupercritical coal (USC)	41	0.48	2,255	0.5	0.5
Integrated gasification combined cycle (IGCC)	39	1.20	2,673	1.5	1.0
IGCC w ith carbon capture (CC)	32	1.30	3,688	1.5	1.0
USC w ith CC and oxyfiring	30	0.58	2,997	1.0	0.5
USC w ith post-combustion capture	28	0.58	3,044	1.5	0.5
Brown Coal					
Supercritical coal w ith drying	35	0.48	1,972	0.5	0.5
Supercritical coal	33	0.48	2,289	0.5	0.5
Ultra supercritical coal w ith drying	37	0.48	2,366	1.0	0.5
IGCC w ith drying	37	1.20	2,788	1.0	1.0
Integrated drying gasification combined cycle (IDGCC)	37	1.20	2,732	1.5	0.5
IGCC w ith CC and drying	30	1.30	3,886	1.5	0.5
IDGCC w ith CC	32	1.30	3,026	1.5	0.5
Co-firing w ith biomass or gas in supercritical plant	35	0.48	2,169	0.5	0.5
Post-combustion capture w ithout drying	28	0.58	3,155	1.5	0.5
Post-combustion capture w ith drying	26	0.58	3,248	1.5	0.5
Natural gas					
Combined cycle gas turbined (CCGT) - small	49	0.60	1,467	0.5	0.5
CCGT - large	53	0.60	1,334	0.5	0.5
Cogeneration	72	0.60	1,740	0.5	0.5
CCGT w ith CC	46	0.70	2,001	1.0	0.5
Renewables					
Wind			2,134	0.5	0.5
Biomass - Steam			2,598	0.5	0.5
Biomass - Gasification			2,784	1.5	1.0
Concentrated solar thermal plant			4,176	1.5	1.0
Geothermal - Hydrothermal			2,227	1.0	1.0
Geothermal - Hot Dry Rocks			4,200	1.5	0.5
Concentrating PV			4,640	1.0	1.0
Hydro			2,320	1.0	0.5

Source: MMA.

There is uncertainty surrounding future technology costs, particularly in relation to technologies that have not yet been deployed. See ACIL Tasman (2008) for a review of capital cost estimates. The Treasury assumptions were developed, taking account of the broad macroeconomic assumptions from the national and global modelling. Comparisons of these assumptions with overseas estimates are not straight forward owing to different environmental regulatory standards, which are not needed in Australia.

Thermal efficiency

The thermal efficiency of a fossil fuel power plant is the ratio of electricity generated to energy input. Assumptions on thermal efficiency improvements for Australia were provided by MMA. Table B.24 shows thermal efficiencies when the plants operate at maximum capacity. As plants do not always operate at maximum capacity, the average thermal efficiency is typically lower than those shown. After 2050, thermal efficiencies are assumed to increase slightly for coal and gas, reflecting a continuation of efficiency improvements from 2030 to 2050.

Assumptions on electricity generation efficiencies are based on information received from ACIL Tasman and MMA. It is assumed the thermal efficiency of new fossil fuel electricity and heat generation plants improves over time. These assumptions apply to new power plants. The thermal efficiency of the average plant in the capital stock improves as a combination of technology advancement and replacement of old capital with new.

Table B.24: Thermal efficiency of new power plants in electricity generation in GTEM

	Coal			Gas		
	2002	2050	2100	2002	2050	2100
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
United States	35.6	47.0	54.6	40.3	61.3	65.7
European Union	35.1	41.2	44.6	48.1	55.2	58.0
China	31.6	43.3	50.3	46.5	63.1	69.8
Former Soviet Union	31.3	33.3	35.4	38.1	41.1	42.3
Japan	37.1	45.5	50.3	45.1	60.1	65.8
India	27.7	47.5	56.8	41.6	64.5	69.9
Canada	38.2	44.9	48.6	46.2	57.9	60.2
Indonesia	27.8	47.2	57.6	32.9	63.1	69.7
South Africa	38.5	46.8	54.3	39.4	65.0	70.4
Other South and East Asia	33.8	46.3	54.8	37.3	61.7	68.1
OPEC	39.0	49.0	58.6	31.9	63.4	70.1
Rest of w orld	32.7	47.1	56.3	41.5	60.9	65.3

Source: ABARE, ACIL Tasman, MMA.

Capital costs

Two main factors drive capital costs over time in MMA: metal prices and technological progress. MMA assume that 25 per cent of capital costs reflect commodity costs.

Treasury provided cost indices for key metals (steel and aluminium) for the reference and policy cases. The metal costs are consistent with the macroeconomic assumptions, such as the terms of trade, including the expected unwind in metal costs as supply responds to high levels of demand. Metal prices are higher in the policy scenarios owing to the cost of emissions associated from metal production.

MMA assume that capital costs decline over time for all technologies owing to general capital productivity improvements. Table B.23 shows the annual rate of capital cost de-escalation.

GTEM assumes that additional global deployment of renewable technologies leads to faster rates of cost decline for these technologies. To capture the impact of global deployment on Australia, additional capital cost reductions were applied on Australian renewable technology capital costs. These were developed by comparing renewable cost declines in GTEM and applying the *additional* rate of cost decline to MMA modelling.

B.9.2 Learning rates

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

Non-renewable and biomass technologies use feedstock, labour and capital to produce electricity, while renewable, including hydro, technologies use only labour and capital as inputs. The efficiency with which new technology uses capital and labour is assumed to increase over time as the scale of these technologies increases.

The GTEM parameters of the learning function were calibrated, given the pathways of the fossil fuel prices and the possibility of substitution between the technologies, to produce shares of each technology that were broadly in line with the MMA analysis and other published results. Learning rates for GTEM were only assumed for new technologies and were broadly constant across all regions. The learning rates for GTEM based on the doubling of the cumulative global output are shown below.[1]

- Wind: 1.9 per cent
- Solar: 3.3-4 per cent
- Other renewables: 2.5 per cent
- Coal carbon capture and storage: 0.7 per cent
- Gas carbon capture and storage: 1.5 per cent

In addition to these learning effects, renewable technologies also benefit disproportionately from overall sector-specific factor productivity growth because primary factors are the only input to these technologies, while for non-renewable technologies the costs of feedstocks, such as coal, are significant.

B.9.3 Constraints

Exogenous assumptions and constraints in the MMA modelling include:

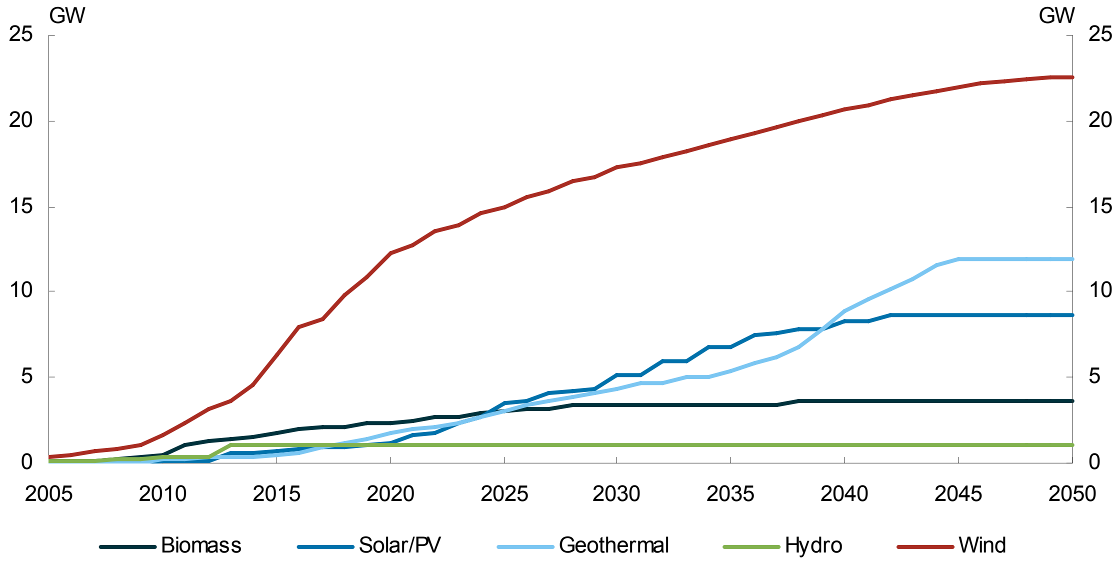
- the impact of the 2006-07 drought is assumed to disappear by 2012 — for instance, hydro dam levels are assumed to be replenished;
- new entry of power plants that are currently not planned was constrained until 2011 for peaking gas, 2012 for baseload gas, and 2013 for coal; and
- limits were placed on the rate of takeup and total takeup of renewable energy capacity reflecting resource availability, and engineering and technical constraints (including constraining wind capacity to no more than 25 per cent of a region's peak demand). Chart

1 Under the GTEM formulation of learning rates, cost reductions depend on cumulative global *output* of electricity from a specific technology. This is different to the more common formulation where cost reductions depend on cumulative global installed *capacity*. Accordingly, the GTEM learning rates are not directly comparable with many estimates in the literature.

B.8 shows the assumed cumulative limits on wind, solar/PV, hydro, biomass and geothermal takeup.

Checks ensured that the amount of carbon projected to be geo-sequestered by carbon capture and storage did not exceed estimates of available storage space (Bradshaw, 2005; Langford, 2005).

Chart B.8: Cumulative renewable capacity constraints — MMA



Note: The charts shows the maximum additional post-2005 capacity that can be installed each year, if it is economical.
Source: MMA.

Exogenous assumptions and constraints in the GTEM modelling are:

- the expansion of hydro electricity is constrained to reflect remaining unexploited hydropower resources. For China, India, Indonesia, other Asia and the rest of the world, hydro electric uptake is unconstrained to 2020, and fixed thereafter. For other regions (except Australia), hydro electric production is assumed to be fixed (based on the assumption that all profitable hydro resources already have been used) from 2001. For Australia, however, hydro electric production is exogenously shocked, based on MMA analysis;
- generation of wind electricity by region is constrained, based on estimates of wind resources (IEA, 2000; de Vries, 2007); and
- checks ensured that the amount of carbon projected to be geo-sequestered by carbon capture and storage did not exceed estimates of available storage space (IPCC, 2005).

B.9.4 Carbon capture and storage

There is a range of views on the viability, cost and timing of carbon capture and storage technology (IEA, 2008; Greenpeace, 2008). Carbon capture and storage technology, combined with coal and gas electricity generation, is assumed to be available on a commercial scale in the main policy scenarios. A sensitivity scenario also was run to test the implications of carbon capture and storage being unavailable. See Chapter 5.

The approach to modelling carbon capture and storage in MMA and GTEM differed, reflecting the level of detail in the respective models and the inherent uncertainty surrounding a technology that has yet to be demonstrated on a commercial scale. In MMA modelling, carbon capture and storage was assumed to be available for various black coal, brown coal and gas technologies. Power plants can be either purpose-built carbon capture and storage, or built ‘capture ready’, with carbon capture and storage installed when the carbon price is sufficiently high. Retrofitting existing power plants with carbon capture and storage was also an option. In contrast, GTEM only models purpose-built carbon capture and storage operations and has a single technology for coal and gas. However, the rates of carbon capture and storage takeup in GTEM were cross-checked in light of possible retrofitting.

In the MMA modelling of the Australian electricity sector and GTEM modelling of the world electricity sector, carbon capture and storage was assumed to be available as a generation option from 2020. This assumption is consistent with assumptions in similar modelling exercises in Australia.[2] However, the actual timing of carbon capture and storage technology deployment was determined by the model, based on economic considerations including the availability of the technology, the relative cost of carbon capture and storage with non-carbon capture and storage alternatives, the requirement for new power plant to meet current and expected future electricity demand and the emission price. Across the full range of scenarios modelled by MMA, the earliest year carbon capture and storage can be deployed ranges from 2026 to 2033, with the emission price in that year ranging from \$45 to \$80 per tonne of CO_2-e for coal and around \$100 per tonne of CO_2-e for gas (MMA, 2008).

MMA assumes that carbon capture and storage technologies capture 85 per cent of emissions before 2050, with this capture efficiency stepped up to 90 per cent after 2050. GTEM assumes a constant 90 per cent capture efficiency throughout the period.

MMA modelling assumes carbon capture and storage capital costs are around 30-40 per cent higher for coal and 50 per cent higher for gas compared to non-carbon capture and storage options. Capturing and compressing carbon requires energy use and, as a result, the sent out efficiency of a power plant with carbon capture and storage is assumed to be around 20 per cent for lower coal generation and 14 per cent lower for gas generation.

MMA models the storage of captured carbon by state. Depending on the proximity of sequestration and the point of emission, extensive pipelines may be required. Existing gas distribution infrastructure could facilitate this but if new pipes are required the modelling assumes the fixed cost of building those pipes is paid by generators. However, these fixed costs are not paid upfront, but as an annual fee which is part of generator’s variable cost of transporting and storing carbon. Generators therefore pay for the fixed cost of building pipelines over the life of the carbon capture and storage operation. This variable cost ranges from \$10 to \$20 a tonne, depending on the state.

B.9.5 Nuclear

Nuclear is assumed to continue to be available in regions where it is currently deployed (and not available elsewhere, including in Australia). No specific constraints were imposed; nuclear

2 Concept Economics (2008), CRA International (2008) and Energy Supply Association of Australia (2006) assumed 2020 as the earliest year for CCS. MMA (2006) assumed 2021 and Allen Consulting Group assumed 2022.

resources and emerging technology were assumed to be able to meet demand for nuclear electricity.

B.9.6 Reference scenario reductions in non-combustion emission intensity

Reductions in emissions per unit of output (emission intensity) were imposed in all CGE models based on assumptions from Australian and world sources (DCCa, 2008a; Weyant and Chesnaye, 2006).

Table B.25: Reductions in non-combustion emission intensity in GTEM

Average annual growth from 2005 to 2050 by sector and gas

	Coal CH_4 Per cent	Non-metallic minerals, CO_2 Per cent	Livestock CH_4/N_2O Per cent	Crops N_2O Per cent	Gas CH_4 Per cent	Oil CH_4 Per cent
United States	-1.4	-0.3	-0.8	-0.8	0.0	0.0
European Union	-1.7	-0.3	-0.8	-0.5	-0.6	0.0
China	-0.7	-0.4	-0.8	-0.3	-1.1	-3.2
Former Soviet Union	-1.0	-0.3	-0.8	-1.2	-2.4	-0.9
Japan	0.0	-0.3	-0.8	-0.5	-1.4	-4.5
India	-3.6	-0.3	-0.8	-0.3	-1.4	-4.1
Canada	0.0	-0.4	-1.1	-2.0	0.0	0.0
Australia	-1.7	0.0	-1.1	-1.5	0.0	0.0
Indonesia	-3.6	-0.3	-0.8	-0.4	-1.4	-4.2
South Africa	-1.0	-0.3	-0.8	-0.5	-1.7	-4.5
Other South and East Asia	-3.6	-0.3	-0.8	-0.4	-1.5	-4.1
OPEC	-3.8	-0.3	-0.8	-0.2	-0.2	-3.2
Rest of w orld	-3.0	-0.3	-0.8	-0.5	-0.4	-2.5

Note: Negative number denotes an improvement in emissions intensity. G-Cubed emission intensity reductions calibrated to be consistent with GTEM.
Source: Treasury; DCC, 2008a; Weyant and Chesnaye, 2006.

Table B.26: Reductions in non-combustion emission intensity in MMRF

Average annual growth

Industry sectors	2005 to 2020 Per cent	2021 to 2050 Per cent
High enteric livestock	4.5	4.5
Dairy cattle	1.7	1.7
Other animals	0.9	0.9
Grains	0.1	0.1
Biofuels	0.3	0.3
Other agriculture	-4.6	-4.6
Forestry	0.9	0.9
Coal mining	0.1	0.1
Oil	0.4	0.4
Gas mining	0.0	0.0
Iron ore mining	0.1	0.1
Non-Ferrous ore mining	0.1	0.1
Chemicals	0.1	0.1
Non-metal construction products	0.2	0.2
Cement	1.0	1.0
Iron and steel	0.6	0.6
Aluminium	0.8	0.8
Gas supply	0.8	0.8
Road transport: passenger	0.4	0.4
Other services	0.2	0.2
Private electricity	0.1	0.1

Source: Treasury and DCC (2008a).

B.9.7 Marginal abatement cost curves

Introduction of an emission price induces industries to reduce the emission intensity of their production; they attempt to reduce the volume of greenhouse gases emitted for each unit of production. One common way to represent and model this reduction, especially when the models do not allow for substitution between intermediate inputs of production, is with marginal abatement cost (MAC) curves. This method is used in the GTEM and MMRF models.

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

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

Where:

Λ is an index of the emissions factor relative to the reference year;

t is the carbon price;

α is set to 0.03 unless otherwise noted;

Min Λ is the minimum emissions intensity of output possible; and

γ sets the speed of adjustment of emissions intensity in response to a carbon price, a higher γ represents a faster adjustment.

The parameters γ and min Λ are selected to model the selected industry as best as possible based on sector-specific information on technology and production possibilities. The MAC curves are non-linear in nature and results can be sensitive to the solution methods used by the models.

Marginal abatement cost curves in GTEM

The MAC curves used in GTEM were derived to fit the functional form listed above to the global level data from the EMF-21 data set by Weyant and Chesnaye (2006). The MAC curves in GTEM are applied only to fugitive/industrial process emissions, that is, only to emissions that are not the consequence of combustion of energy.

Table B.27: GTEM fugitive/industrial process emission MAC curve parameters

Sector	γ	minΛ
Coal	0.90	0.1
Gas	0.80	0.1
Oil	0.75	0.1
Landfill/solid w aste	0.85	0.1
Livestock	0.60	0.1
Crops	0.45	0.1
Fertilizer use	0.45	0.1
Non-ferrous metals	0.80	0.1
Non-metallic minerals	0.60	0.1

Source: Treasury; and EMF 21 (2006).

Marginal abatement cost curves in MMRF

Industrial process MAC curves

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

Table B.28: MMRF industrial process emission MAC curve parameters

Sector	γ	minΛ
Livestock	0.50	0.1
Crops	0.56	0.1
Coal	0.70	0.1
Oil	0.55	0.1
Gas	0.63	0.1
Non-ferrous ore mining	0.50	0.1
Paper products	0.50	0.1
Refinery	0.55	0.1
Chemicals	0.90	0.1
Non-metal construction	0.50	0.1
Cement	0.89	0.1
Steel	0.90	0.1
Aluminium	0.90	0.1
Gas supply	0.64	0.1
Trade	0.99	0.1
Accommodation and hotels	0.99	0.1
Road transport: passenger	0.99	0.1
Other services	0.99	0.1
Private transport	0.99	0.1
Private electricity	0.99	0.1

Source: Treasury; EMF21 (2006); MMA; and Industry consultation.

Combustion MAC curves in MMRF

The MMRF model does not currently capture the potential for fuel switching, that is, substitution between say coal and gas within each sector. Fuel switching is a feature of the GTEM and G-Cubed models. In the MMRF model MAC curves were applied to combustion emissions in the industrial (non-transport) sectors, to capture the notion that industrial combustion emissions will fall in response to rising carbon prices.

The MAC curve for each type of fuel was calibrated to reflect possible use of using carbon capture and storage technology (as in the electricity generation sector) or to reflect the decarbonisation of the transport sector through the electrification of transport.

Table B.29: MMRF combustion emission MAC curve parameters

Fuel	α	γ	minΛ
Coal	0.000001	2.75	0.1
Gas	0.000001	2.33	0.1
Gasoline	0.000006	2.05	0.1
Diesel	0.000007	2.05	0.1
LPG	0.000006	2.07	0.1
Air fuels	0.000007	2.05	0.1
Other fuels	0.000007	2.05	0.1

Source: Treasury.

B.10 LAND-USE AND FORESTRY ASSUMPTIONS

B.10.1 Forestry

Detailed modelling of the forestry sector can be problematic within CGE models. Owing to this sector's importance to both Australian and global responses to emission pricing, more detailed, bottom-up modelling of the forestry sector was commissioned from ABARE (for Australia) and from Lawrence Berkeley National Laboratory (for the rest of the world).

The Australian estimates are based on the Kyoto Protocol Article 3.3 emissions accounting framework. Specifically, Article 3.3:

- includes only new forests established on land not forested in 1990;
- requires the reporting of all greenhouse gases;
- excludes harvest wood products; and
- includes the 'short rotation' harvest sub-rule, to protect individual stands from returning a negative outcome until the end of the Kyoto period.

The global emission estimates are more consistent with the United Nations Framework Convention on Climate Change (UNFCCC). The differences largely reflect availability of data. The main differences between the carbon accounting in international forestry modelling and in the Kyoto reporting adopted for Australia are:

- inclusion of all identified managed native forests and plantations (even if cleared after 1990);
- reporting of all carbon including harvested wood products; and
- inclusion of the no sub-rule mechanism.

Australia

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

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

The assumed percentage changes each year to the returns to agriculture and timber from 2007 to 2100 are based on MMRF reference scenario projections. These changes are applied to both agricultural land values; and the returns and costs associated with timber plantations.

Three types of forestry activity were assumed to be available: softwood and hardwood timber plantations and environmental (carbon sequestration) plantations. All types have establishment costs, but environmental plantings do not have transport or harvesting costs, and are assumed not to incur ongoing management costs. These costs are presented in Table B.30.

The cost assumptions relating to the establishment, harvesting and transport of timber plantations and environmental plantings are based on data from NSW Department of Primary Industry (Roberts, 2007) and ABARE estimates. These costs are assumed to remain constant in the analysis, but are discounted at a rate of 7 per cent each year. Further, the cost assumptions are based on large-scale investments and may differ considerably from small-scale operations.

Table B.30: Cost assumptions, 2007 prices

		Timber plantations	Environmental plantings
Establishment	\$/ha	2,500	2,000
Management	\$/ha	180	0
Harvesting	\$/m^3	22	0
Transport	\$/m^3.km	0.123	0

Source: ABARE estimates; Roberts, 2007.

The assumed return from traditional timber production is calculated using the average mill-door log price in each state. These mill-door log prices are assumed to range from \$42/m^3 to \$71.5/m^3 in 2007 (Table B.31). The variation is due to the differences in the demand and supply of softwood and hardwood timber across states. Only one price is estimated for hardwood (broadleaved) and softwood (coniferous) logs. However, these prices are a good approximation of the expected return from native and forest plantations in Australia between 2000-01 and 2006-07 (ABARE, 2008). Mill-door log prices by state and species are derived from ABARE forest industry survey data.

The ABARE analysis uses a broad definition of available agricultural land and assumes a 100 per cent takeup of sequestration opportunities. Factors other than economic viability, including water availability and environmental restrictions, may make some land unsuitable for afforestation and therefore reduce the sequestration potential.

Table B.31: Assumed mill-door price by type in the reference scenario, 2007 prices

	Hardwood	Softwood
	\$/m^3	\$/m^3
New South Wales	54.5	52
Victoria	62.8	59.6
Queensland	54.5	66.8
South Australia	62.8	61.9
Western Australia	71.5	59.6
Tasmania	60.6	61
Northern Territory	67.3	42

Source: ABARE, 2008.

The ABARE modelling is supplemented by estimates from the Department of Climate Change of net carbon sequestration for plantations occurring between 1990 and 2006, and adjustments to account for the 'short rotation' harvest sub-rule over the Kyoto period.

B.10.2 Emissions from Australian land use and land use change

There is no economic modelling of Australian land use and land-use change. Emissions from this sector are exogenously imposed in the models. Land-use emissions for Australia largely represent emissions from clearing regrowth as part of agricultural management rather than clearing for new land.

In the reference scenario, emissions from land clearing were assumed to remain at 44 Mt CO_2-e per year throughout the projection period, based on a simple extrapolation from projections in the most recent national emission projections (DCC, 2008). Under the policy scenarios, land clearing emissions are assumed to decline linearly to 24 Mt CO_2-e in 2050 and to zero in 2100.

B.10.3 Emissions from global land use and land use change

International land use and forestry estimates were commissioned from the Lawrence Berkeley National Laboratory, and are based on their GCOMAP model. See Sathaye et al. (2006) for details.

The GCOMAP model establishes a level in the reference scenario for land use, without emission prices, for 2000 to 2100. It then simulates the response of forest land users (farmers) to changes in prices in forest land and products, and emerging emission prices. The aim is to estimate ow much more land area land users would plant than in the reference scenario, or prevent from being deforested, in response to emission prices. The model then estimates the net changes in carbon stocks while meeting the annual demand for timber and non-timber products.

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