CHAPTER 5: MITIGATION SCENARIOS — INTERNATIONAL RESULTS

Key points

Stabilisation is only possible with action by all major emitters.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.1 GLOBAL EMISSION ALLOCATIONS

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

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

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

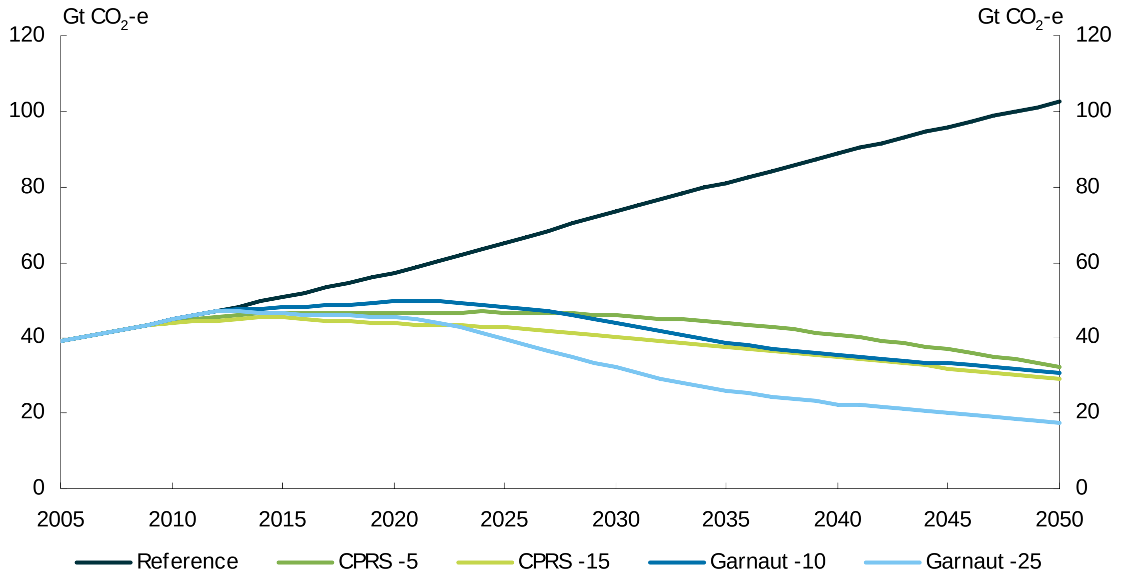
Table 5.1: Global emission allocations

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

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

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

Chart 5.1: Global emission allocations



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

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

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

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

Table 5.2: National emission allocations

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

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

5.1.1 Global emission price

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

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

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

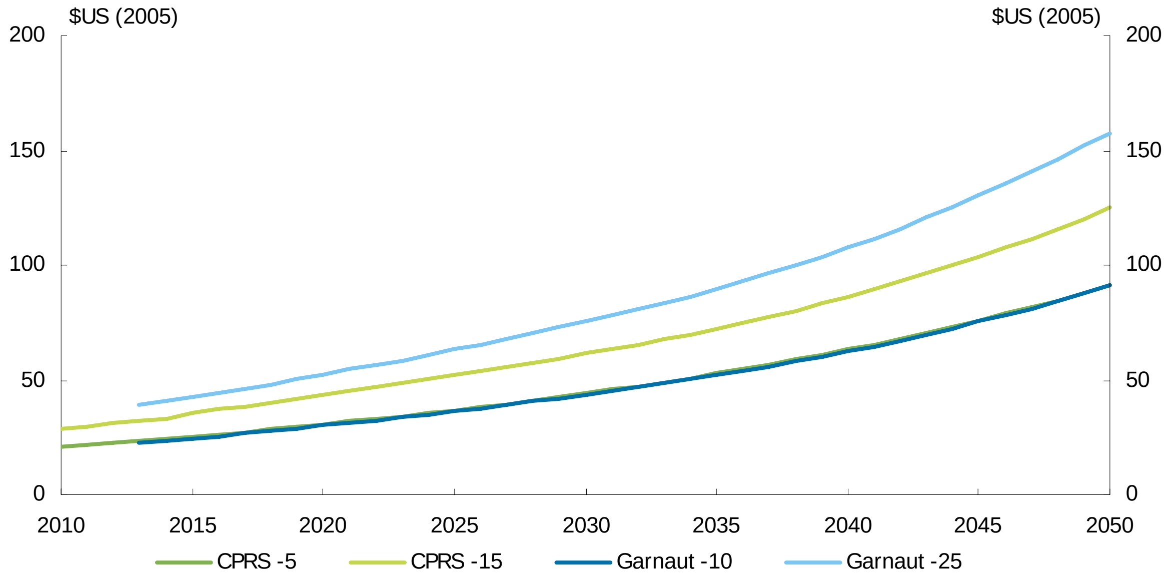
Table 5.3: Global emission prices

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

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

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

Chart 5.2: Global emission prices



Source: Treasury estimates from GTEM.

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

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

5.1.2 Global emissions

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

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

Box 5.1: The emission price in G-Cubed

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

Table 5.4: Emission prices (US\$/tCO_2-e, nominal) first year of scheme

	GTEM	G-Cubed
	nominal US\$/tCO_2-e	nominal US\$/tCO_2-e
CPRS -5	23	9.3
CPRS -15	32	11.3
Garnaut -10	27	8.9
Garnaut -25	47	13.1

Source: Treasury estimates from GTEM and G-Cubed.

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

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

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

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

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

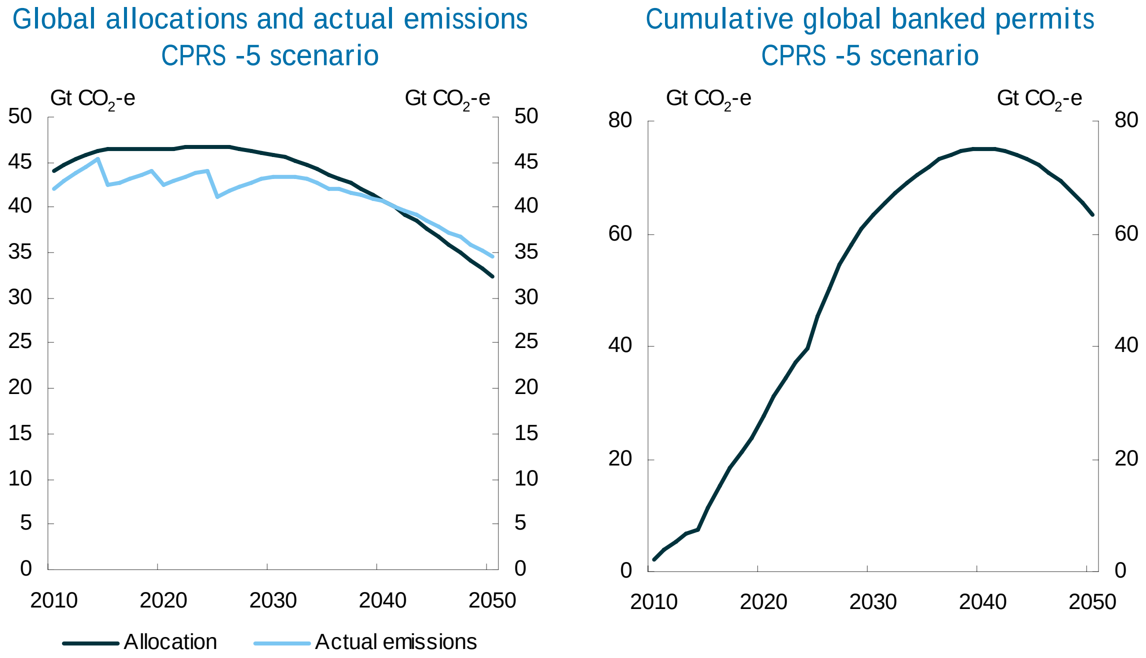
Table 5.5: Global allocations, emissions and banked permits

CPRS -5 scenario

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

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

Chart 5.3: Emissions, allocations and cumulative banked permits



Source: Treasury estimates from GTEM.

Emissions by gas

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

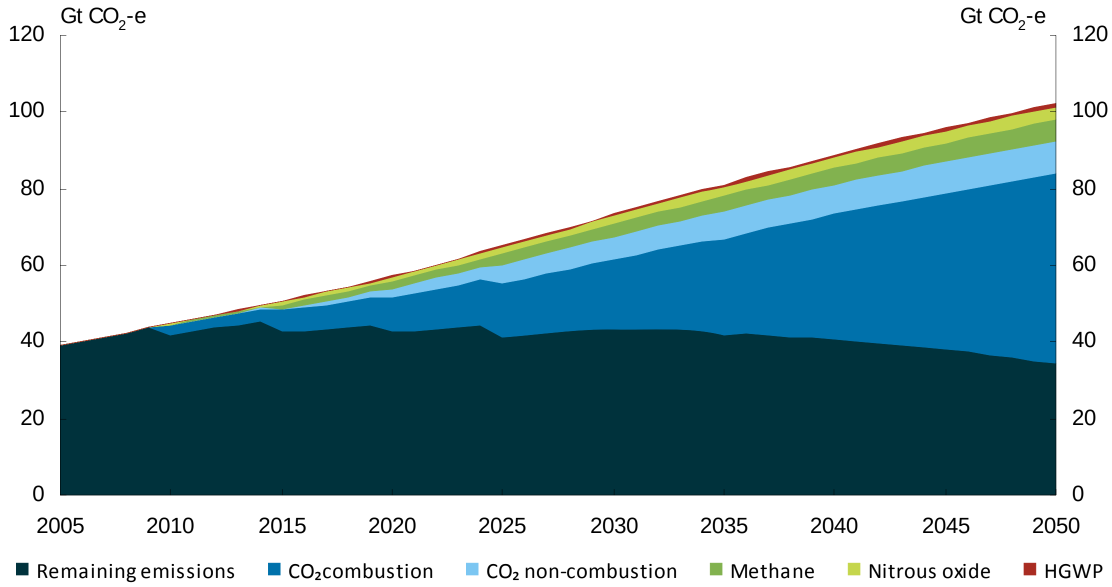
Forestry sinks across most regions provide substantial emission sequestration, wholly offsetting non-combustion CO_2 emissions from all sources by 2020. Non-combustion CO_2 emissions are negative for most of the projection period as reafforestation continues.

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

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

Chart 5.4: Decomposition of global mitigation by gas

CPRS -5 scenario



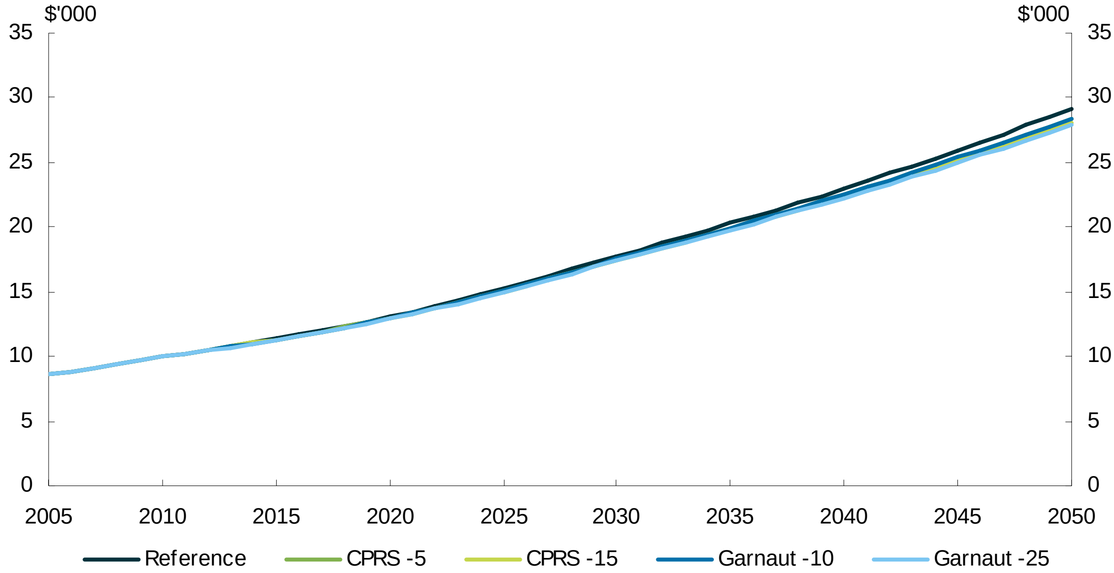
Note: HGWP: High-global-warming-potential gases, including SF_6, HFcs and PFCs.
Source: Treasury estimates from GTEM.

5.2 Global mitigation costs

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

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

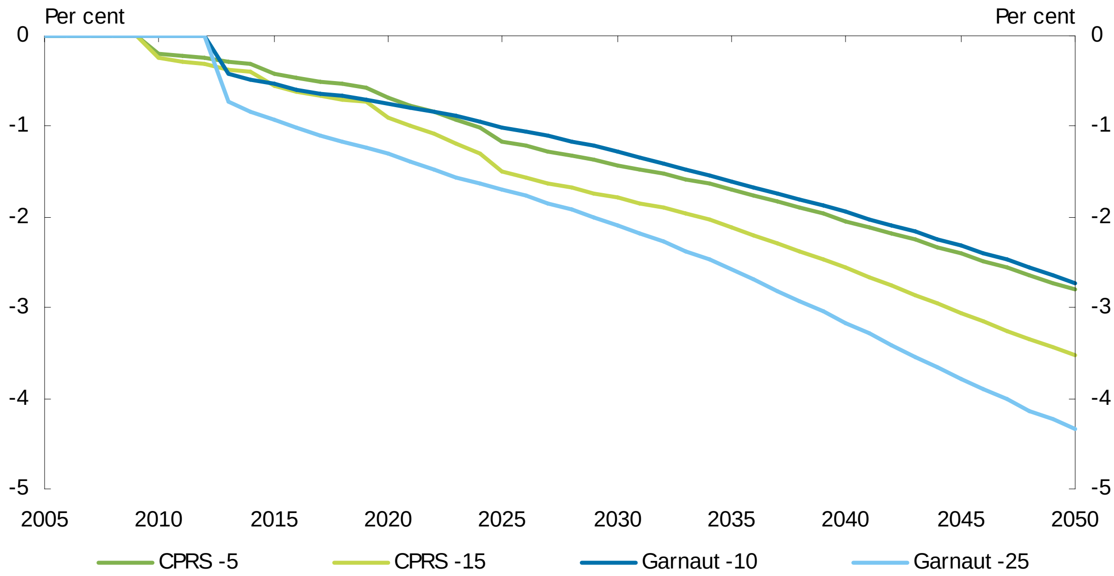
Chart 5.5: GTEM: Gross world product per capita



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

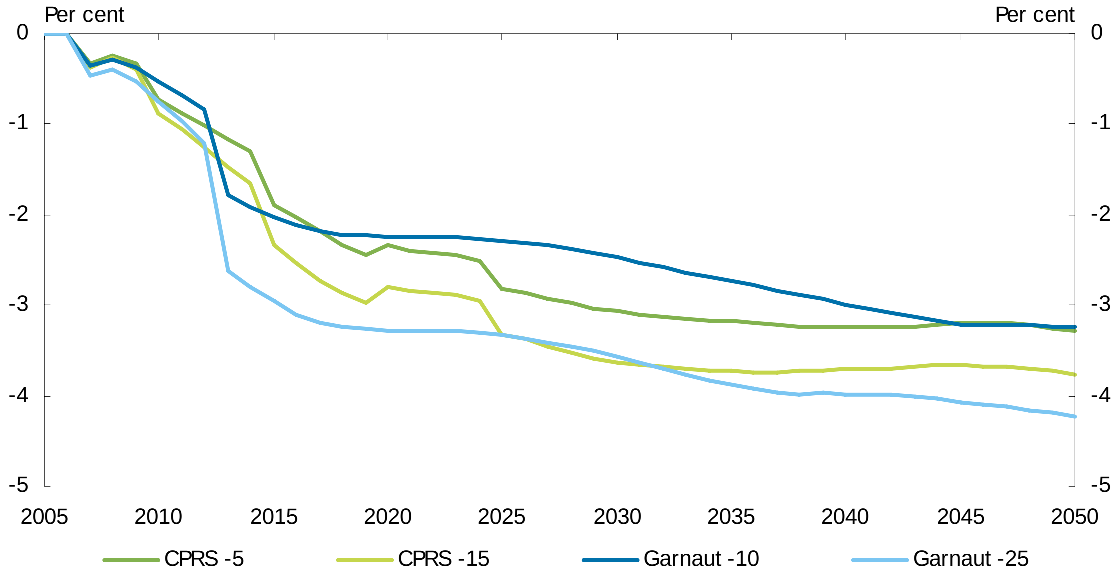
Chart 5.6: GTEM: Gross world product

Change from reference scenario



Source: Treasury estimates from GTEM.

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



Source: Treasury estimates from G-Cubed.

Table 5.6: Gross world product, change from reference scenario

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

Source: Treasury estimates from GTEM and G-Cubed.

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

Table 5.7: Gross world product, average annual growth rates

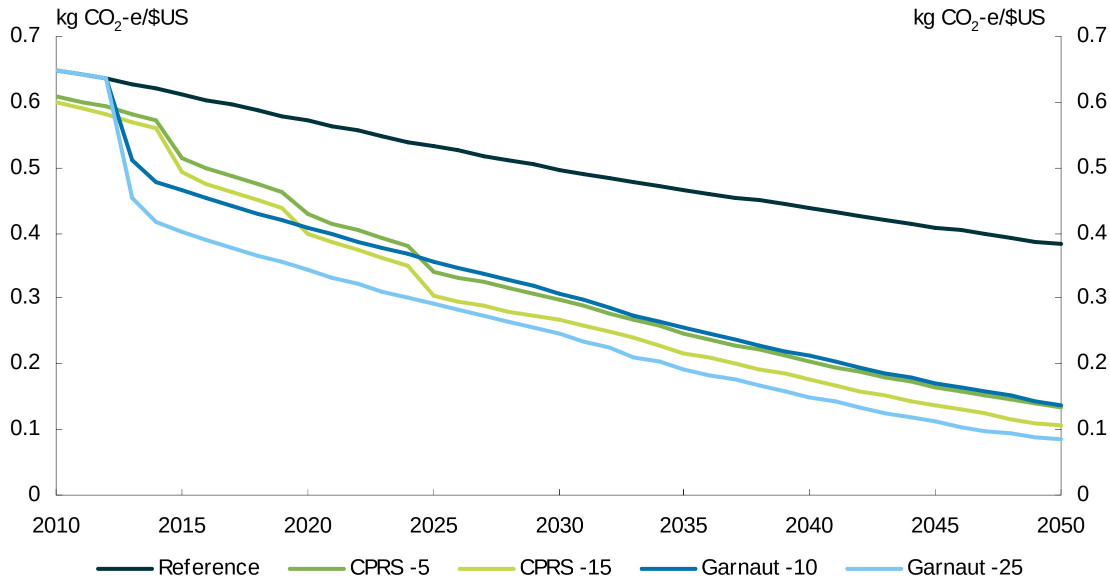
	2010 to 2050		2010 to 2020		2020 to 2030		2030 to 2040		2040 to 2050	
	GTEM	G-Cubed	GTEM	G-Cubed	GTEM	G-Cubed	GTEM	G-Cubed	GTEM	G-Cubed
	Per cent		Per cent		Per cent		Per cent		Per cent	
Reference scenario	3.5		3.8		4.0		3.2		2.8	
CPRS -5	3.4	3.4	3.8	3.6	3.9	3.9	3.2	3.2	2.7	2.8
CPRS -15	3.4	3.4	3.7	3.6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

Source: Treasury estimates from GTEM and G-Cubed.

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

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

Chart 5.8: Emission intensity of gross world product



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

Box 5.2: How do mitigation costs arise?

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

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

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

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

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

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

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

Box 5.3: Forward-looking behaviour and early action

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

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

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

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

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

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

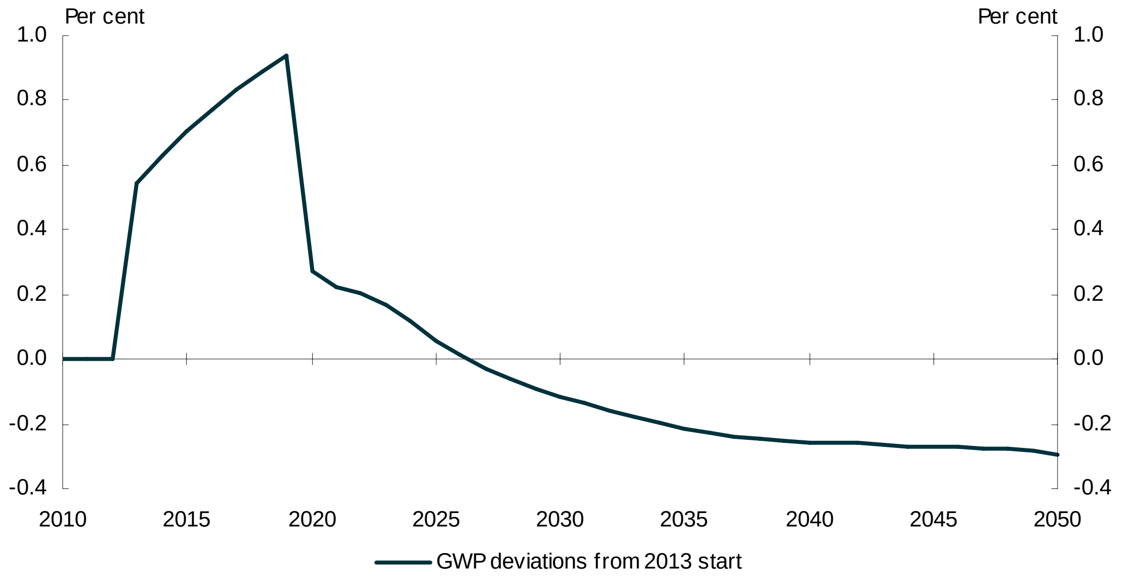
5.2.1 The cost of delaying global action

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

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

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

Chart 5.9: Cost of global mitigation policy delay
Change from Garnaut -10 scenario



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

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

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

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

Box 5.4: Impact of a multi-stage global framework

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

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

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

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

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

Table 5.8: Regional GDP costs in 2050

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

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

5.2.2 Cost of uncertainty

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

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

Box 5.5: Implications of revising stabilisation goals

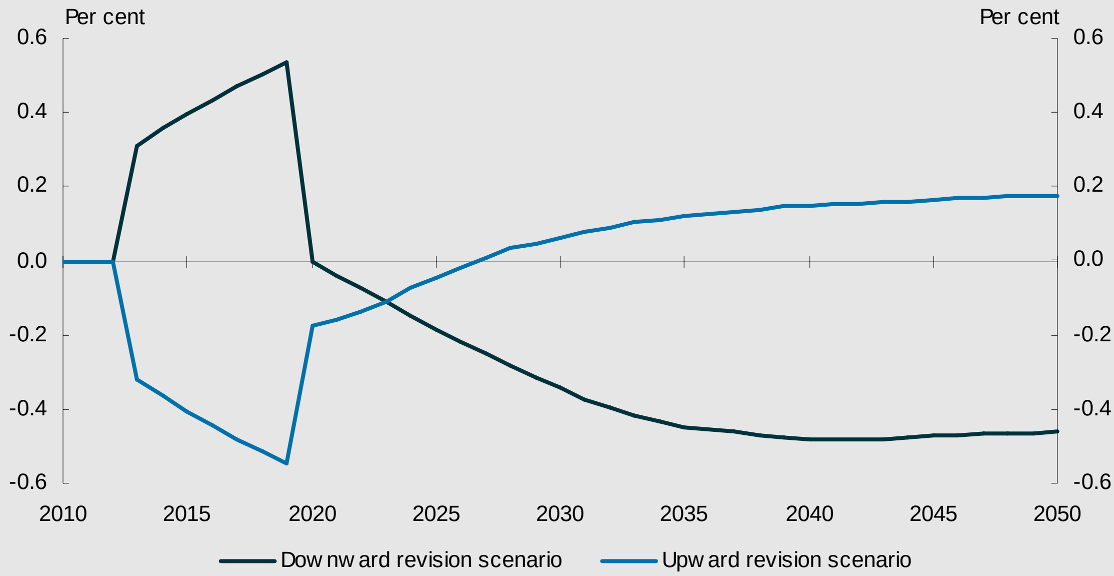
To explore the possibility of upwards or downwards revision of the future stabilisation goal, sensitivity simulations were conducted in GTEM. Revising stabilisation targets is not without costs, especially when the move is from a higher to a lower goal.

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

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

Chart 5.10: Gross world product

Compared with corresponding stabilisation scenario



Source: Treasury estimates from GTEM.

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

After 2020, cost differences become asymmetric.

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

Box 5.5 Implications of revising stabilisation goals (continued)

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

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

Table 5.9: Net present value of GWP

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

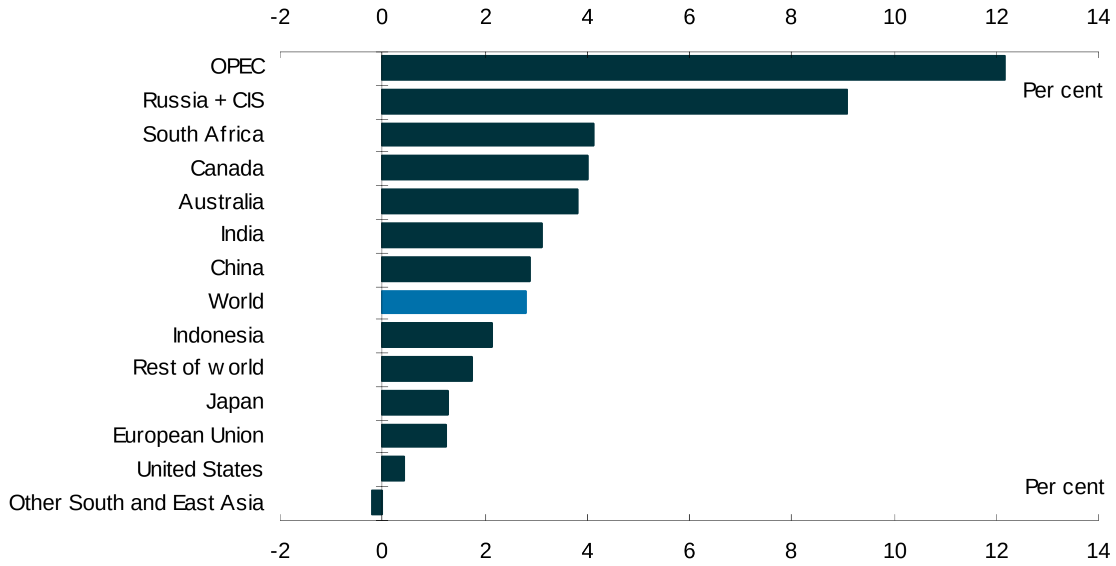
Note: Rounded to nearest 50 billion.
Source: Treasury estimates from GTEM.

5.3 Regional mitigation costs

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

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

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



Source: Treasury estimates from GTEM.

5.3.1 Gross national product

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

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

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

Box 5.6: Comparison with other mitigation cost studies

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

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

Table 5.10: Gross world product mitigation cost estimates

Change from reference scenario

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

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

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

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

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

Table 5.11: Emission Intensity of GDP

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

Source: Treasury estimates from GTEM.

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

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

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

Table 5.12: Regional GNP costs

Change from reference scenario, GTEM

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

Change from reference scenario, G-Cubed

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

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

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

Table 5.13: Delay in growth, GNP per capita

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

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

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

Table 5.14: Regional GDP costs

Change from reference scenario, GTEM

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

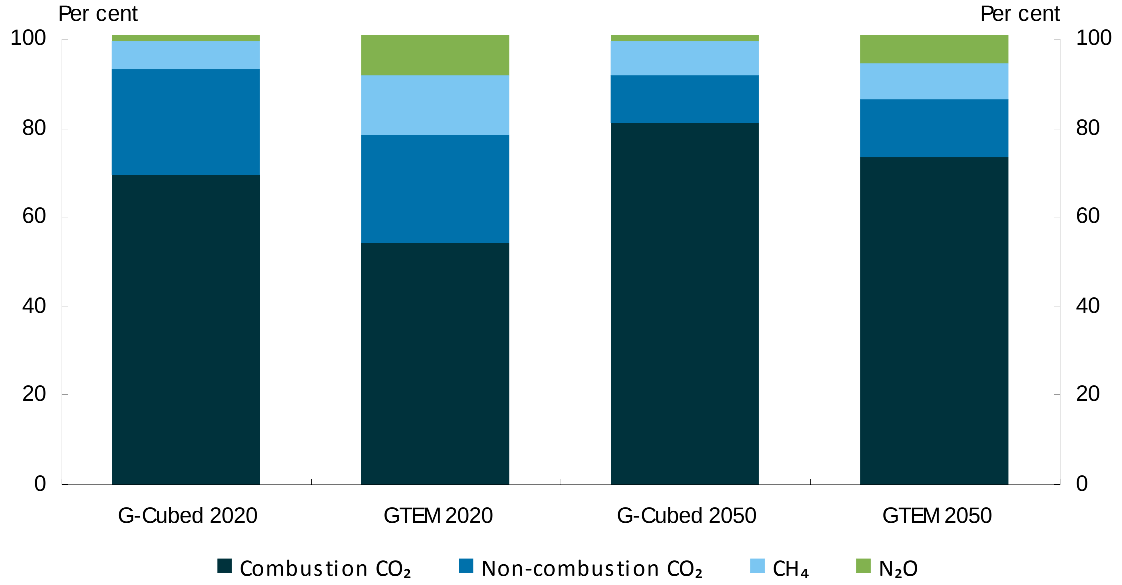
Change from reference scenario, G-Cubed

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

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

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

Chart 5.12: Mitigation by gas
Garnaut -25 scenario



Source: Treasury estimates from GTEM and G-Cubed.

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

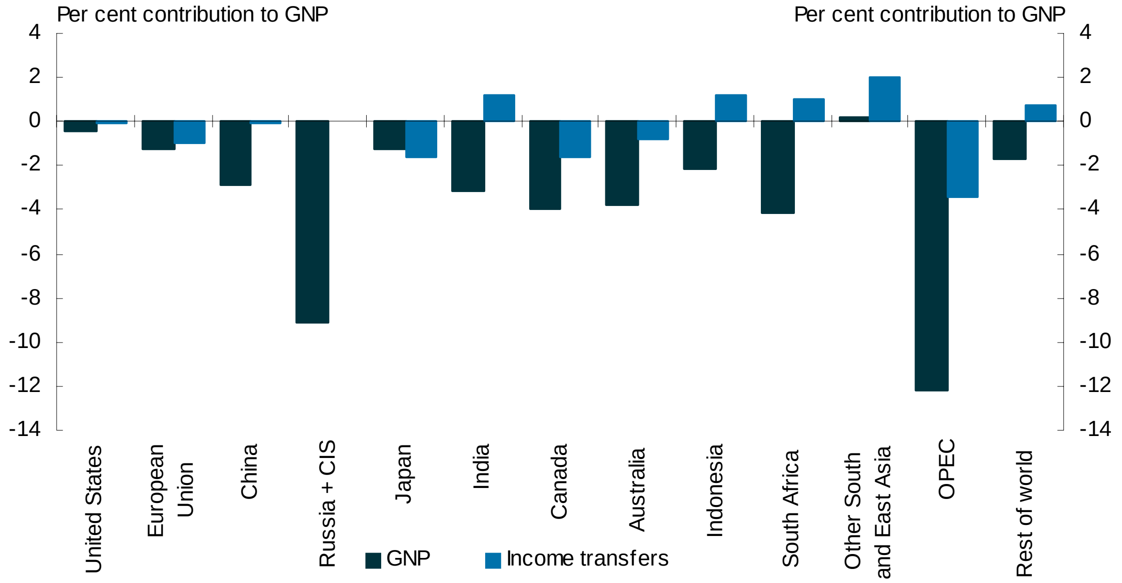
5.3.2 International income transfers

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

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

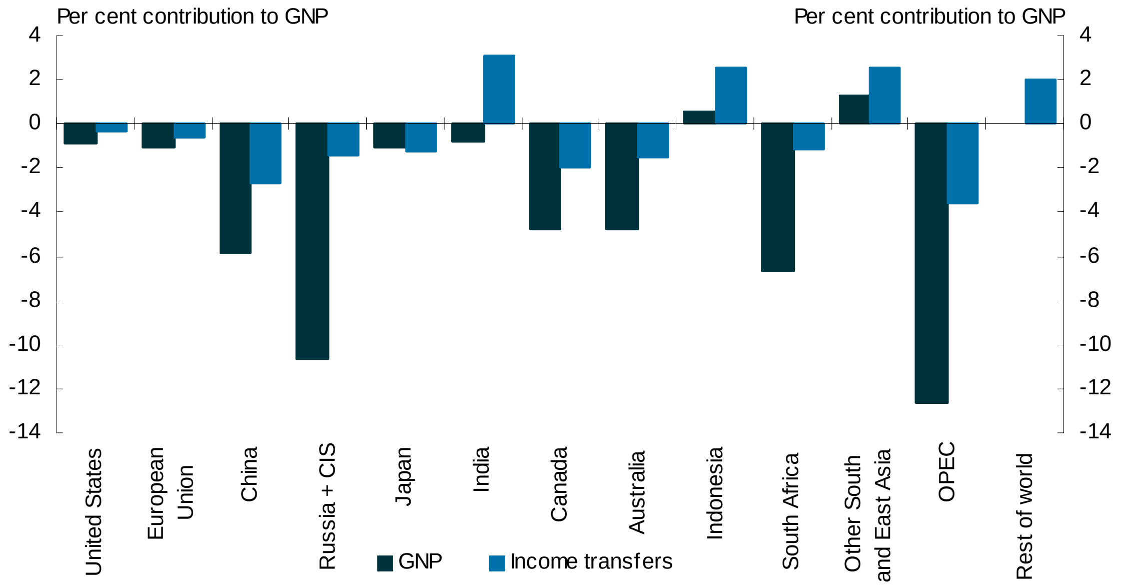
All developed economies buy permits in the Garnaut -10 and CPRS -5 scenarios, raising GNP mitigation costs (Chart 5.13 and 5.14). For some regions (such as China and India) income transfers differ significantly depending on the emission allocation approach.

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



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

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



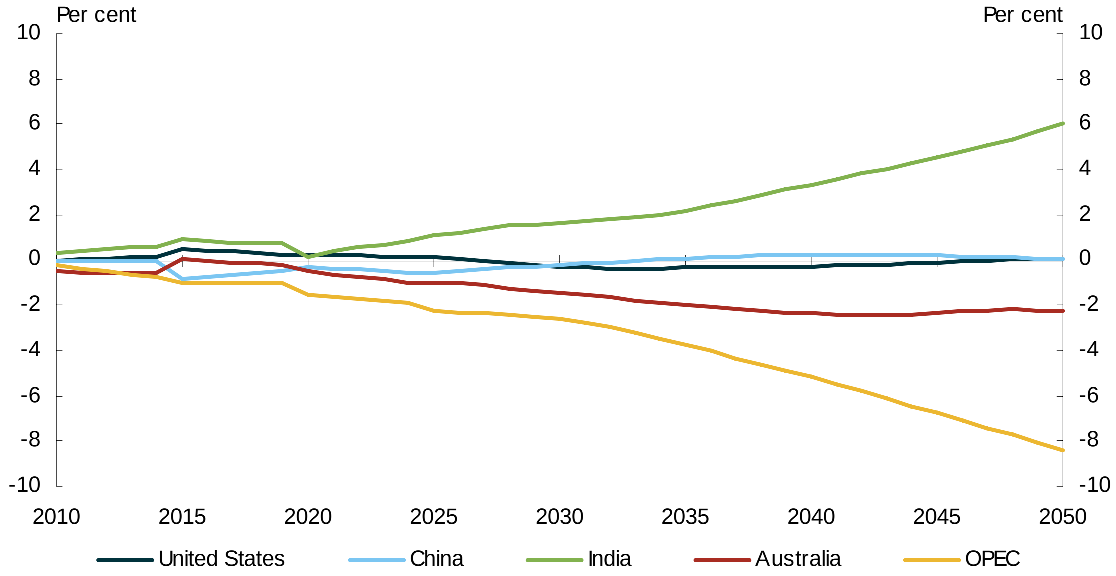
Note: The difference between GNP and income transfers is the GDP impact.
Source: Treasury estimates from GTEM.

Terms of trade

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

Chart 5.15: Terms of trade

Change from reference scenario, CPRS -5 scenario



Source: Treasury estimates from GTEM.

Table 5.15: Terms of trade impacts

Change from reference scenario

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

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

Permit sales

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

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

Table 5.16: GTEM international trade in permits

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

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

Table 5.17: GTEM regional emissions
Change from 2001

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

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

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

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

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

Table 5.18: G-Cubed international trade in permits

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

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

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

Table 5.19: G-Cubed CO_2-e permit prices

CPRS scenarios

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

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

Foreign interest payments

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

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

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

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

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

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

5.4 SECTORAL ANALYSIS

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

5.4.1 Sectoral output

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

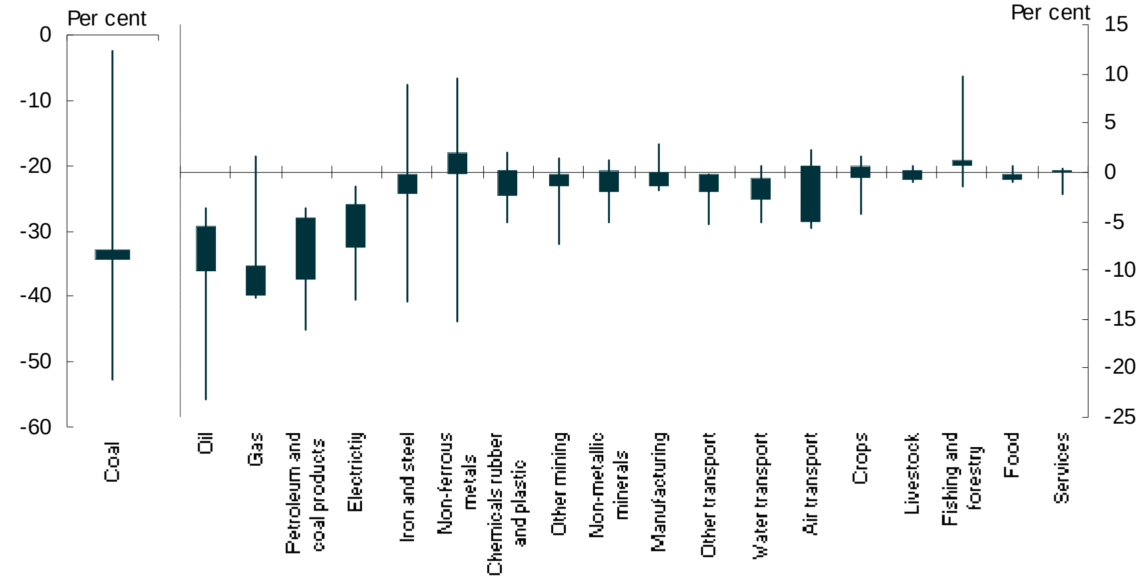
Services are generally less affected than other sectors of the economy, with output across most regions declining in 2050 by less than 1.5 per cent below reference scenario levels in the

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

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

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

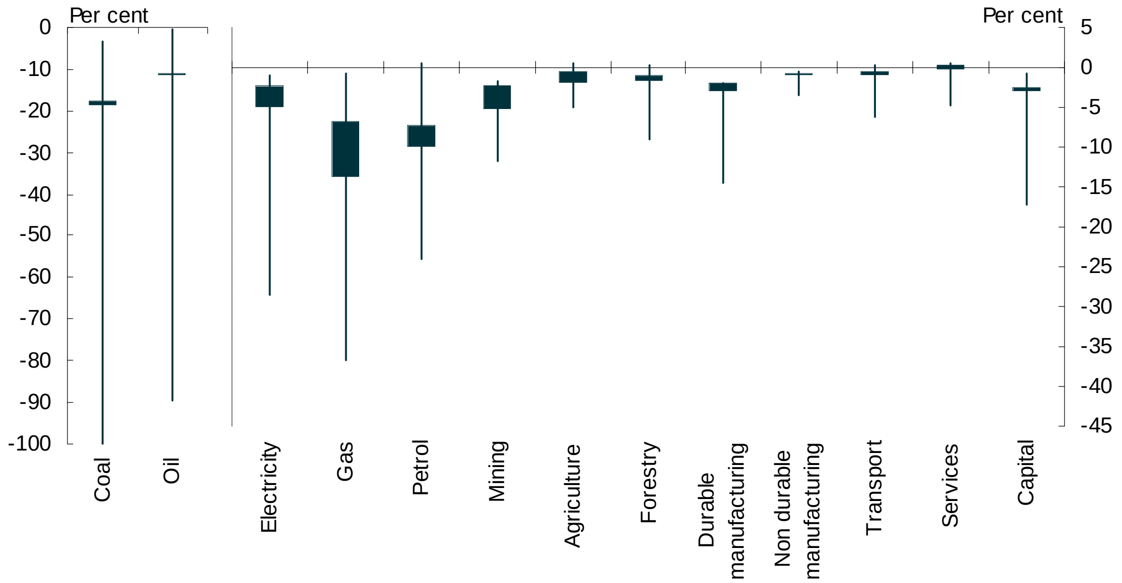
Chart 5.16: GTEM sectoral output relative to the reference scenario in 2020
Change from reference scenario, CPRS -5 scenario



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

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

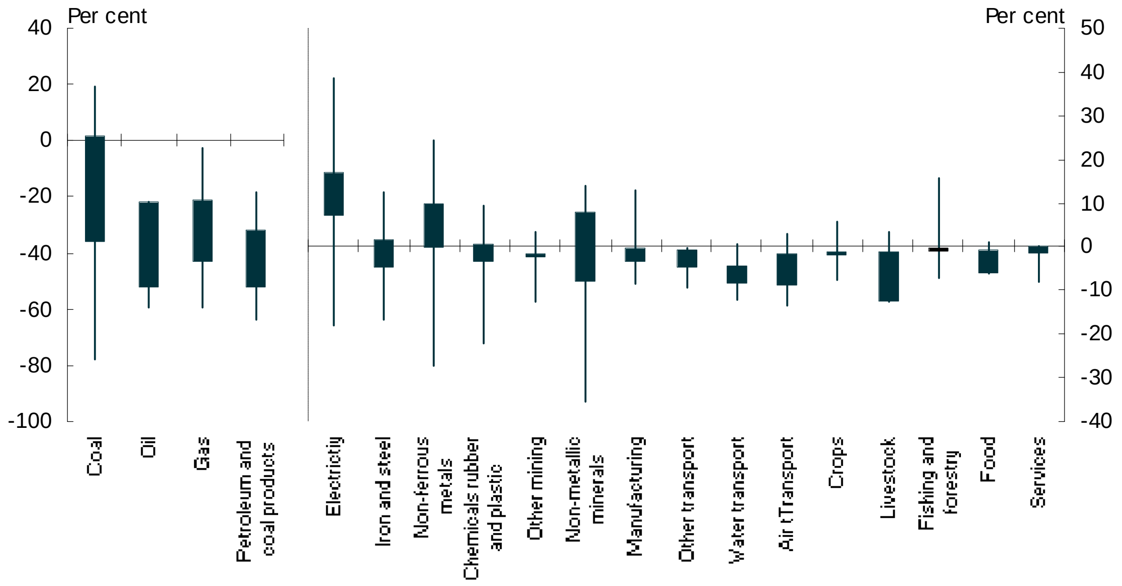
Change from reference scenario, CPRS -5 scenario



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

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

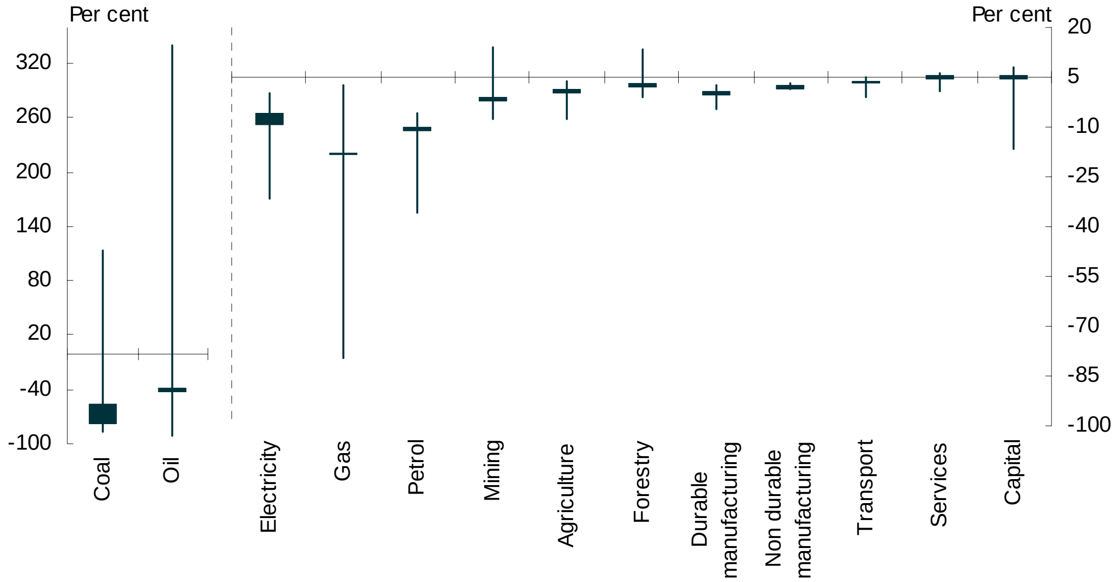
Change from reference scenario, CPRS -5 scenario



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

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

Change from reference scenario, CPRS -5 scenario



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

5.4.2 Sectoral emissions

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

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

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

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

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

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

Table 5.21: Emissions by sector

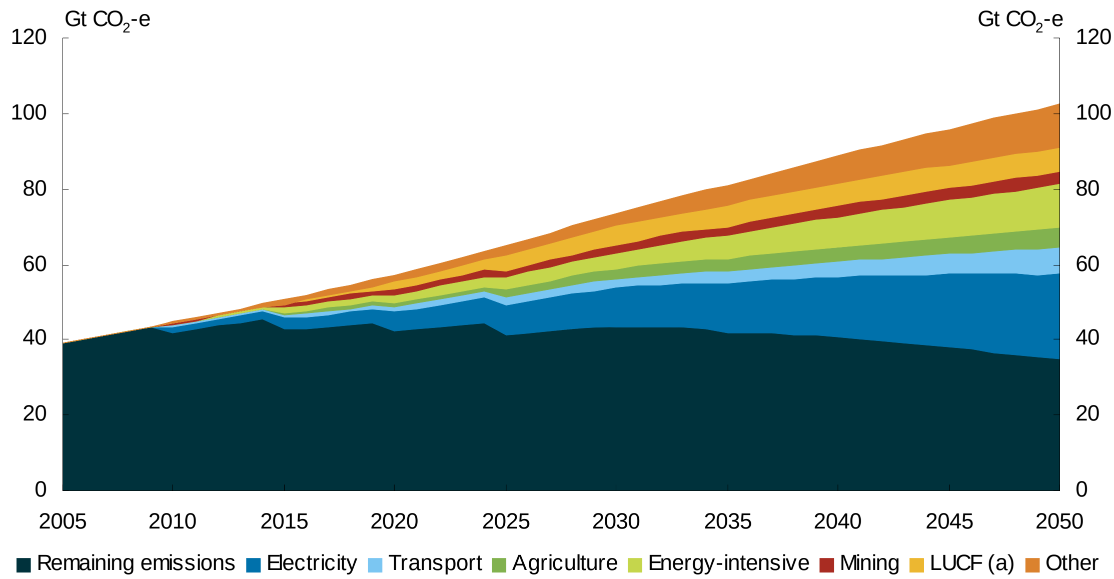
Change from reference scenario

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

Source: Treasury estimates from GTEM.

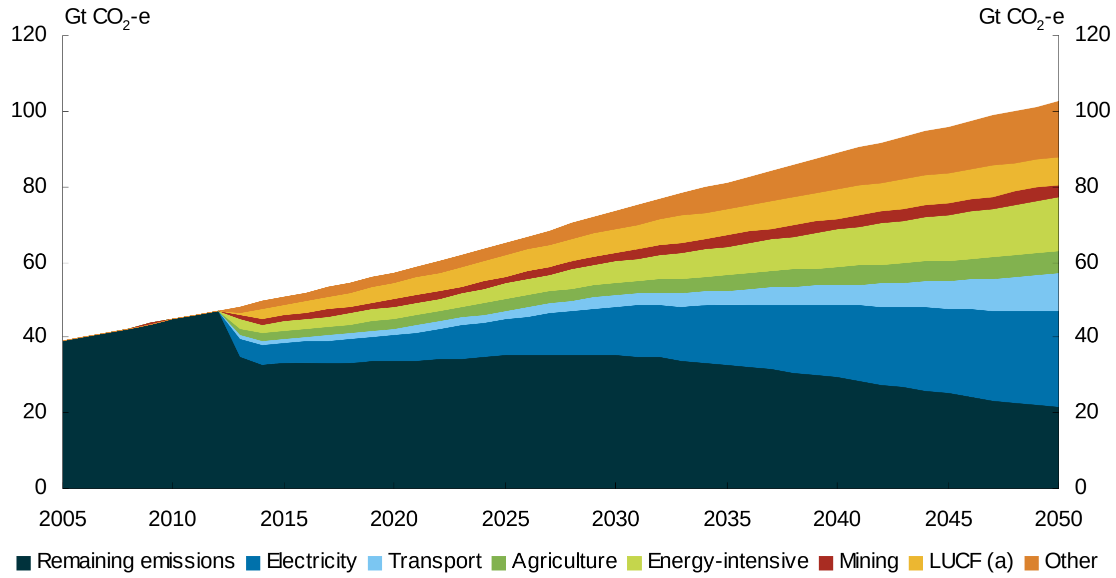
Chart 5.20: Global emissions mitigation, by sector

CPRS -5 scenario



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

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



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

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

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

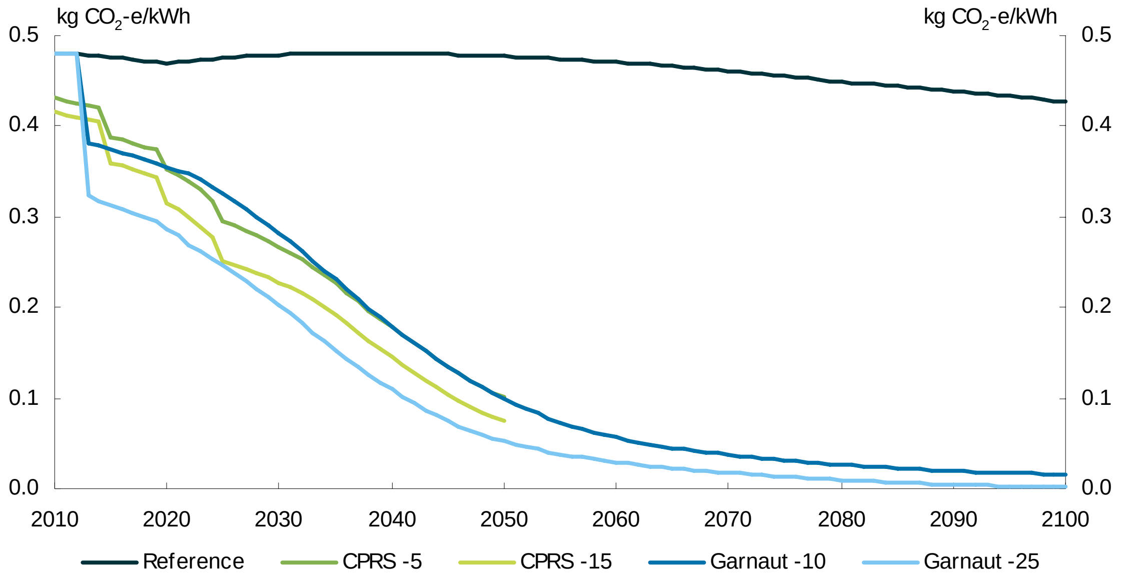
For developing economies, where non-energy emissions from agriculture and land-use change and forestry play a larger role, similar adjustment processes are expected. For agriculture, while proven low-emission options are fewer, areas of promise include changing fertiliser application methods, changes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

5.4.3 Electricity

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

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

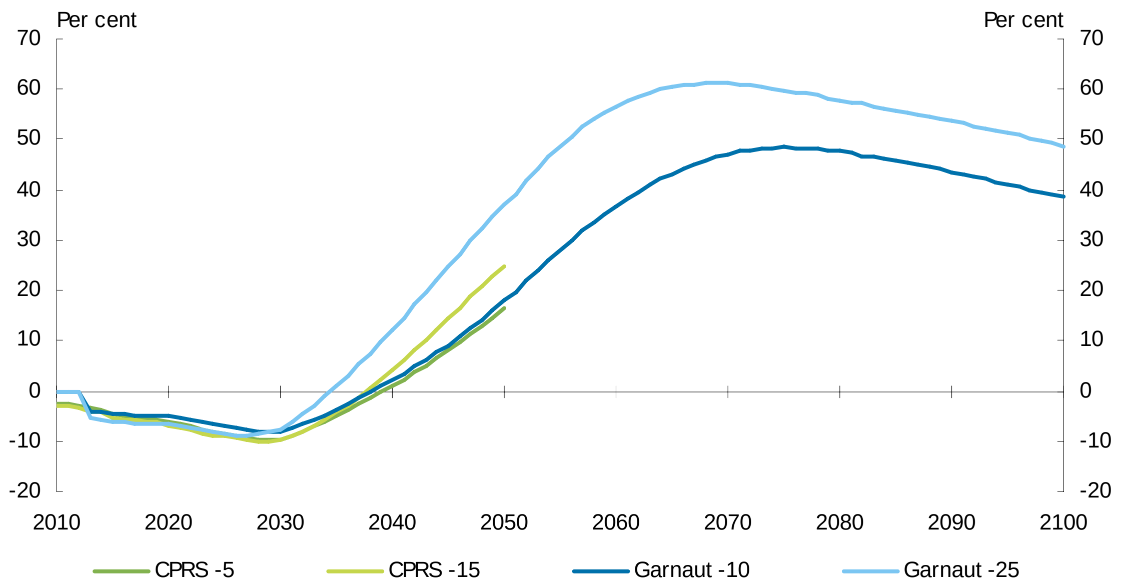
Chart 5.22: Emission intensity of world electricity generation



Source: Treasury estimates from GTEM.

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

Chart 5.23: Global electricity generation, Change from reference scenario



Source: Treasury estimates from GTEM.

Electricity technologies

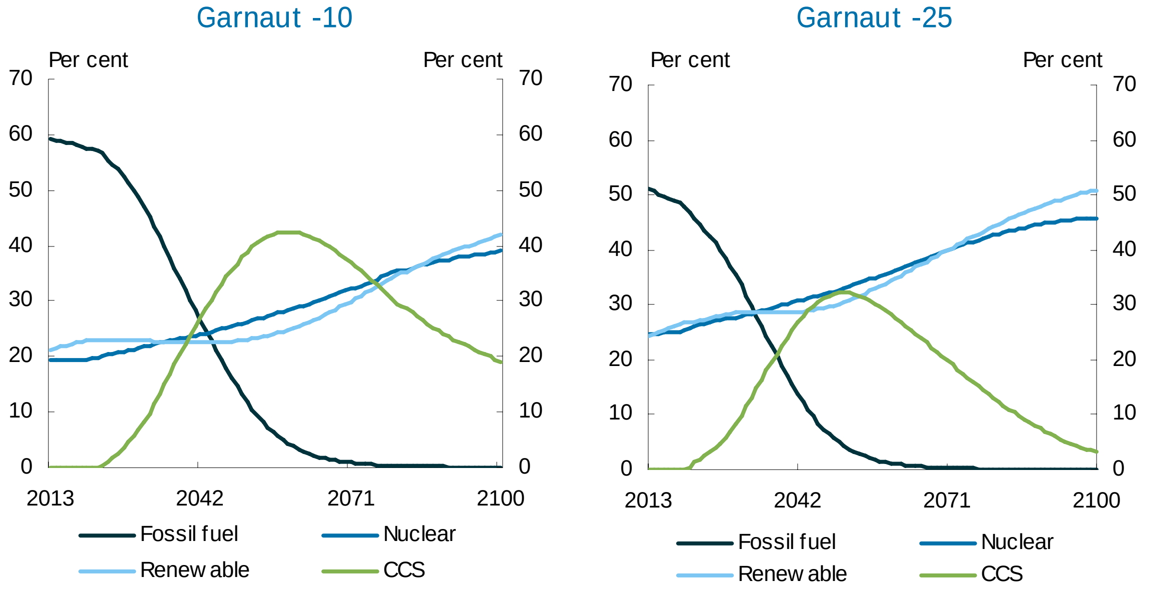
Fossil fuels, particularly coal, dominate global electricity generation in the reference scenario. In the policy scenarios, the emission price adds to the costs of fossil fuel-fired electricity. This makes zero emission technologies, such as renewables and nuclear, more cost competitive. Once a threshold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

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

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

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

Chart 5.24: Global electricity sector technology share



Source: Treasury estimates from GTEM.

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

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

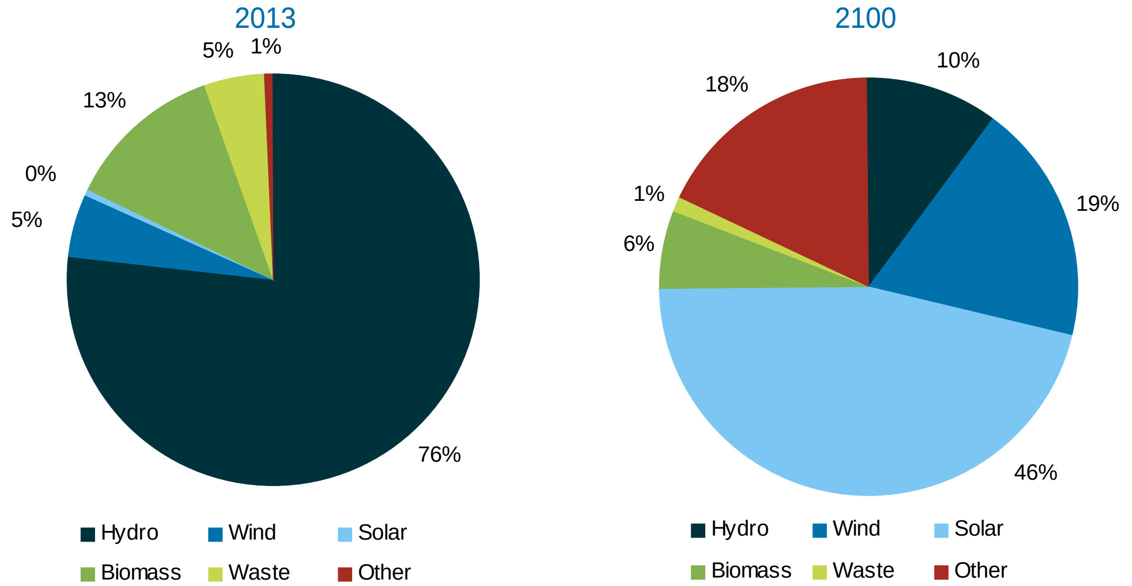
The uptake of carbon capture and storage across the range of scenarios result in the capture and storage of 900-1,600 Gt of CO_2-e globally over this century. This is well within existing estimates of global storage capacity (IPCC, 2005; and CCSP, 2007).

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

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

Chart 5.25: Composition of renewable electricity generation

Garnaut -10 scenario



Source: Treasury estimates from GTEM.

Box 5.7: The role of carbon capture and storage

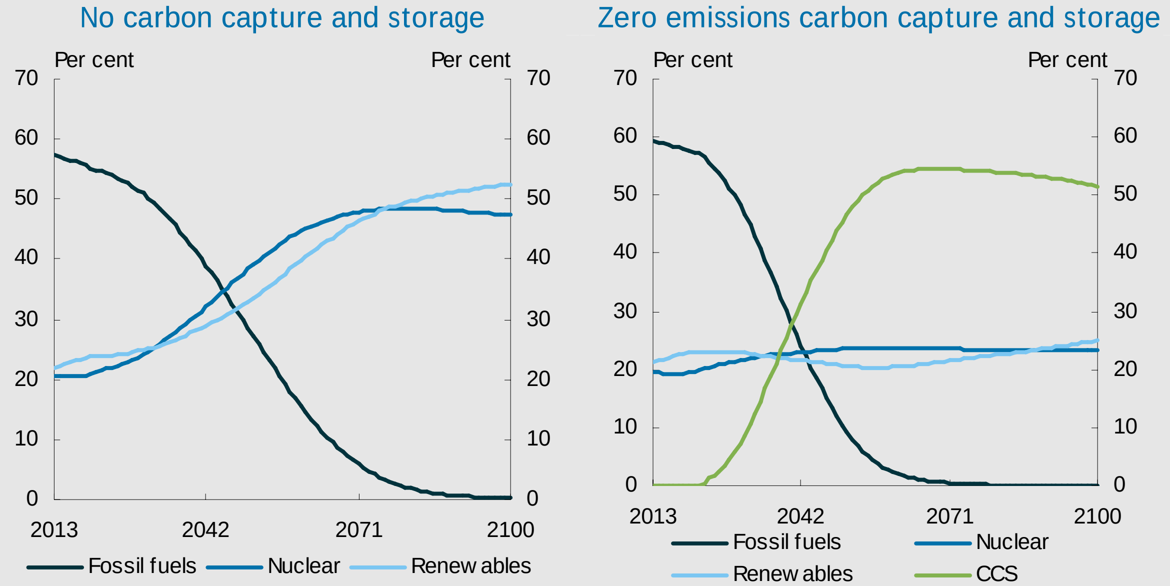
How global electricity generation responds to emission pricing depends on how technology options develop, such as carbon capture and storage (IEA, 2007; Stern, 2007). While carbon capture and storage eventually may be deployable, its future role is uncertain, especially as it is currently at the demonstration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

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

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

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

Chart 5.26: Global technology shares in electricity generation



Source: Treasury estimates from GTEM.

Source: Treasury estimates from GTEM.

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

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

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

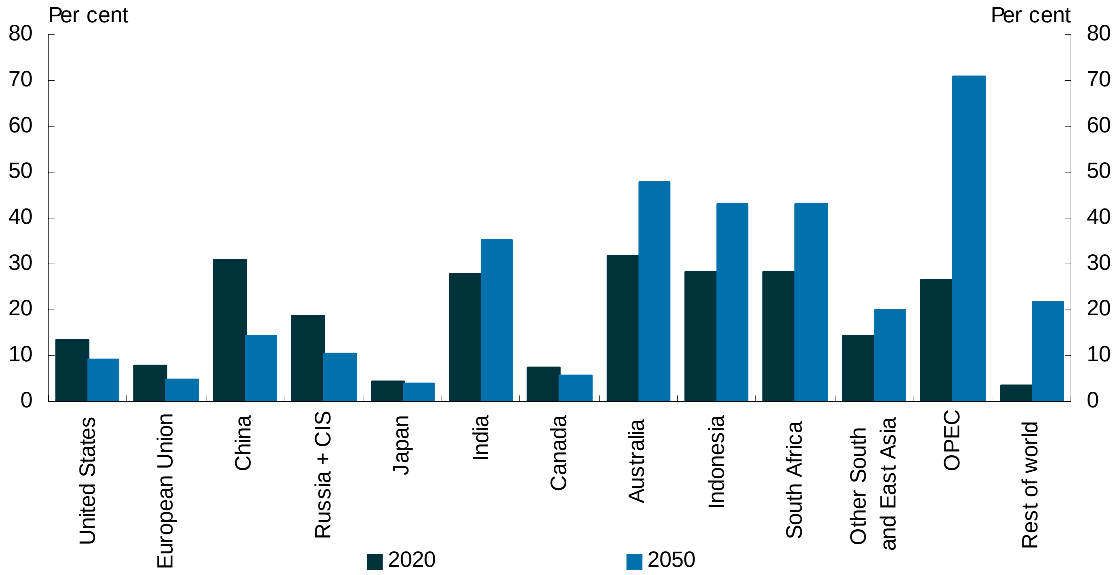
Electricity prices

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

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

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

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



Source: Treasury estimates from GTEM.

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

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

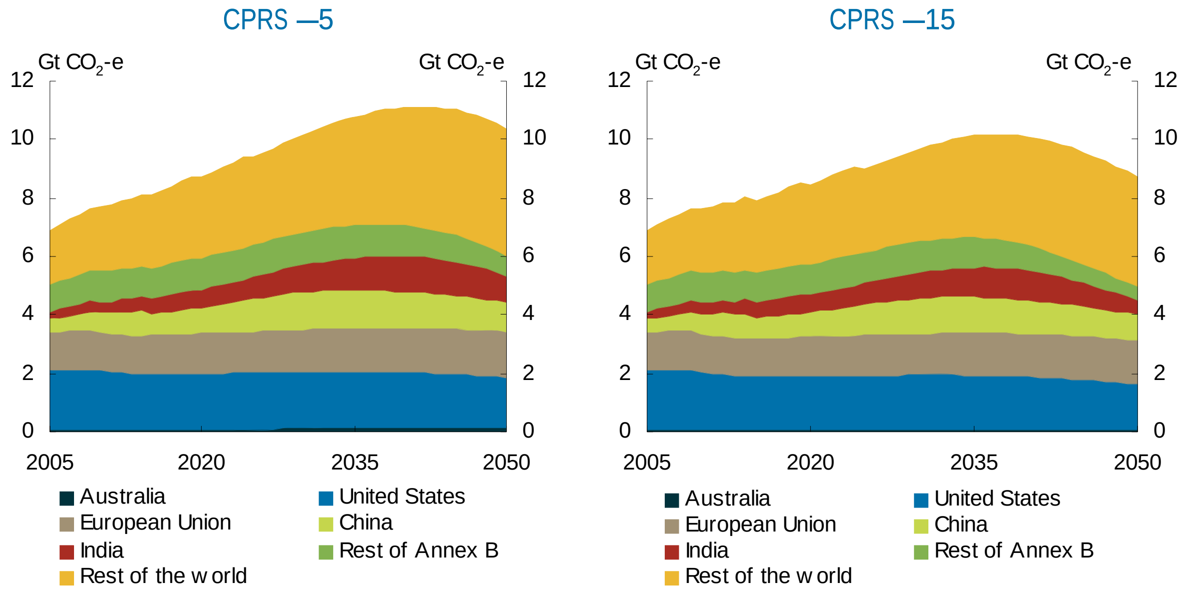
5.4.4 Transport

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

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

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

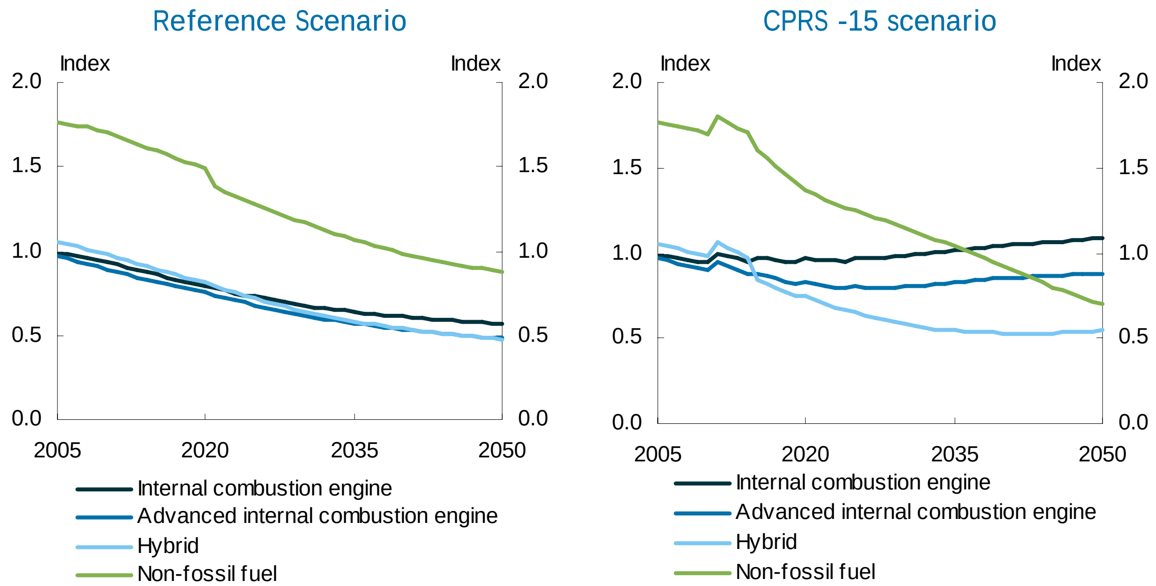
Chart 5.28: Global transport emissions



Source: Treasury estimates from GTEM.

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

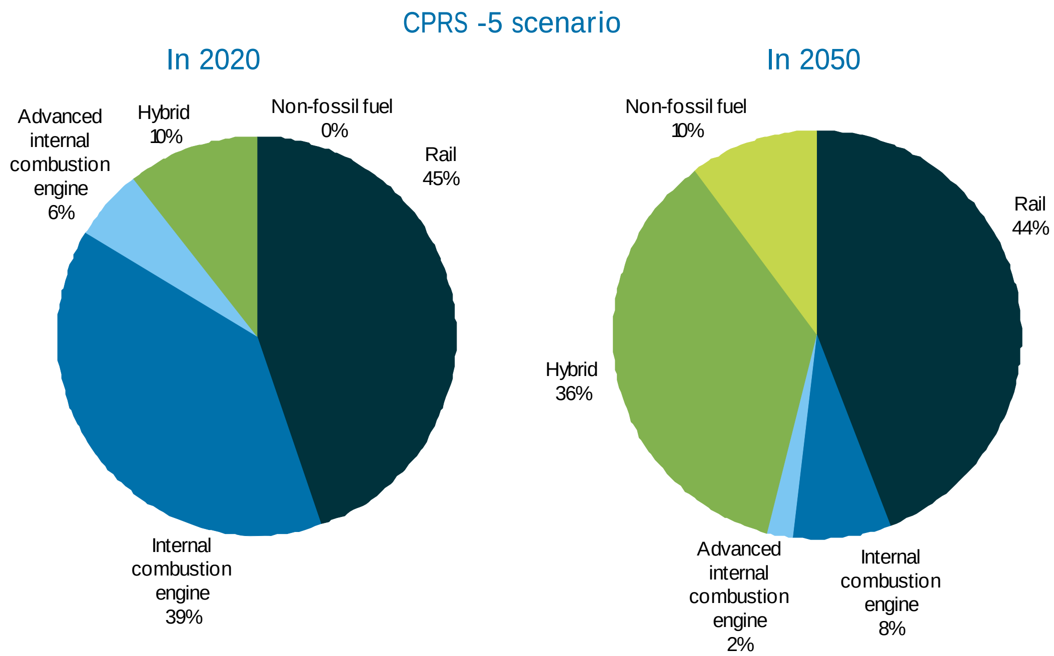
Chart 5.29: Cost of transport technology



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

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

Chart 5.30: Transport technology shares



Source: Treasury estimates from GTEM.

Box 5.8: Electric vehicles and fuel cell technology

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

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

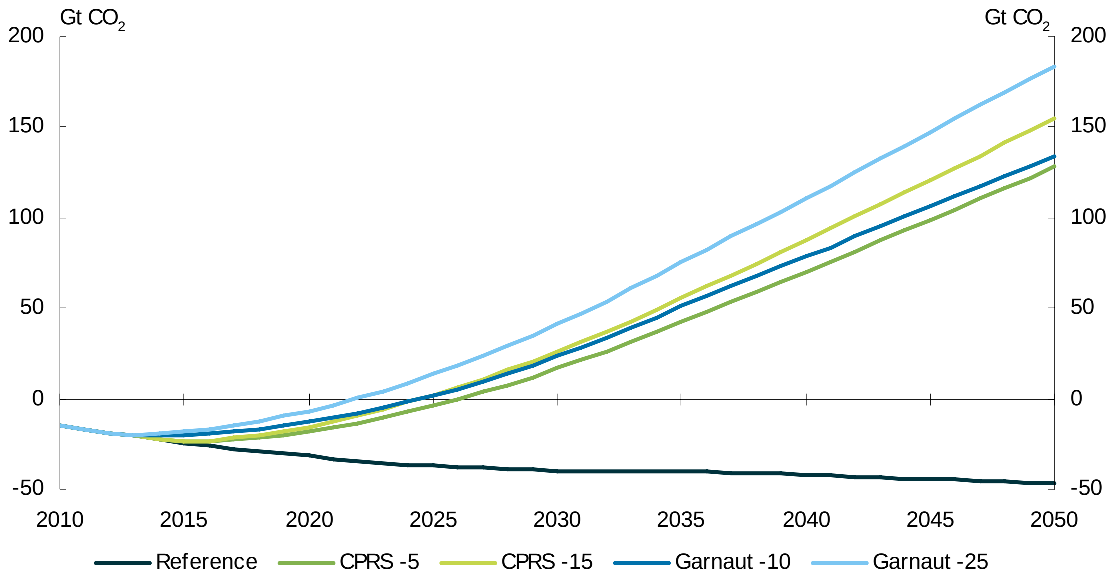
Fuel cells are electrochemical devices that convert hydrogen and oxygen into water to produce energy. An electric motor propels fuel-cell vehicles, and electricity is produced within the vehicle. These vehicles generally store hydrogen on board or in a blend with ethanol.

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

5.4.5 Land-use change and forestry

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

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



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

Box 5.9: Future transport fuels

Biofuels

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

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

Hydrogen

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

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

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

Other fuels

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

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

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

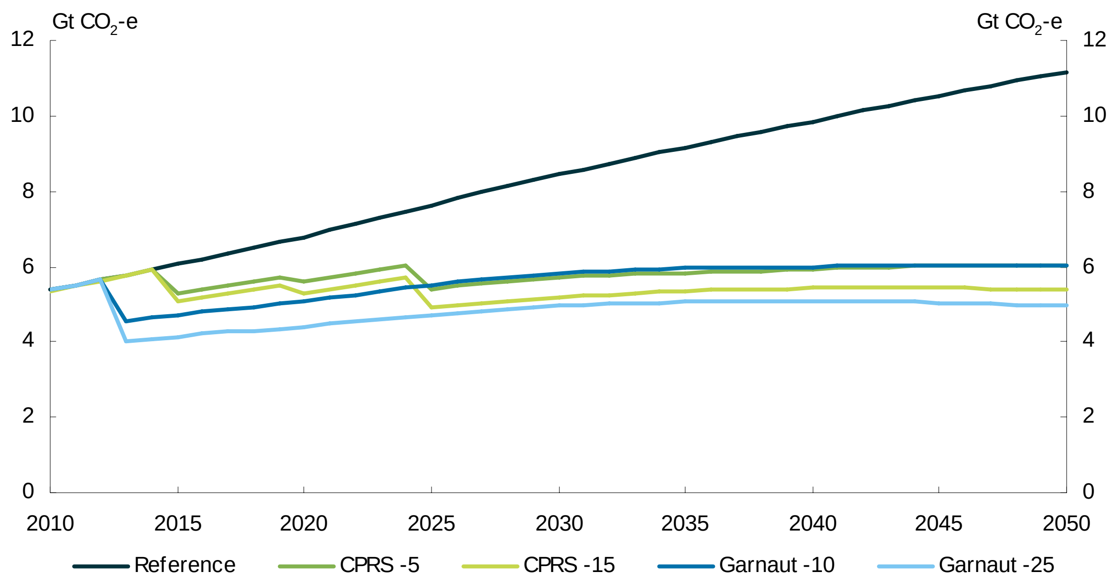
	Reference	CPRS -5	CPRS -15	Garnaut -10	Garnaut -25
	Gt CO_2	Gt CO_2	Gt CO_2	Gt CO_2	Gt CO_2
Africa	-57	-7.0	-5.5	-4.1	-1.3
Central America	-6.1	-1.5	-1.0	-1.4	-0.5
China	16	17	17	17	17
European Union	3.8	15	19	15	22
India	9.0	9.5	9.5	9.1	9.1
Oceania	3.3	7.2	9	7.4	10.6
Rest of Asia	26	58	71	58	82
Russia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

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

5.4.6 Agriculture

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

Chart 5.32: Global agriculture emissions



Source: Treasury estimates from GTEM.

5.4.7 Other

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

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

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

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

Source: Treasury estimates from GTEM.

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