ECONOMIC MODELLING TECHNICAL PAPER 7

THE NET COST OF CLIMATE CHANGE MITIGATION FOR AUSTRALIA

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Garnaut
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REVIEW

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This is the seventh in a series of Technical Papers of the Garnaut Climate Change Review's discussion of the methodology and results of Modelling of the Net Costs of Climate Change Mitigation. Other Papers in the series, available on the Review's website **www.garnautreview.org.au** are as follows:

Technical Paper Number 1: Overview and approach to the economic modelling

Technical Paper Number 2: Climate data, methodology and assumptions

Technical Paper Number 3: Assumptions and Data Sources

Technical Paper Number 4: Methodology for modelling climate change impacts

Technical Paper Number 5: Modelling the costs of unmitigated climate change

Technical Paper Number 6: Global Climate Change Mitigation: Implications for Australia

Technical Paper Number 7: The net costs of global mitigation for Australia

1 Introduction

Working with the Australian Treasury, the Review has modelled the gross costs to Australia of participating in a global effort to stabilise carbon dioxide equivalent (CO2-e) concentrations at 450 ppm (with overshooting) and 550 ppm. In addition, the Review has independently modelled in MMRF the net costs of participation to Australia, subtracting from the gross costs of mitigation, the benefits of avoided climate change.

The modelled net costs of mitigation are presented in this paper[1]. These net costs form only part of the Review's wider cost benefit evaluation of climate change mitigation. The wider cost benefit evaluation is conducted in a framework that considers the broad spectrum of climate change costs, including market and non-market impacts, and the insurance value associated with avoiding the possibility of extreme and catastrophic climate change outcomes and events. The conceptual underpinnings of the Review's wider cost benefit framework are outlined in chapter 1 of the Final Report, and the results are presented in Chapter 11. As noted in that discussion, economic modelling is an important tool within this framework but only one part of it.

For this reason the modelled net economic costs of mitigation discussed in this paper should be considered in a broader context. The net costs of climate change mitigation for Australia can be interpreted as the economic cost, or 'risk premium', that Australia would need to pay to avoid the unquantified costs of climate change. These include the risks of extreme and catastrophic outcomes and the non market effects of climate change this century, and all the costs of climate change next century. Chapter 11 concluded that the costs of a 550 ppm mitigation scenario are worth the benefits to Australia of avoiding unmitigated climate change, and that the additional costs of a 450 mitigation scenario are worth the additional benefits this scenario will bring relative to the 550 ppm mitigation scenario. This paper does not repeat these arguments, but rather is confined to reporting the modelled results in greater detail.

As per the terminology introduced in Chapter 1 of the Final Report, the modelled, market costs of climate change are the Type 1 costs of climate change. The non-modelled market costs are the Type 2 costs. The risks associated with more severe and extreme climate change are Type 3 costs, and the non-market costs are Type 4 costs. In these terms, this paper focuses mainly on Type 1 costs. As in Chapter 11, however, some of the key results also include an estimation of Type 2 costs: as per the arguments put forward in Chapter 11, Type 2 costs are estimated to be 30 per cent of Type 1 costs.

The modelling framework used to determine the net costs of climate change is the Monash Multi Regional Forecasting Model (MMRF). MMRF is a computable general equilibrium model of the Australian economy capable of capturing the economy wide effects of climate change and mitigation policy (see Technical Paper number 1). The global modelling framework used to provide the international trade effects of climate change for Australia is the Global Integrated Assessment Model (GIAM) discussed in Technical Paper number 2 and 4. The economic module of the GIAM is the Global Trade and Environment Model (GTEM).

[1] Chapter 11 of the Final Report discusses some of the results of the gross costs of mitigation. Further details of the results of the gross costs of mitigation will be released alongside the Commonwealth Government modelling report in late October.

2 Assumptions of climate change and mitigation

The Australian analysis of climate change impacts was considered under a range of unmitigated and mitigated climate change scenarios. The benefits of mitigation are the avoided climate change impacts that would have occurred in the absence of mitigation.

To represent some of these benefits, results are reported relative to a baseline of no mitigation and inclusive of the impacts of climate change that would occur under no mitigation (refer to Technical Paper Number 1 for a diagrammatic representation). This allows the evaluation of the avoided impacts of climate change (the benefits of climate change mitigation). The results for the 550 and 450 scenarios presented in this paper are reported inclusive of the net impacts of climate change mitigation.

The analysis of climate change and climate change mitigation policy requires the use of long term economic and emissions projections that are highly dependent on underlying assumptions. The assumptions used in the modelling draw on a wide range of expert views and research. However, the uncertainties inherent in economic modelling of climate change and climate change mitigation policy over long time periods means that a range of assumptions are necessarily speculative.

The important assumptions likely to have considerable influence on the modelling outcomes, in both a world with and without mitigation policy, include the size of the mitigation task and the types and costs of mitigation technologies. The size of the mitigation task is determined by the outlook for economic growth and emissions intensity of that growth. Emissions intensity is in turn driven by sectoral productivity growth, technological options, relative cost of energy inputs (coal, oil, gas) against other production inputs and structural trends in consumer preferences for goods.

The policy assumptions used in the modelling and the specification of the modelling scenarios are discussed below. Technical Paper Number 3 summarises the key assumptions under standard technology assumptions that have been used as part of the Review's joint modelling with the Australian Treasury as part of the gross costs of mitigation.

Climate Change Mitigation Assumptions

The assumptions underlying the global cooperative arrangement assumed in the modelling are discussed in detail in Technical Paper Number 6. The key features of this arrangement include:

- Cooperative global action from 2013 where all countries take on emissions targets covering all sectors of the economy, including agriculture and forestry.
- Emissions allocation rights determined by the Review's modified contraction and convergence and framework where all countries converge from current emissions to equal per-capita emissions rights over time.
- Unlimited trading of emissions rights between countries and across time.

The key features of Australia's mitigation policy within this global arrangement are outlined in Box 1 below.

Box A1: Domestic mitigation policy assumption

Scheme Commencement: 2013

Sectoral Coverage: all sectors included from 2013

Gas coverage: all Kyoto Protocol gases (CO2, CH4, N2O, SF6, HFCs and PFCs)

Carbon accounting standards: Kyoto Protocol

Emissions Allocations:

Emission rights determined by the international allocation rule discussed in chapter 9 of the Final Report All countries allocations converge from current emissions to equal per-capita emissions rights over time. Convergence occurs by 2050.

Australia's actual emissions will be determined within the model and by the global permit price. For Australia, the allocation rule implies a target for Australia of 90% below 2000 levels by 2050 for the 450 ppm stabilisation scenario and 80% for the 550 ppm stabilisation scenario.

Treatment of trade-exposed emissions-intensive industries (TEEIIs)

No shielding or compensation is provided to TEEIIs - comparable action is assumed to be occurring in competing nations as a result of the global cooperative arrangement.

This assumption is assumed to hold irrespective of the nature of each country's emissions allocation. For example, even if the allocation rule allows developing countries a rising cap on national emissions, the establishment of a global emissions trading scheme immediately introduces a uniform carbon price across all countries, and hence an opportunity cost of emissions growth, into the economy.

Permit allocation / use of auction revenue

100% auctioning of permits. Revenue recycled as a lump sum transfer to households.

Complementary policy measures

The reference case includes existing state and national policies of climate change mitigation. These measures are phased out upon the commencement of the ETS in 2013[2].

Price curve

As explained in Technical Paper Number 6, the global emissions price path is generated within GTEM by applying a Hotelling-style price function (the start price is fixed and then increases over time at the prescribed interest rate of 4%) to the lowest starting price which delivers the atmospheric concentration objectives of the 450 ppm and 550 ppm scenarios. This approach provides a proxy for banking and borrowing, and imitates an efficient intertemporal distribution of abatement effort[3]. The resulting price path is imported into MMRF. The domestic carbon price diverges slightly from a Hotelling curve due to the movements in the exchange rates.

Permit Trading

Unlimited import and export of international emissions permits.

Other assumptions

No nuclear power in Australia. In the global modelling, nuclear power is only a technological option in those countries that currently have nuclear power.

Technology assumptions - capturing uncertainty in technological progress

To capture the uncertainties about long term technological change across the economy, the Review has modelled in MMRF two scenarios, a 'standard technology' scenario and a 'backstop technology' scenario. The standard technology scenario was modelled jointly with the Australian Treasury. The Review independently modelled the backstop technology scenario using the joint modelling with the Australian Treasury as its basis.

The 'standard technology' mitigation scenario represents an estimate of the cost, availability and

[2] The existing policies are:

- NSW and ACT Greenhouse Gas Abatement Scheme (GGAS) (target is held fixed at 7.27t CO2e per capita until 2020 then policy is terminated).
- Qld 15% gas scheme (target increases to 15% by 2020, then policy is terminated)
- Victorian renewable energy target – 10% target by 2016 (3274GWh).
- National mandatory renewable energy target – currently legislated level of 9500GWh per annum by 2010 (target is held fixed at this level until 2020 then the policy ceases).

Under the policy cases, the NSW and ACT GGAS, the Qld Gas scheme, and the VRET are removed upon the commencement of the ETS in 2013.

[3] See Box 1 of Technical Paper Number 6.

performance of technologies based on historical experiences, current knowledge and expected future trends. The assumptions incorporate improvements in existing technologies and the emergence and wide scale deployment of currently unproven technologies such as carbon capture and storage (CCS), hot rocks geothermal and hydrogen cars. The assumptions also incorporate learning effects, which result in substantial reductions in the cost of new technologies over time.

Strong, globally coordinated mitigation action creates a large and sustained shift in relative prices (and therefore relative competitiveness) of high emissions and low/zero emissions technologies. This shift, together with improved understanding of the likely impacts and risks of climate change over time, may result in faster technology improvements and a stronger change in consumer preferences than might be expected based on past experience and current knowledge. It is also likely to result in the emergence of new technologies, such as the emergence of a 'backstop' technology, which would offset or reduce emissions across the economy. As an alternative to the standard technology case the Review therefore modelled a 'backstop technology' scenario in MMRF which assumes the emergence of such a technology later in the century in response to high carbon prices (at around A$250 per tonne of CO2-e[4]). This scenario can be thought of as a proxy for the wide range of possible improvements in technology, processes, and consumer preferences. Examples of technology developments that would make a material difference to the cost and timescale of deep, long-term cuts in emissions include zero emissions CCS, large scale geothermal, nuclear fusion, algal production from fuel, wastes, algal absorption from the atmosphere, and more generally, biosequestration with permanent storage.

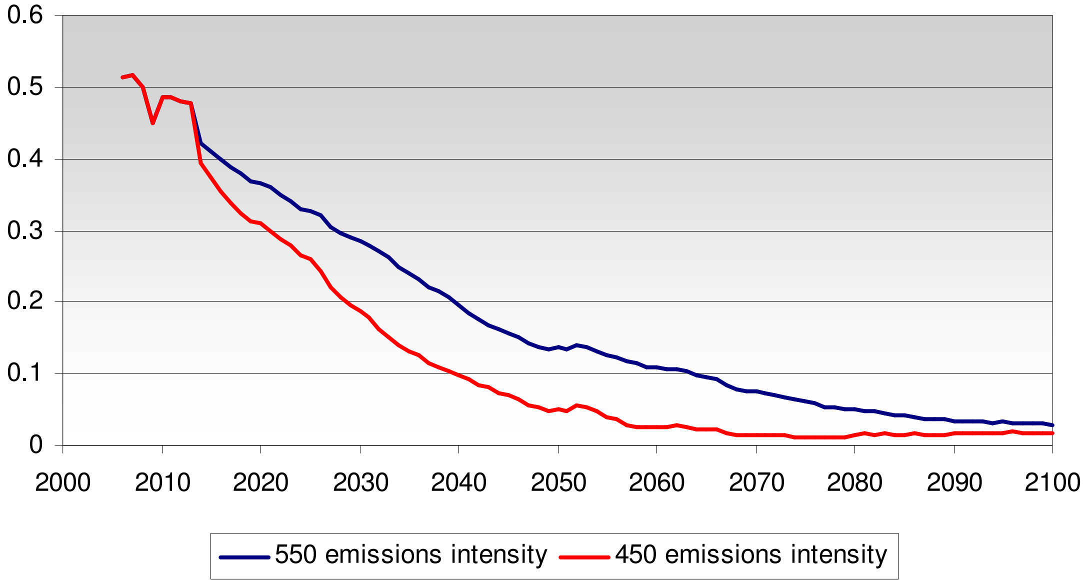
Such a backstop technology has been introduced into the modelling in a stylised manner. No single technology has been modelled. Rather, the backstop technology is assumed to be able to absorb emissions and therefore to be available to all industries. The cost of using the backstop technology is equivalent to the quantity of emissions abated multiplied by the carbon price (around $250). The costs are shared evenly across the economy, as a loss in total primary factor productivity, and emissions are reduced from all sources, since we do not know how the technology would operate - nor who would pay for it. The simplicity of this assumption means that the regional and sectoral results under the backstop technology scenario are highly uncertain post implementation of the backstop technology. In reality, a backstop technology scenario would have a different impact on activity and growth in sectors depending on the nature of the technology and the sector in which it arose. It is therefore not possible to project sectoral changes with a high degree of certainty in the second half of the century.

As argued in the Final Report, it is unrealistic to expect that carbon prices will continue to rise to the many hundreds of dollars (as in Figures 3 and 8) without the development of new technology to offset emissions. Accordingly, very long run cost modelling is best undertaken with the assumption that at some price a backstop technology develops, even if there is uncertainty about the price at which that technology will develop, and the precise form it will take. Thus the backstop technology scenario is the preferred scenario in MMRF, and the one emphasised in the Final Report. Figure 1 below illustrates the implausibility of the standard technology scenario towards the end of the century in MMRF. In the 450 ppm scenario, the emissions intensity of the Australian economy (the ratio of emissions to GDP) stops declining in around 2070 and starts to increase slightly thereafter. This appears most unlikely in a context in which the carbon price is well above $A 1,000 per tonne of CO2-e.

Although the backstop scenario is the preferred one, for reasons of completeness, this paper presents MMRF results both with and without a backstop.

[4] The backstop technology scenario is assumed to be available globally at a price of around $US 200 per tonne of CO2-e. Under the 550 scenario, this price is reached in around in 2073 for the 550 scenario and 2055 for the 450 scenario.

Figure 1: Emissions intensity of Australian GDP (ratio of emissions to GDP) under the 450 and 550 standard technology scenarios.

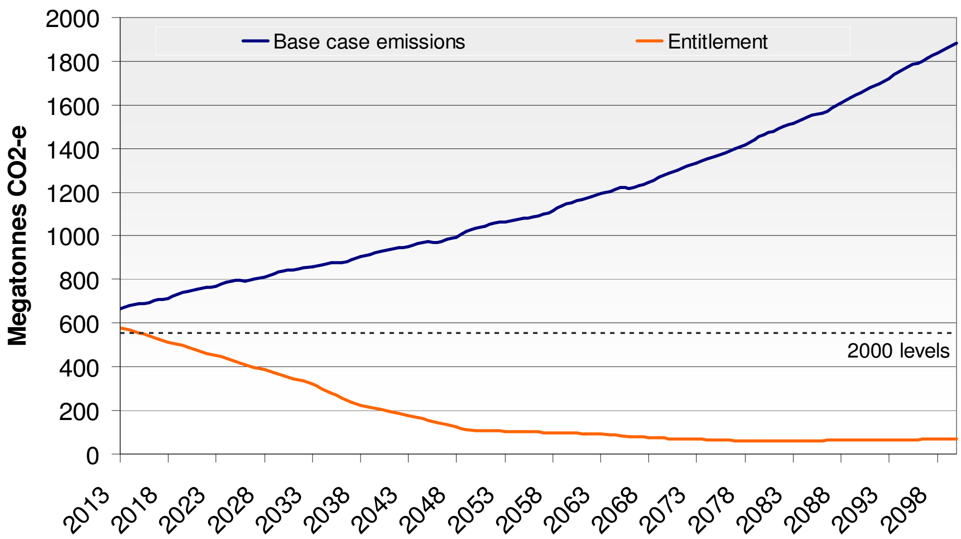


Source: MMRF

3 The macroeconomic consequences of climate change mitigation - 550 ppm scenario

Under the global emissions allocation rule discussed in Technical Paper Number 6, Australia's implied emissions reduction target relative to 2000 levels for the 550 ppm scenario is -10% by 2020 and -80% by 2050 (See Final Report Chapter 12).

Figure 2: Australia's emissions and emissions entitlements under the 550 mitigation scenario.

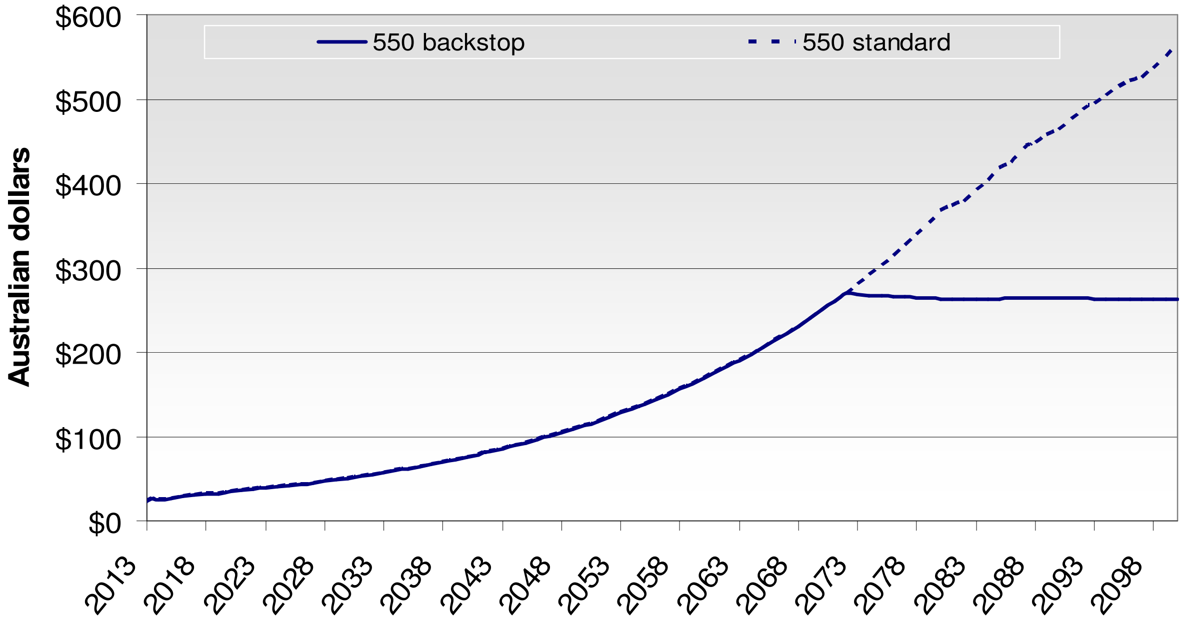


Source: MMRF

Australian permit price and permit trades

The Australian permit price under the 550 ppm standard technology and backstop technology scenarios are shown in Figure 3 below. Under both scenarios, the Australian permit price starts at $A24 (in 2005/06 dollars) in 2013 rising to A$34 by 2020 and A$113 by 2050[5] Once stabilisation of CO2-e concentrations is reached at around 2080 the permit price rises more slowly reaching A$567 by 2100. Under the backstop technology scenario, the marginal cost of abatement using the backstop technology is assumed to be around AU$250. The backstop is not utilised until the permit price reaches this level in 2073. The modelling assumes the backstop has an unlimited ability to constrain emissions at a cost of around AU$250. As a result, the permit price remains unchanged from around 2073.

Figure 3: Australian carbon price under the 550 mitigation scenario with and without backstop technology



Source: MMRF (2005/06 dollars)

Under the global cooperative arrangement assumed in the modelling, the permit price in each region is equalised as a result of unlimited trading of permits between countries. Countries which are able to reduce emissions below agreed trajectories are able to sell surplus permits to countries which are above their trajectories. This tends to equalise permit prices across countries, removing distortions associated with trade exposed industries. Countries in which mitigation costs are high buy permits from countries in which mitigation costs are low. This increases economic welfare in the buying and selling countries alike.

In the backstop technology scenarios it is assumed that the backstop technology is available to all countries at the same cost[6.] This effectively removes any international trading in permits, since abatement can be undertaken at a cost equivalent to purchasing permits. For this reason the modelling assumes that trading in permits slows, such that trading ceases a decade after the introduction of the

[5] The foreign carbon price is imposed on the Australian modelling based on the global modelling. The foreign price is a world trade weighted index. The Australian price diverges from the foreign price because of exchange rate movements.

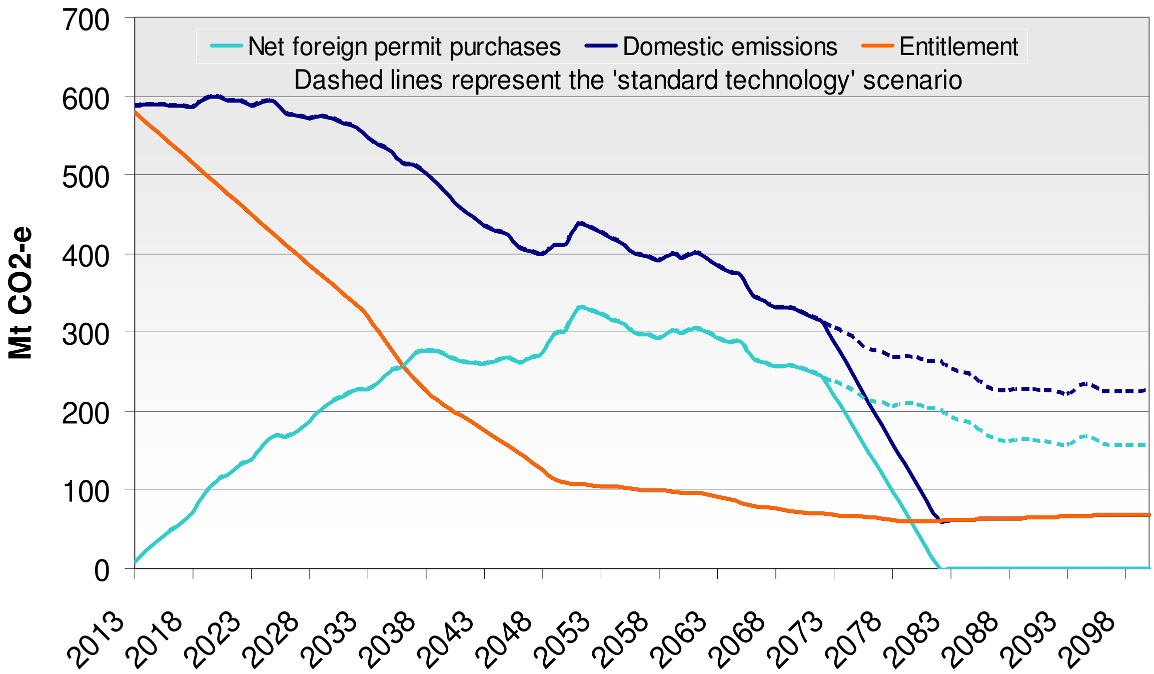
[6] It is unlikely that this would occur simultaneously around the globe since it is likely that technologies for undertaking efficient abatement would vary from country to country. However, the Review has not attempted (nor is it possible) to identify the future technological developments that may allow low-cost abatement, nor how fast any technology would diffuse across the world.

backstop technology.

Figure 4 below demonstrates the difference between Australia's allocated emissions entitlements and domestic emissions after trading, and the effect of the backstop technology on Australia's trade in permits. Over the modelled period, Australia is a net purchaser of international permits. Purchases of emissions are the difference between emissions entitlements and domestic emissions (foreign permit purchases) shown in Figure 4.

When emissions trading is initially introduced in Australia in 2013, Australia's allocation implies an immediate step down in emissions, either through domestic abatement or the purchase of international permits. Australia's allocation is progressively tightened in the first few decades of global mitigation as allocations rights converge towards per capita emissions by 2050.

Figure 4: Australia's emissions, entitlements and trading in the 550 scenario



Source: MMRF

In the scenario with a backstop technology the allocation is the same but domestic emissions and trading are both influenced by the more optimistic technology assumptions. From 2073 firms begin to buy less international permits, and instead use the new backstop technology to meet Australia's international mitigation obligations. By 2083, firms cease to buy any international permits and use the backstop technology instead[7]. After this point, Australia's emissions are equal to allocated emissions. Emissions do not return to zero as the backstop technology still comes at a cost of US$200 per tonne of CO2-e. As a result, the backstop will only be used to the extent required for Australia to meet its international mitigation target.

[7] Trading in international permits is reduced to zero over a ten year period to reflect a phasing in of the backstop technology.

Macroeconomic implications of climate change mitigation - the quantified market impacts of climate change – Type 1 costs and benefits

The long term nature of climate change and climate change stabilisation analysis requires modelling over very long timeframes. As a result, the Review has considered and reported the net costs of climate change mitigation over the current century. These results should be interpreted with caution, particularly beyond 2050. There is considerable uncertainty in many aspects of the modelling beyond the first few decades of the current century. Results should be considered as illustrative of the broad magnitude of net costs that might be experienced if the world were to collectively act to mitigate climate change.

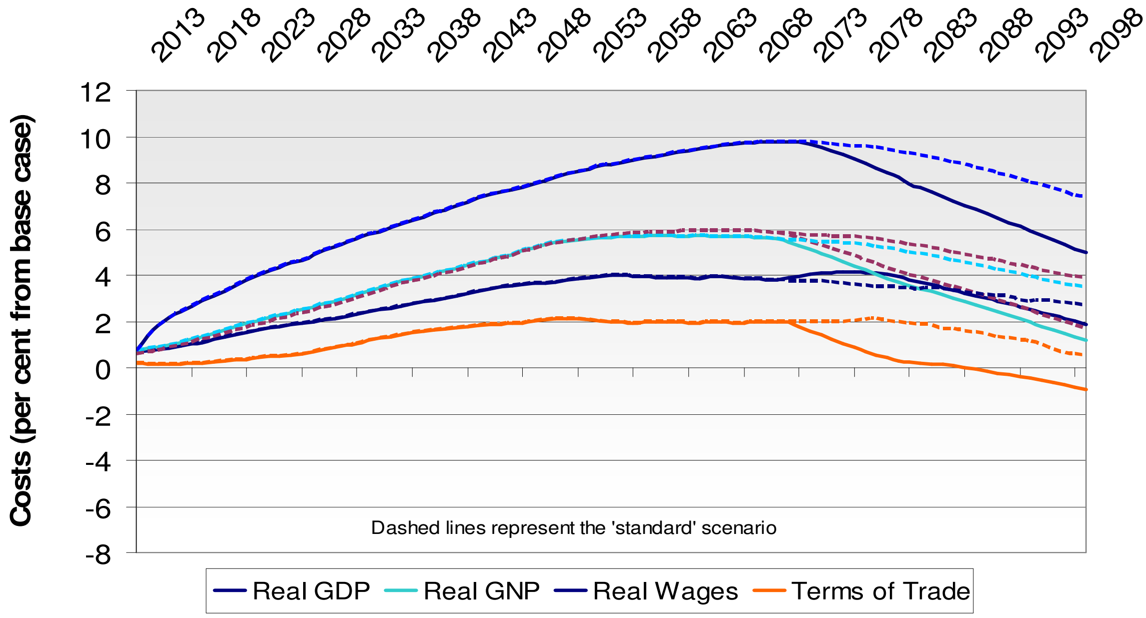
The Australian mitigation effort under strong and ambitious global mitigation is likely to be associated with large international financial (income) flows from permit trading. As a result, GDP becomes a less useful indicator of economic welfare. GDP is often one of the most quoted economic indicators when consideration is given to the economic implications of policy. However, GDP is not a useful measure of welfare. Rather, it is a measure of the amount of value added being undertaken – the returns to capital and labour. Where this hard work generates income that is able to be used for consumption it can be a useful proxy for economic welfare. However, where policy results in large flows of income between nations, such as would occur under a global trading regime, GDP becomes much less useful as a measure of welfare. In the modelling undertaken by the Review, a more appropriate indicator of welfare to Australians is real consumption or Gross National Product (GNP). Both consumption and GNP take into account the income implications from the purchase of international permits.

Figure 5 below shows the net effects of climate change mitigation to GDP, GNP, consumption, real wages and the terms of trade for the 550 ppm scenarios with and without the backstop technology.

The first several decades of the Australian mitigation effort are dominated by the costs associated with the global effort to stabilise GHG concentrations. The introduction of the emissions trading scheme is projected to have an immediate effect, reducing GDP by -0.7 per cent relative to the basecase; in reality this step change would be spread out over several years. As there is only a small amount of trade in permits at this point, real income, and hence consumption falls by a similar amount. In 2020 GDP is projected to fall relative to the basecase by 1.1 per cent of GDP.[8] By 2020 Australia's trading in permits has risen substantially, with around 18 per cent of Australia's total emissions being offset through the purchase of international permits. At this point the gap between GDP and GNP consumption starts to widen as a greater amount of permits are purchased internationally.

[8] During the first two decades of mitigation, the high levels of fossil fuel reductions reduce sulfate aerosols. Aerosols have a cooling effect, so their removal results in a slightly higher temperature and consequently slightly elevated climate and economic impacts in the short term. After about 2040, the benefits of reductions in GHG concentrations start to override the short term increased warming associated with aerosols. For further discussion on this issue see Technical Paper Number 2.

Figure 5: The net macroeconomic effects of mitigation. 550 standard and backstop technology scenarios. Type 1 costs of climate change only.



Source: MMRF

By 2050, the net costs to GDP are projected to be 3.6 per cent relative to the base case. That is, the level of GDP will be 3.6 per cent lower than if there were no attempt to mitigate climate change. By this time, a large amount of Australia's mitigation effort is met through the purchase of international permits (at a value of almost $35 billion in 2005/06 dollars). Hence, real income falls by a greater amount (as reflected by the reduction in real GNP). This contributes to a fall in GNP and consumption levels, relative to the base case, of around 5 percent.

The impact of the backstop technology becomes evident after 2073 where the economic costs begin to unwind more quickly (shown as the solid lines in Figure 5). Upon the emergence of the backstop technology scenario in 2073, GDP falls slightly compared to the 550 ppm standard technology scenario as more resources (land, labour and capital) and drawn out of the economy to support the backstop technology. However, as the backstop technology costs remain unchanged over time, the benefits from its emergence are soon realised, By 2100, GDP costs are reduced from 2.7 per cent in the scenario without backstop to 1.9 per cent (relative to the base case). However, even under the standard technology assumptions, the net economic impacts begin to fall and are smaller than in 2050.

The impacts on consumption are significantly higher than this since Australia is meeting a large portion of its obligations through the purchase of international permits. Without the backstop technology, almost 70 per cent of Australia's domestic emissions are offset through the purchase of international permits by 2100. This reduces income available for consumption. Consumption is projected be around 3.9 per cent lower than in the basecase in 2100. Australia's terms of trade become positive after the introduction of the backstop technology.

Comparing the macroeconomic implications of mitigation between the scenarios with and without backstop assumptions demonstrates the critical importance of technology as a key determinant of mitigation costs.

The implications for GNP and consumption are even more pronounced, with consumption increasing immediately compared to the standard 550 ppm scenario as industries switch from buying international permits to using the backstop technology. Hence the large financial flows out of Australia are avoided through the use of the backstop technology. By 2083, international permits are no longer needed for Australia to meet its mitigation target and consumption is 4 per cent below the base case compared to

5.4 per cent in the standard technology scenario. By 2100, consumption declines relative to the base case by 1.7 per cent compared to 3.9 per cent in the standard technology scenario.

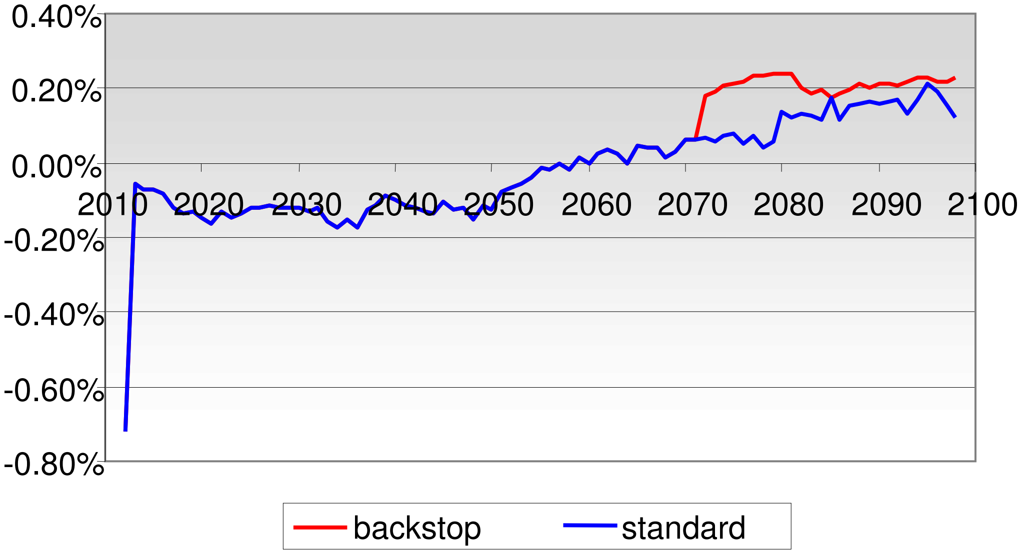
It should be noted that the modelling assumes that revenue from domestic permit allocation is recycled back to households. In 2050, permit revenue is equal to approximately two per cent of total household income.

Throughout the modelling period, long run national employment is assumed to be driven primarily by demographic factors such as population and participation rates. Some short run employment consequences are observed in response to climate change and climate change mitigation. However, over the longer term, the wage rate adjusts to clear the labour market consequences such that employment heads back to its basecase level. There will however be some permanent regional and industry level changes in employment to reflect the underlying structural change that will likely result from climate change and climate change mitigation.

This adjustment results in a decline in the real wage rate. By 2050, the real wage is projected to be around 8 per cent lower than base case levels. By 2100 the wage rate is projected to fall by less, 7.3 per cent in the standard scenario and 4.8 per cent in the backstop scenario, relative to the base case, as a result of climate change impacts avoided.

These results can be put in context by assessing them in terms of growth foregone. Figure 6 shows the GNP growth penalty associated with the 550 scenario both with and without backstop technology assumptions and incorporating the Type 2 costs of climate change. The figure shows that after an initial modelled shock to the economy of around 0.7 percentage points (a cost which in reality would be spread over several years), the net costs of mitigation as modelled in MMRF typically shave about 0.1 per cent per annum from GNP growth until after the half-way mark in the century. In the second half of the century, mitigation towards the 550 goal adds to the growth rate of the economy, as, at the margin, more new climate change damages are avoided than new mitigation costs are added. In fact, by the end of the century, under the backstop scenario, GNP is higher than it would have been without mitigation, even when all the costs and only the expected market benefits (Types 1 and 2, but not Types 3 and 4) of mitigation are taken into account.

Figure 6 Change in annual Australian GNP growth (percentage points lost or gained) due to net mitigation costs under the 550 backstop and standard technology scenarios compared to no mitigation, 2013–2100



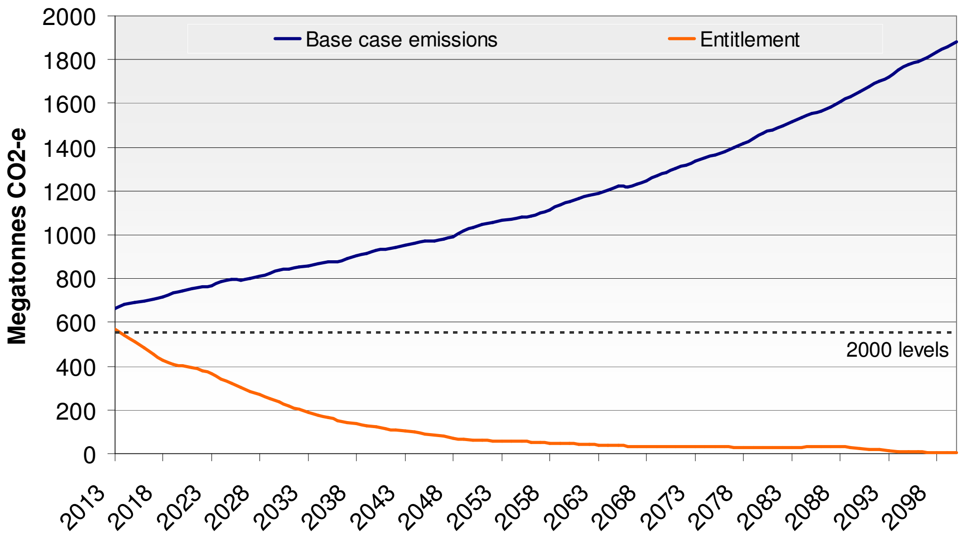
Note: Source: MMRF adjusted to incorporate Type 2 costs of climate change.

4 The macroeconomic consequences of climate change mitigation - 450 scenario

The 450 ppm scenario requires a more onerous mitigation effort by 2100. Under the global emissions allocation rule, Australia's implied emissions entitlement reduction target relative to 2000 levels is -25% by 2020 and -90% by 2050 (see Final Report chapter 12).

As with the 550 ppm scenario, the 450 ppm scenario has been modelled with and without backstop technology assumptions.

Figure 7: Australia unmitigated emission and emissions entitlements (450 mitigation scenario).



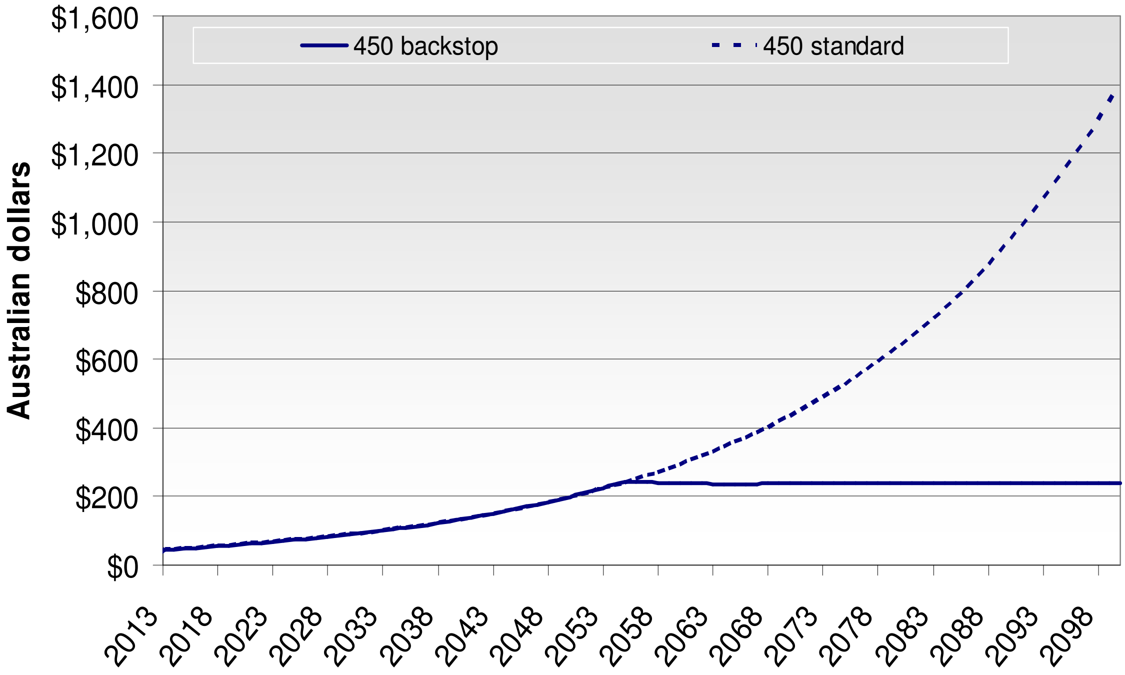
Source: MMRF

The more ambitious abatement requirements under the 450 overshooting scenario requires a higher global carbon price to achieve stabilisation by 2100. Again, the carbon price equalises across countries and differs only as a result of exchange rate movements. In Australia, the carbon price begins in 2013 at a price of A$43, rising to A$60 in 2020 and almost A$200 by 2050. Unlike the 550 ppm scenario, where the permit price begins to plateau after stabilisation of emissions is reached in the second half of the century, the 450 without backstop scenario sees carbon prices continue to rise as stabilisation is not reached until the end of the century. By the end of the century, the permit price reaches almost $A1400 (figure 8).

Under the 450 ppm backstop technology scenario the emergence of a backstop technology in the future is assumed in response to a permit price of US$200. As a result of the more onerous mitigation target under the 450 ppm scenario, this permit price is reached much earlier (around 2055), than in the 550 scenario (around 2073). International trading in permits ceases by around 2065 (figure 9)

As discussed previously, the imposition of a backstop technology stabilises the permit price at the marginal cost of abatement of the new technology.

Figure 8: Carbon prices under the 450 mitigation scenario

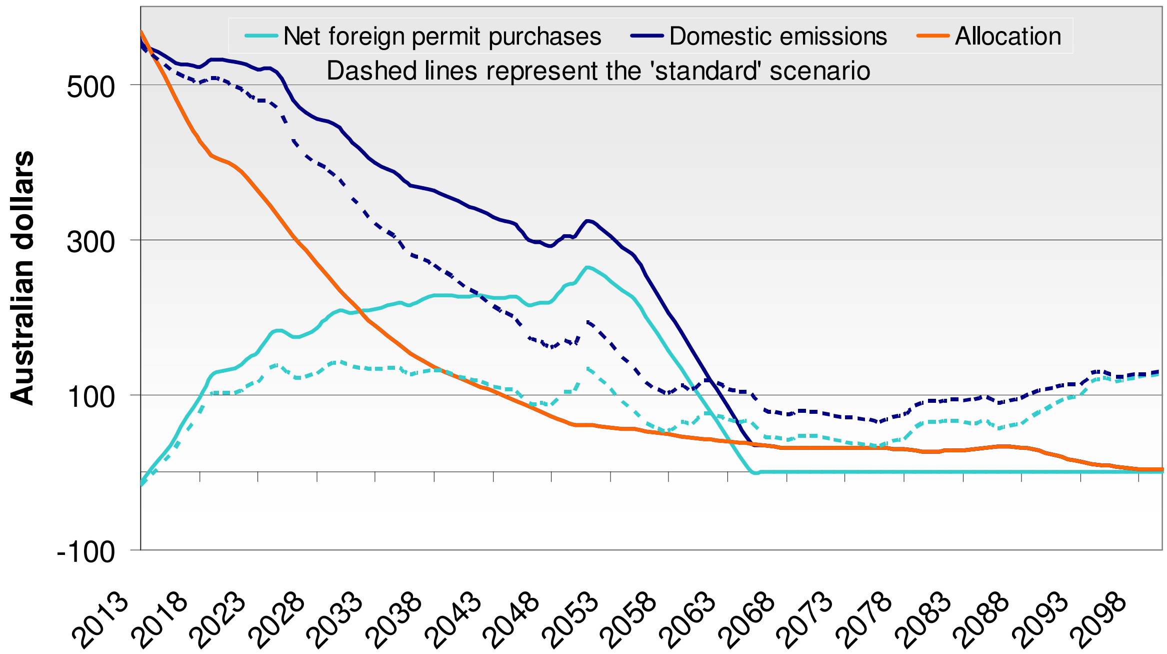


Source: MMRF (2005/06 dollars)

The much higher permit prices under the 450 ppm without backstop scenario are assumed to make economic the reforestation of large tracts of grazing land. Forestry contributes approximately 12 per cent to the total cumulative abatement of emissions against the base case over the modelled period in the 450 ppm without backstop scenario, compared to only 3 per cent in the 550 scenario. The costs of this forestry sequestration are accounted for by a reduction in land use in agriculture. This slightly reduces the ratio of international permit purchases to emissions, relative to the 550 scenario, particularly prior to 2050. However, the higher carbon prices under the 450 ppm scenario mean that the total value of these permits is higher than in the 550 ppm scenario.

For the 450 with backstop scenario, it is assumed that the stabilisation of permit prices is anticipated by investors who might otherwise have funded the reforestation of grazing lands. For this reason, the emissions reductions from forestry are assumed to revert to those that were used in the 550 scenarios.

Figure 9: Australia's emissions and net foreign permit sales – 450 mitigation scenario



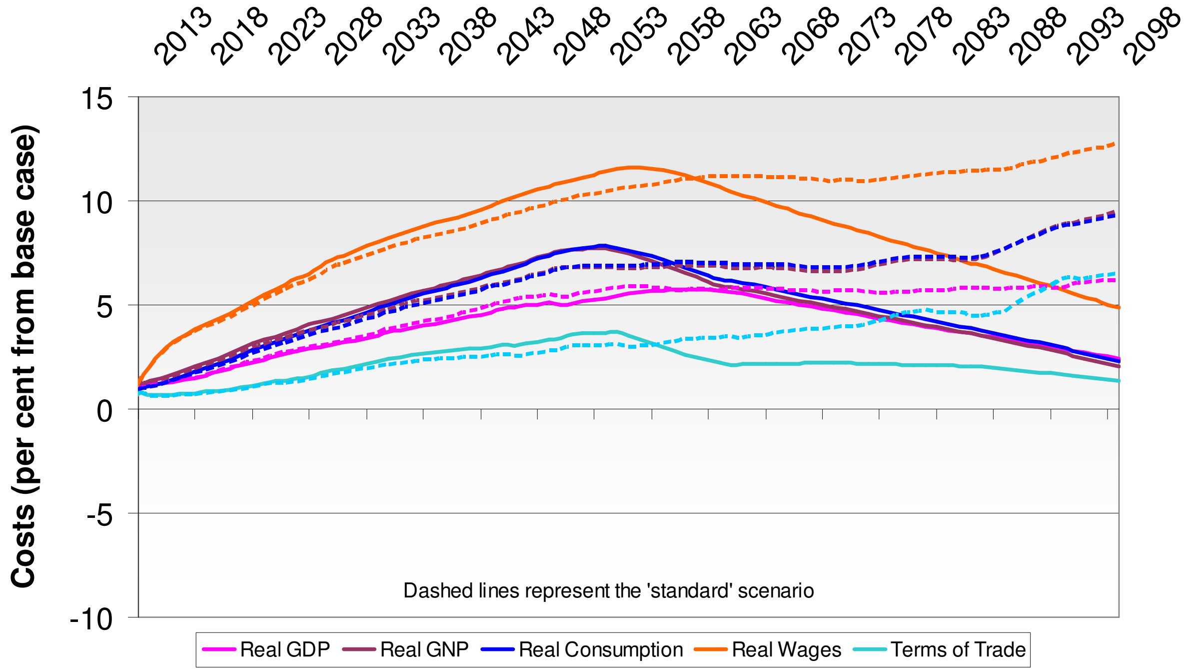
Source: MMRF

Macroeconomic implications of climate change mitigation – Type 1 costs

Figure 10 show projections for key macroeconomic variables for the 450 standard and backstop scenarios. These results show that the economic costs of climate change mitigation under the 450 scenarios are greater than in the 550 scenarios. In the 450 standard scenario (shown by the dashed lines) GDP is expected to be around 1.6 per cent lower in 2020 relative to the base case and compared to 1.1 per cent in the 550 ppm standard technology scenario. Real GDP is projected to be 5.4 percent lower by 2050 and 6.0 per cent lower by 2100, relative to the basecase. Real consumption is projected to be 6.5 per cent lower by 2050 and 9.2 per cent lower by 2100, relative to basecase.

The high economic costs after 2050 are primarily a result of the rapidly rising costs of abatement. These high costs offset the benefits from avoided climate change. After around 2085, the economy is assumed to have limited ability to reduce emissions further. Hence the majority of additional abatement is met through the purchase of international carbon permits. This results in escalating welfare costs (as measured by GNP and consumption) after this period.

Figure 10: The net macroeconomic effects of mitigation. 450 standard and backstop technology scenarios. Type 1 costs of climate change only.



Source: MMRF

In the standard technology scenario, the costs to key macroeconomic variables (as presented in Figure 10) begin to escalate late in 2080. At this point, all modelled technological abatement opportunities have been exhausted as sectors reach the limits of the assumed marginal abatement cost curves. As a result, in order to meet the emissions constraints implied by the 450 target, some mitigation is achieved through a reduction in output of emissions intensive sectors.

Under the 450 backstop scenario economic costs become much lower once the backstop technology begins in 2055, compared to the 450 standard scenario. Real GDP is projected to be 5.0 percent lower by 2050 and 2.2 per cent lower by 2100, relative to the basecase. Real consumption is projected to be 7.3 per cent lower by 2050 and 2.1 per cent lower by 2100, relative to basecase.

5 Comparison of the 450 and 550 scenarios

Table 1 summarises the results of the earlier two sections by presenting the annual average growth rates under the three scenarios compared for both GDP and GNP, incorporating both Type 1 and Type 2 costs.

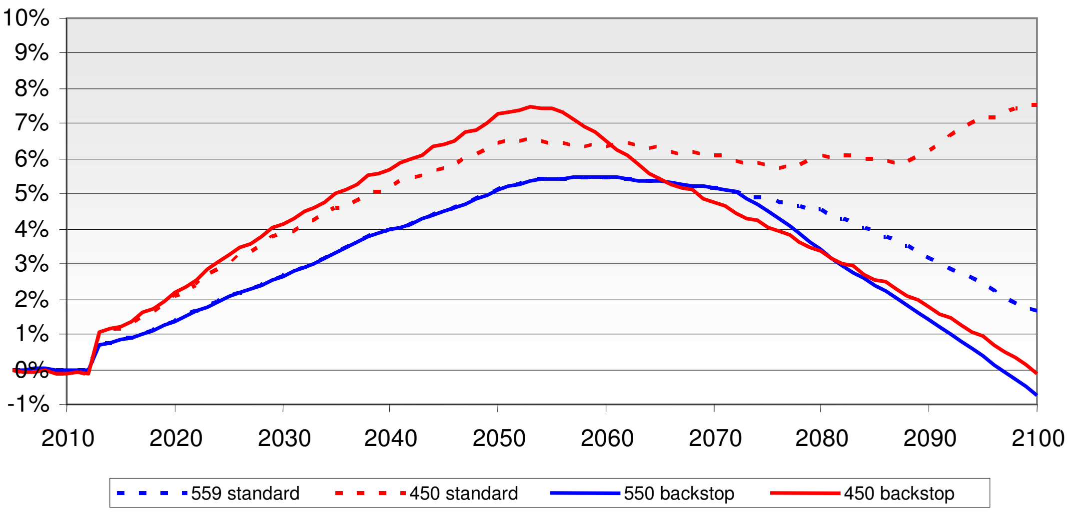
Table 1: Annual average growth rates for GNP and GDP under the no-mitigation, 450 and 550 scenarios with backstop technology (Type 1 and Type 2 costs of climate change).

Average annual growth rates	2013-20	2021-50	2051-2100
Unmitigated climate change (GNP)	2.1%	1.7%	2.0%
Unmitigated climate change (GDP)	2.7 %	1.7%	2.0 %
Stabilisation to 550 ppm backstop technology (GNP)	1.9%	1.6%	2.1%
Stabilisation to 550 ppm backstop technology (GDP)	2.5 %	1.7%	2.1 %
Stabilisation to 450 ppm backstop technology (GNP)	1.8%	1.6%	2.2%
Stabilisation to 450 ppm backstop technology (GDP)	2.5%	1.6 %	2.1 %

Source: MMRF adjusted to include Type 2 costs of climate change. As discussed in chapter 11 of the Final Report, the Type 2 costs of climate change are estimated to be 30 per cent the size of the Type 1 costs of climate change.

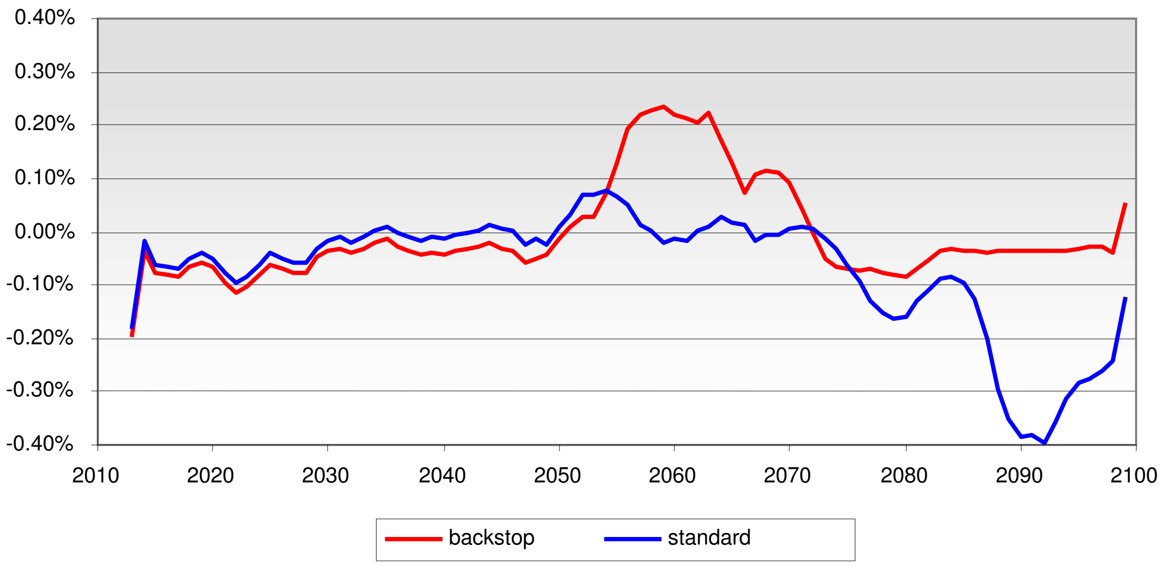
Figure 11 directly compares the GNP net costs under both the 450 and 550 mitigation scenarios, (taking into account both Type 1 and 2 costs) as modelled in MMRF. Figure 12 provides a comparison of the change in annual Australian GNP growth rates due to the net mitigation costs under the 450 scenario compared to the 550 scenario.

Figure 11: GNP costs of mitigation – 450 and 550 scenarios (Type 1 and Type 2 costs combined)



Source: MMRF adjusted to incorporate Type 2 costs of climate change.

Figure 12: Change in Australian annual GNP growth (percentage points lost or gained) due to net mitigation costs under the 450 compared to the 550 scenario and under standard and backstop technology assumptions.



Source: MMRF adjusted t to incorporate Type 2 costs of climate change

Table 2 summarises the cost difference between the 450 and 550 scenarios. It presents calculations of the present or discounted value of mitigation under the 450 and 550 scenarios through the 21st century. It presents results from the MMRF model (with the post-2050 backstop and standard scenario) for net mitigation costs (costs net of Type 1 and Type 2 benefits). It calculates the net present value of these costs using two discount rates the Review considers appropriate, namely 1.4 and 2.7 per cent (as derived in Chapter 1).

If the standard technology case, the net present cost of the 450 ppm scenario is 1.5 per cent of GNP more than that of the 550 ppm scenario. However, as discussed earlier, this scenario is considered to be implausible. Under the backstop scenario the difference in costs (the "450 premium") is less than 1 per cent.

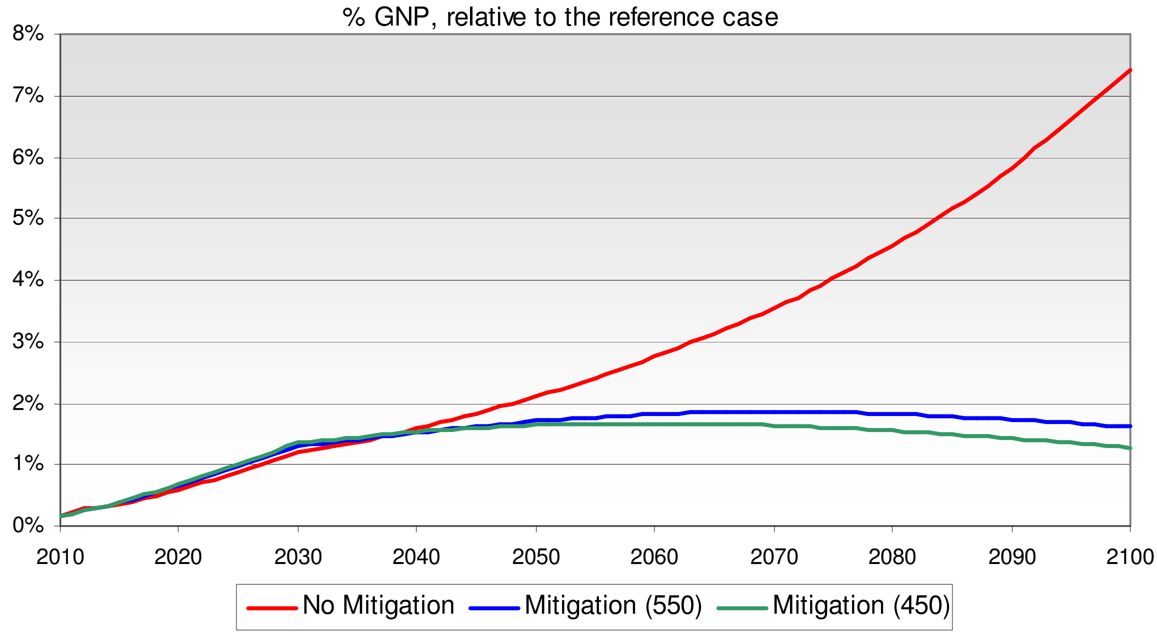
Table 2 Net present cost of the 450 ppm and 550 ppm scenarios (in terms of no-mitigation GNP) and "450 ppm premium" to 2050 and 2100 – Type 1 and 2 costs.

(a) Discount rate equals 1.4%	**550**	**450**	**450 Premium**
Net mitigation cost to 2100			
MMRF backstop	3.2%	4.0%	0.8%
MMRF standard	3.8%	5.5%	1.7%
(b) Discount rate equals 2.7%	**550**	**450**	**450 Premium**
Net mitigation cost to 2100			
MMRF backstop	3.3%	4.2%	0.9%
MMRF standard	3.6%	5.1%	1.5%

Note: The "450 Premium" is the difference in costs between the 450 and 550 scenarios.

Figure 13 below helps explain why the 450 scenario is always the more expensive one in terms of modelled results. Expected climate change damages are less in the 450 scenario than in the 550, but only by half a per cent of GNP. The small expected market gain from the 450 scenario is not in itself adequate to justify the additional mitigation costs associated with it. Rather, the more significant difference between the 450 and 550 scenarios is in terms of additional Type 3 and Type 4 avoided costs. Chapter 11 concluded that avoidance of these additional costs was worth the premium of 1 per cent of GNP associated with a 450 ppm scenario compared to a 550 ppm scenario.

Figure 13 A comparison of the modelled expected market costs for Australia of unmitigated and mitigated climate change up to 2100 (Type 1 costs only).

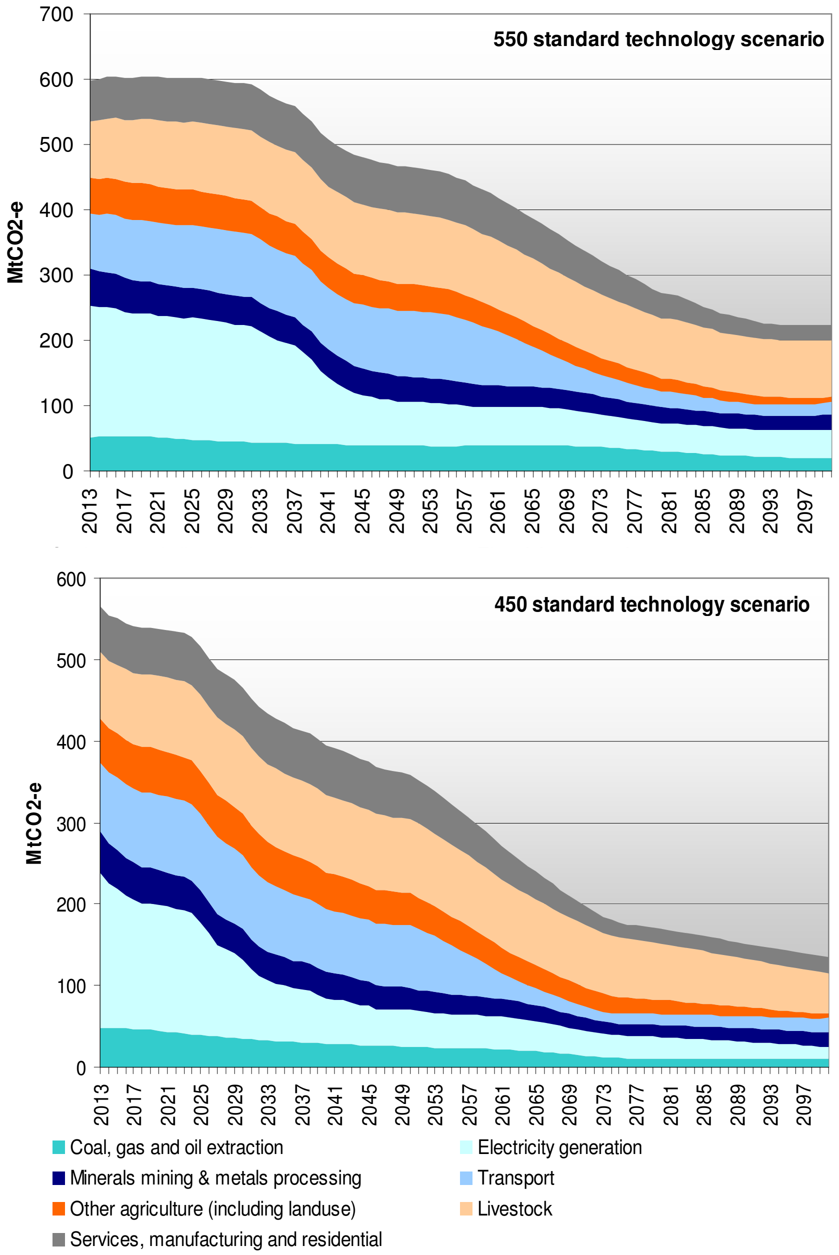


Notes: The graphs show the cost as a percentage of GNP of expected market damages from the level of climate change associated with the three scenarios. These estimates are achieved by 'shocking' the reference case with the differing levels of impact associated with the temperatures expected from the two different scenarios. The results do not include the costs of mitigation that would be incurred to produce either the 450 or 550 climate change outcomes.

6 Australia's emissions in a mitigated future

The contribution of the abatement task across sectors is dependent on current emissions intensities, technological options, the degree of substitution between inputs into the production process and the price responsiveness of commodity demand to the change in relative prices. Emissions over the modelling period for the 450 and 550 scenarios under both the standard and backstop technology assumptions are shown below.

Figure 14 Australian emissions sources to 2100 (excluding forestry) for the standard technology scenarios



Source: MMRF

As a general principle, those sectors responsible for a higher percentage of current emissions are those that undertake the majority of the abatement task. Under the standard technology scenarios, electricity generation is responsible for the majority of abatement in the first half of the century, with a higher rate of abatement under the 450 scenario. In the second half of the century there are considerable reductions in 'other stationary energy' and the transport sector.

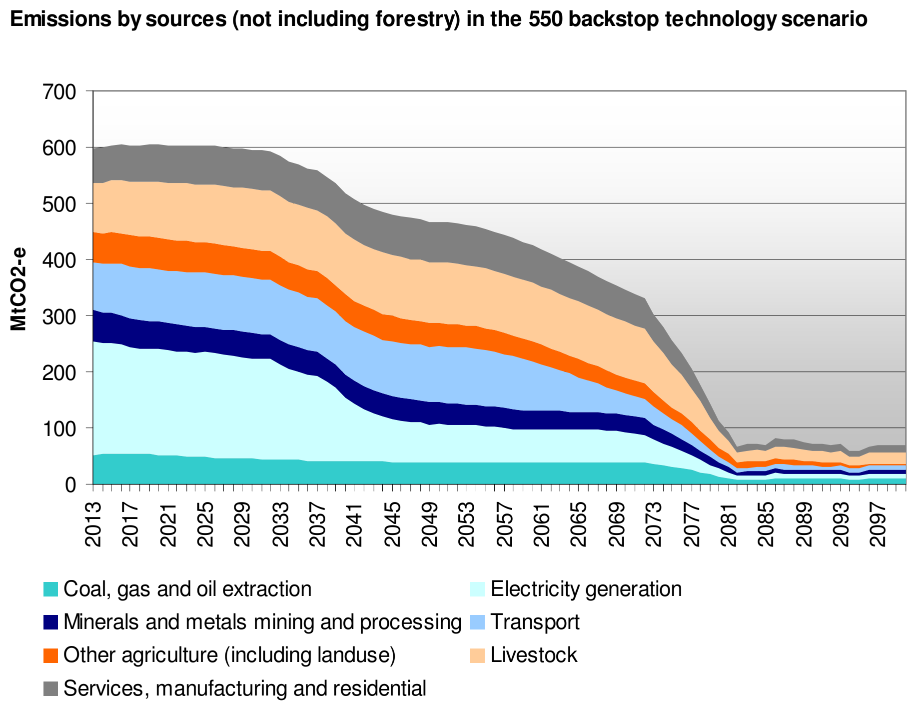
By the end of the century, agriculture, under the standard technology scenario is the dominant source of emissions under both mitigation scenarios, responsible for around 40 percent of total emissions in both policy scenarios. This dominance is due to expectations that abatement opportunities from ruminant livestock such as sheep and cattle are more limited than other abatement opportunities, and also at higher cost.

The carbon prices under the 450 scenario mean that coal-based electricity generation becomes less competitive relative to renewable generation technologies towards the end of the century. The residual emissions from carbon capture and storage mean that the cost of electricity from CCS continue to rise over time while the cost of renewables continue to fall as they increase in scale.

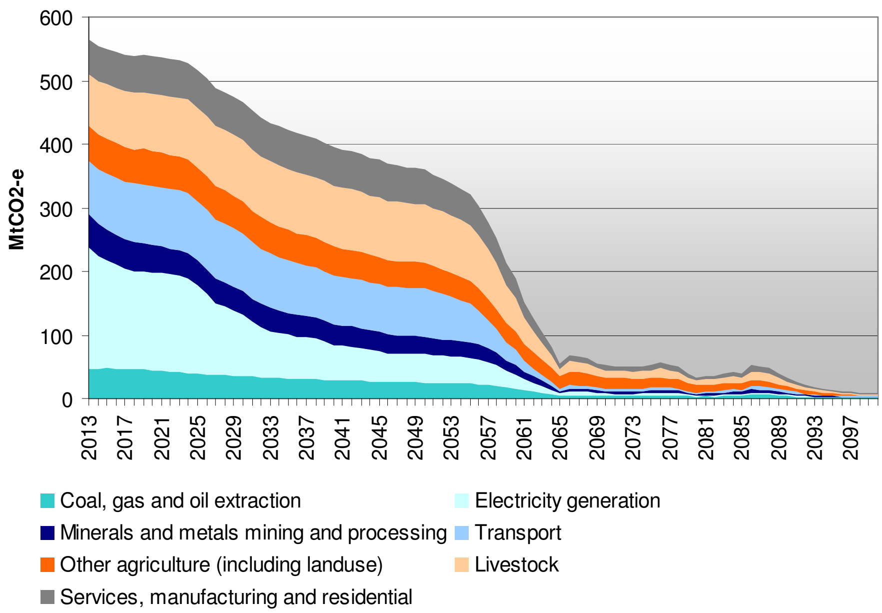
Small amounts of residual emissions remain from most emissions sources, which reflect the ongoing willingness of consumers to pay high prices for emissions intensive goods. Consumers' income continues to grow, even with these high prices. However it is possible that at these carbon prices, new technologies that can not be reliably modelled at this stage would allow further reductions in emissions.

The emissions over the modelling period for the 550 and 450 backstop technology scenarios are shown in Figure 15. Emissions until the point that the backstop technology becomes available (at around \$AU250 per tonne of CO2-e or \$US200 per tonne of CO2-e) are the same as the standard technology scenarios.

Figure 15 Australian emissions sources to 2100 (excluding forestry) for the backstop technology scenarios



Emissions sources (not including forestry) in the 450 backstop technology scenario



Source: MMRF

The affect of the introduction of the backstop technology is shown in the sharp reduction in emissions from all sources as the technology is phased into the economy across all sectors over a ten year transition period. During this transition period the trading of permits gradually decreases, structural change intensifies and the carbon price continues to influence emissions prior to the complete uptake of the backstop technology across all sectors. Once the technology is phased in, total emissions are equivalent to the national allocation.

After the transition period, the division of overall emissions between various emissions sources generally reflects the proportions at the point at which trading ceases. These proportions vary slightly with structural change and changes in sector activity and demand out to the end of the modelling period.

The cumulative mitigation task over the whole modelling period shows the influence of sequestration in the forestry sector on emissions reductions[9]. See figure 16 below for the cumulative mitigation effort for both the standard and backstop scenario. The additional abatement required in the 450 scenario is undertaken by all emissions sources, with the proportion of the abatement task fairly similar in the majority of sectors. However, more than 40 per cent of the additional abatement is achieved by sequestration in the forestry sector under the standard technology case, increasing the sector's contribution to 11 percent in the 450 scenario from 3 percent in the 550 scenario.

When a carbon price is introduced, emissions intensive sectors will generally experience a drop in demand and a decline in activity. As the carbon price increases, those sectors that have the capacity to abate greenhouse gas emissions will undergo structural change to adjust to alternative low emissions technologies or fuel sources.

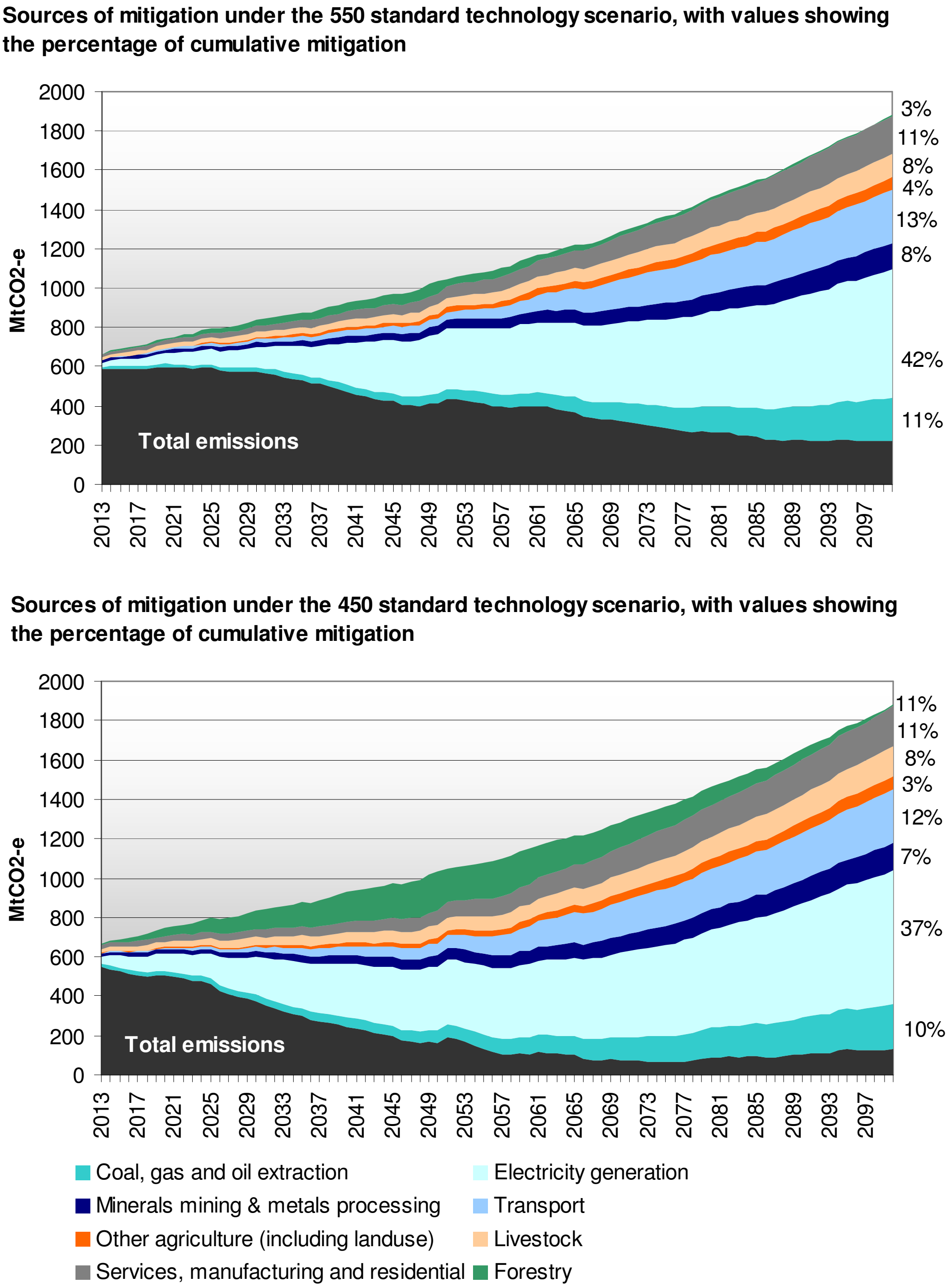
The implementation of a backstop technology that is available to all emissions sources would be likely to influence growth and structural change in all sectors. Some sectors would benefit, while others could be disadvantaged. An example is the forestry industry, where decisions would need to be made decades in advance to plant areas that would be viable under the high carbon prices expected to be reached at a later point in time. Under the backstop scenarios these higher carbon prices may never be achieved, so that forestry on more marginal land would be less likely to be viable. In the modelling,

[9] Cumulative abatement is equal to the sum of annual emissions under the base case less the sum of annual emissions under the policy case.

forestry is assumed not to make the same contribution to overall abatement in the 450 backstop scenario.

The unknown nature of the backstop technology was recognised in the simplicity of the assumptions and methodology used in the Review's modelling exercise. Costs were applied evenly across all sectors, and the technology was assumed to be applicable to all emissions sources. As a result, there is not a strong sector-by-sector story from the backstop modelling scenarios. In reality, impacts on sectors would depend on the type of technology that became available.

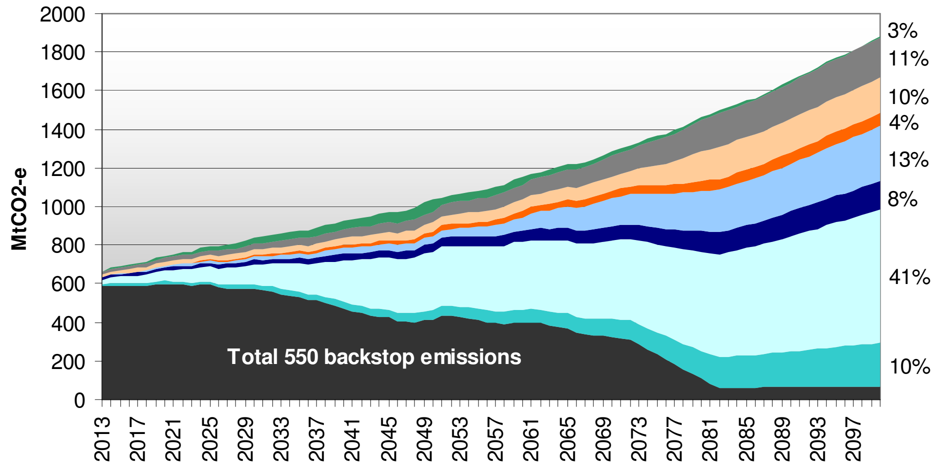
Figure 16: Cumulative mitigation task – standard technology scenarios



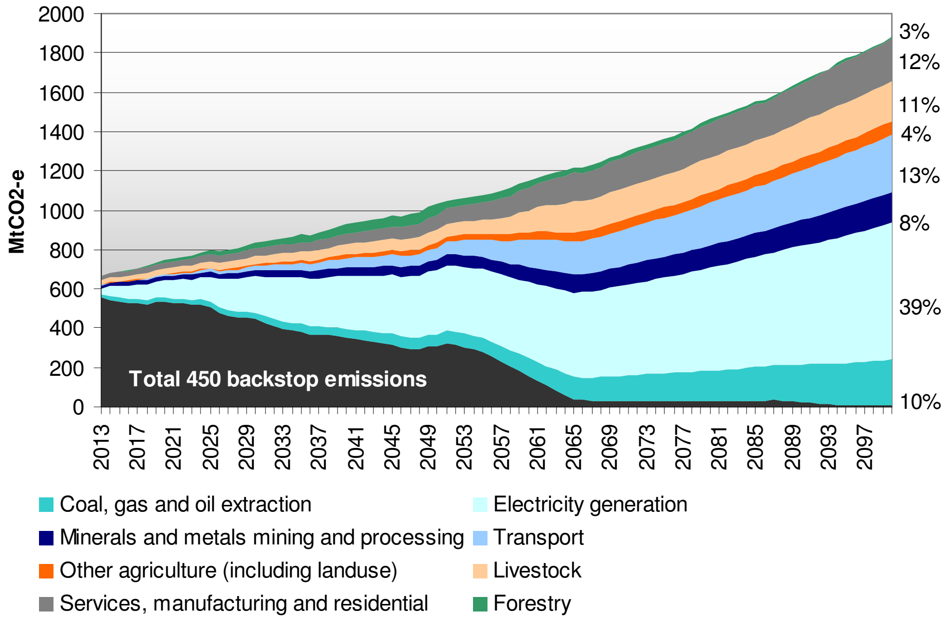
Source: MMRF

Figures 17: Cumulative mitigation task – backstop technology scenarios

Sources of mitigation under the 550 backstop technology scenario, with values showing the percentage of cumulative mitigation to 2100



Sources of mitigation under the 450 backstop technology scenario, with values showing the percentage of cumulative mitigation to 2100



Source: MMRF

7 The sectoral implications of climate change mitigation

Climate change mitigation will have diverse effects across Australian regions and industries. Significant structural change is likely to occur, particularly for the energy generation sector and emissions intensive industries.

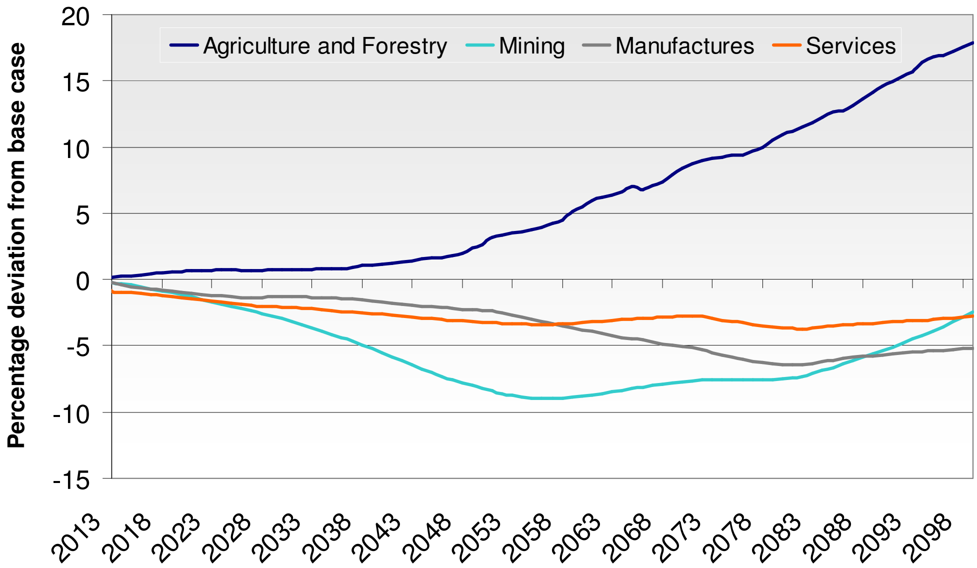
Australia currently enjoys a competitive advantage in cheap energy from coal. This advantage is likely to be eroded significantly as mitigation policy raises the cost of energy in Australia relative to the rest of the world. Since coal is emissions intensive, the modelling suggests that energy prices would rise more in Australia than in most other countries, converging with energy prices elsewhere in the world. This would, to some extent, tend to erode the relative competitiveness of Australia's energy intensive, trade exposed industries. However other sources of competitiveness, including Australia's high quality natural resources, and in some instances the transport cost advantages of processing close to the natural resource locations, economies of scale and skilled workforce are not affected by mitigation policy and so Australia will not necessarily lose global market share in these industries.

Mitigation will also result in benefits for some industries. In particular, the agriculture, forestry and renewable electricity generation sectors. Chapters 20 to 21 of the Final Report discuss the effects of Australian mitigation policy on the electricity generation, transport, and agricultural and forestry sectors.

Agriculture is particularly exposed to the effects of climatic change. As discussed in Technical Paper Number 5, the effects of unmitigated climate change is likely to be significant for agriculture, with agricultural activity as a whole projected to decline by more than 20 per cent by 2100. Global mitigation of climate change will therefore result in significant benefits to agriculture as the more severe climate outcomes are avoided, particularly the projected reductions in rainfall.

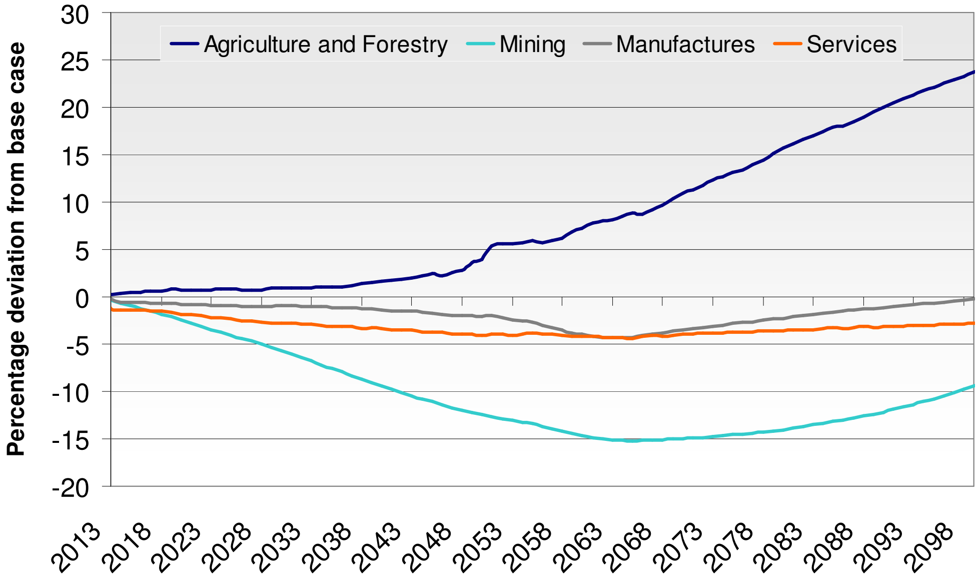
Figures 18 and 19 below shows the changes to activity for industry aggregates for the 550 and 450 backstop technology scenarios. As noted earlier, the sectoral results post implementation of the backstop technology should be interpreted cautiously. The unknown nature of the technology was reflected in the way the technology was modelled. In reality, sectoral results would vary depending on the nature of the technology and the sector within which it arises.

Figure 18: Industry Aggregates – 550 backstop technology scenario: percentage deviation from the no mitigation scenario.



Source: MMRF

Figure 19: Industry Aggregates – 450 backstop technology scenario: percentage deviation from the no mitigation scenario.



Source: MMRF

Mining is likely to be the sector most adversely affected by mitigation policy. This is mainly due to a large decline in international demand for coal and gas as energy generation moves towards low emission technologies. The effect on the demand for many of Australia's mining commodities is determined primarily by the international environment. This is particularly the case for coal which exports around 90 per cent of production. Chapter 20 discusses the central importance of the global environment to the future of the Australian coal industry.

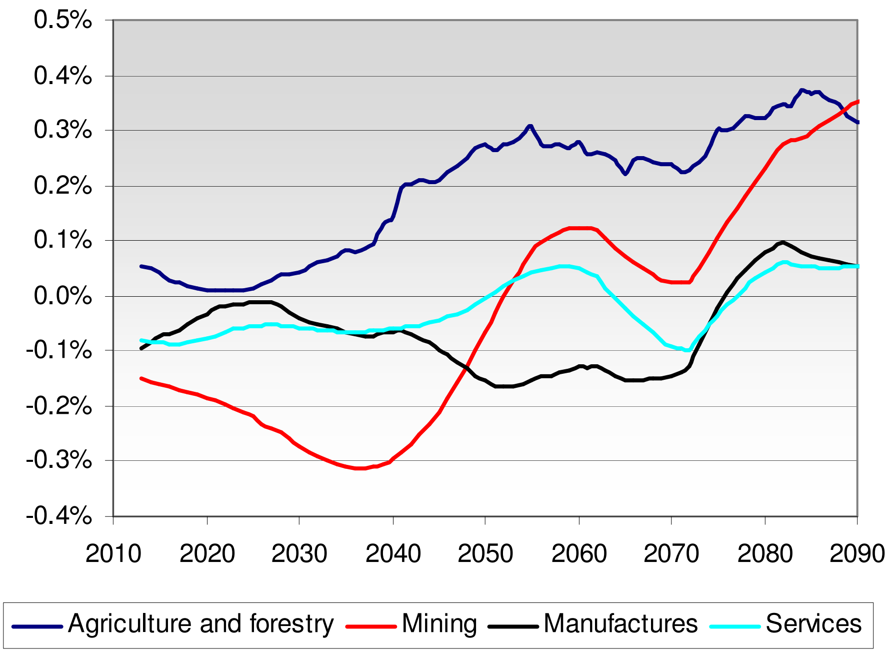
Some of Australia's low emissions manufacturing industries do well as a result of the depreciation of the exchange rate that accompanies mitigation. However, the manufacturing sector as a whole is adversely affected. Some of Australia's manufacturing industries are energy intensive, such as aluminium smelting, and their competitive advantage in cheap energy is eroded with the introduction of the mitigation policy. The effects on the aluminium industry are discussed in chapter 20 of the Final Report. The benefits from the avoided climate change later in the second half of the century increases agriculture exports relative to the no mitigation scenario. This results in an exchange rate appreciation that unwinds some of the benefits to the manufacturing industry.

The agriculture sector benefits from mitigation through avoided impacts of climate change, particularly in the second half of the century. By 2050 in the 550 ppm scenario activity in the agriculture sector increases by around 3.4% relative to the basecase and by 17.4% relative to the basecase by 2100. The main beneficiaries from climate change mitigation are the dairy, grains and other agriculture industries. The sheep and cattle industry experiences a reduction in activity throughout the modelled period as a result of their high emissions intensity and relatively lower benefits from avoided climate change.

The effects of mitigation on the agriculture and forestry sectors, transport sector and the electricity generation sector are discussed in chapters 20 to 22 of the Final Report.

Figure 20 shows the sectoral growth rates from mitigation under the backstop technology scenario compared to the no mitigation scenario.

Figure 20 Change in Australian sectoral growth rates (percentage points lost or gained) due to net mitigation costs under the 550 backstop scenario compared to no mitigation



Note: Sectoral growth rates are the growth in sectoral activities (value added), as modelled in MMRF. Note only Type 1 costs are shown here. Ten-year forward moving averages are used to smooth annual variability.

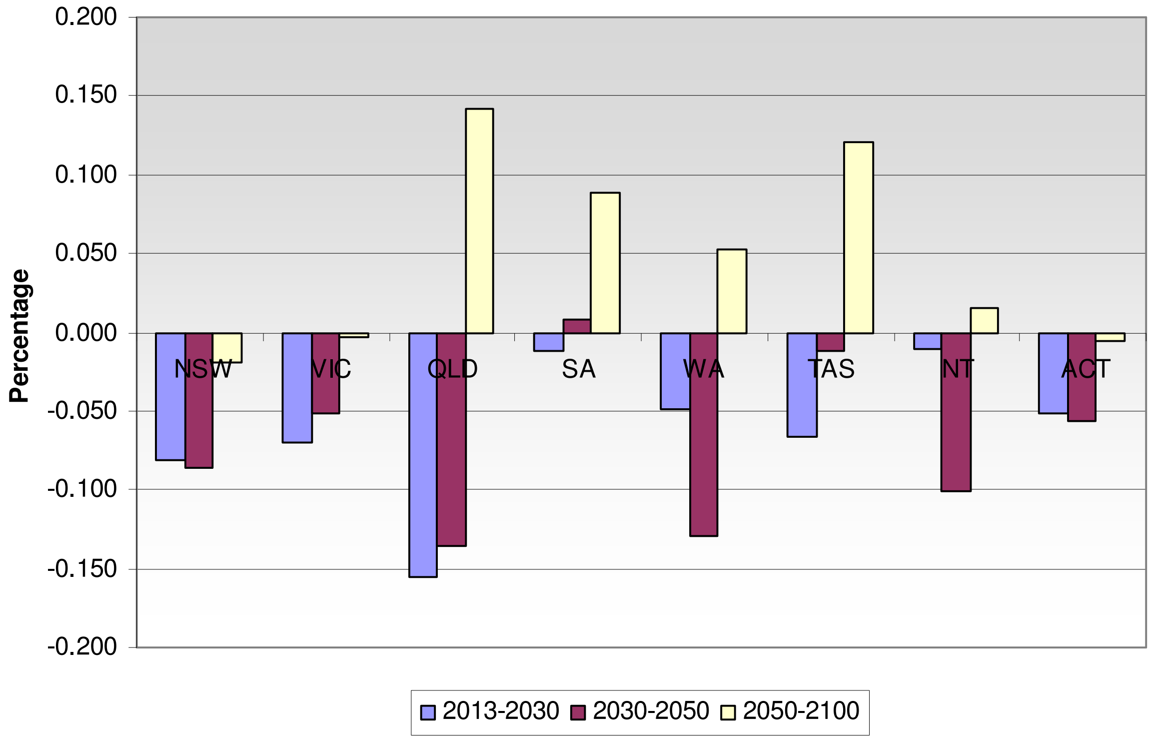
8 The regional implications of climate change mitigation

The relative effects of mitigation on each State and Territory are driven, primarily, by two main factors:

- the relative emissions and energy intensities of each region. In particular, each regions reliance on coal, which is a particularly important explanatory factor in the early years of mitigation;
- the sensitivity of each region to climate change impacts and hence the benefits gained from mitigation. This is driven primarily by the relative share of industries which benefit from climate change mitigation (that avoid damages or assist with the mitigation effort, such as forestry) and the share of industries which are adversely affected by mitigation (such as aluminium);

Figure 21 shows the average change in annual GSP growth due to mitigation under the 550 backstop technology scenario. Estimating economic impacts over long time periods for small economies like the Northern Territory is difficult since their economies are dominated by only a few sectors. Hence, results for small economies, particularly the Northern Territory and the ACT are likely to be subject to a higher degree of uncertainty than other regions. In addition, since unknown future changes in technology under the backstop technology scenario are likely to have large sectoral impacts, depending on the nature and the sector the technology arises in, it is not possible to project sectoral changes, and hence the relativities between States and Territories, with a high degree of certainty, in the later half of the century for the backstop technology scenario.

Figure 21 Average change in annual GSP growth (percentage points lost or gained) due to mitigation costs under the 550 backstop scenario in Australia, 2013 - 2100



Source: MMRF

South Australia and Tasmania are projected to be the least affected regions. With the exception of the Australian Capital Territory, these regions have the least energy and emissions intensive economies resulting in a relatively low carbon price burden.

Tasmania and South Australia generate most of their electricity from fuel other than coal, as a result, the transformation in the electricity sectors in these states is not as significant, unlike the more coal dependent regions. As a result, Tasmania and South Australia's GSP holds up, relative to the other states, in the early years of the simulation.

South Australia's reliance on water from the Murray Darling basin makes it sensitive to climate change, and so it benefits from the avoided impacts from mitigation.

Tasmania's forestry and forestry processing industries are projected to do well. Income from carbon sequestration helps the forestry industry expand, relative to the basecase[10].

Western Australia is relatively unaffected by mitigation in the initial few years. This is largely because only a relatively small share of electricity generation is from coal (46 per cent in 2005-06[11]). Reductions in foreign demand are projected to have a significant effect on exports of gas from Western Australia. By 2060, exports of gas from Western Australia have declined by 85 per cent from basecase levels. Domestic demand, however, helps maintain activity, such that by 2060, activity levels of the gas industry in Western Australia are projected to level out at a little more than 30 per cent below the base case.

Western Australia does well in the second half of the century primarily as a result of the benefits in the grains industry resulting from avoided climate change.

Queensland is particularly adversely affected in the first half of the century. The initial moderation in

[10] There is some uncertainty regarding the benefits on wood production arising from forestry sequestration. Hence, impacts on Tasmania may be slightly higher than shown.
[11] Source: MMRF

GSP growth arises since Queensland's electricity generation sector is almost totally reliant on coal fired power stations. The introduction of an emissions reduction scheme causes a significant contraction in the coal based electricity industry, such that by 2020, generation from coal falls by almost 30 per cent, relative to basecase. By 2050, generation from coal falls by more than 50 per cent, relative to basecase.

Queensland also has a relatively high concentration of emissions intensive industries (particularly the beef cattle, coal and alumina industries) and so bears a high burden from the carbon price. The coal industry, and particularly coal exports, makes a large contribution to Queensland's GSP. Queensland's coal exports are projected to fall by almost 25 per cent by 2050, relative to basecase.

Queensland's economic activity recovers somewhat, relative to other states, in the second half of the century when its agriculture industries benefit from avoided climate change. In the second half of the century demand for coal also recovers slightly from the combined effects of expansion in low emissions CCS generation technologies and increased demand for electricity as transport switches to electricity.

Electricity generation in Victoria and New South Wales is also very dependent on coal (93 and 90 per cent of total electricity generation is from coal, respectively[12]). The introduction of the mitigation policy forces the retirement of significant generation capacity in both states. This is particularly pronounced in Victoria since coal fired generation relies on emissions intensive brown coal. By 2020, electricity generation from coal in Victoria declines by 40 per cent, relative to the basecase.

Apart from their electricity generation sectors, the Victorian and New South Wales economies have relatively low emissions intensities. This reflects the larger than average service sectors in these regions.

A number of Victorian and New South Wales manufacturing industries (such as textiles and car part manufacturing) also do well relative to other sectors since they benefit from a significant exchange rate depreciation in the middle half of the century[13].

Victoria and New South Wales also benefit from avoided climate change. However, as the industries that benefit (mostly agriculture) mainly sell into the domestic market where demand is relatively inelastic, benefits tend to be reflected in lower prices rather than changes to output. While lower food prices benefit consumers, these benefits are distributed across regions where these agricultural goods are sold. Hence benefits from reduced climate change tend to be distributed across Australia rather than being concentrated in Victoria and New South Wales.

The Northern Territory is relatively unaffected by climate change mitigation in the early years. This reflects the fact that the Northern Territory generates electricity from (relatively) low emissions gas. This competitive edge over the rest of Australia is eroded over time as carbon capture and storage expands in the eastern States.

Since the Northern Territory is the most emissions intensive economy, it becomes significantly adversely affected as the carbon price rises but benefits once the backstop technology comes in later in the century.

The effects on the Australian Capital Territory closely reflect the Australian average due to its reliance on Government services.

[12] Source: MMRF

[13] the exchange rate depreciation is triggered by declining global demand for commodities and the high demand for global carbon permits from the domestic economy. This exchange rate depreciation assists industries such as textiles that compete heavily with imports.