:vivideconomics

The costs and benefits of greater Australian emissions reduction ambition

Report prepared for WWF - Australia

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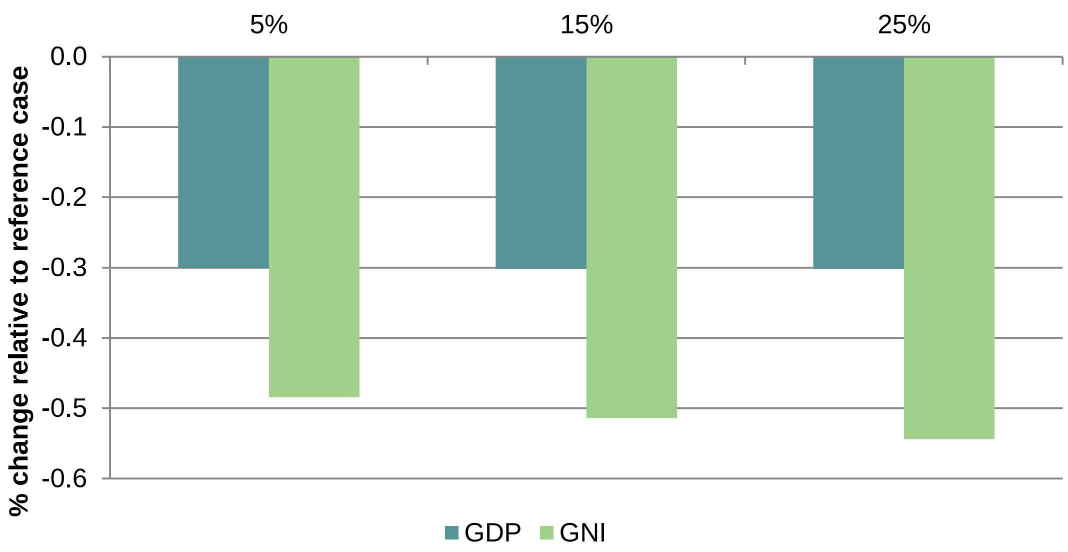
The modelling for this report was undertaken by the Centre of Policy Studies (CoPS), Monash University.

Executive Summary

This report contributes analysis to the debate on Australia's emission reduction ambition. It provides input into the process for the 'Caps and Targets Review' by the Climate Change Authority. We present new macroeconomic modelling analysis of the economic impact of Australia adopting a more ambitious emissions reduction target. The modelling takes account of recent changes in both economic and policy circumstances, especially the much lower price outlook for carbon prices in Australia and internationally. We also investigate the effects of greater domestic mitigation effort and fewer imported emissions reductions. Further, we provide a review of possible long-term benefits associated with taking more ambitious action on climate change in the near term. We use the Monash Multi-Regional Forecasting (MMRF) model with modelling undertaken by the Centre of Policy Studies (CoPS) at Monash University.

The macroeconomic costs of achieving Australia's 5 per cent emissions target are moderate. Achieving a 5 per cent national emissions reduction at 2020 in our modelling would result in gross domestic product (GDP) and consumption being 0.3 per cent lower in 2020 than in the reference case which assumes no additional action to curb emissions. The same level of GDP would be reached less than two months later than if no action was taken; the annual reduction in the pace of economic growth would be less than 0.05 per cent.

Figure 1. **The additional cost of achieving a stronger target is very small**

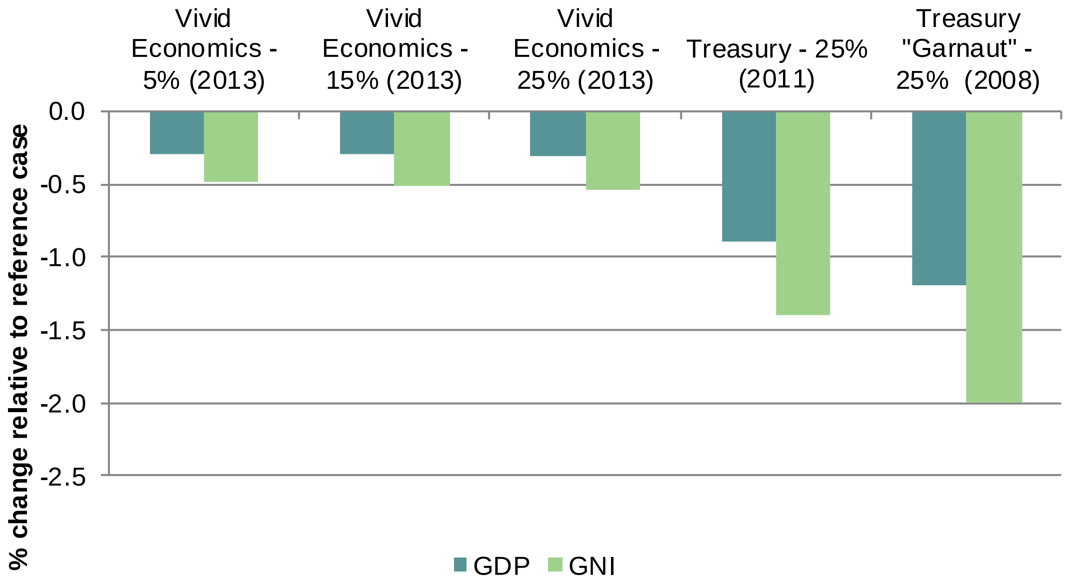


Source: Vivid Economics based on modelling results from CoPS MMRF.

Moving to a stronger reduction target has very low additional macroeconomic costs. The level of domestic economic activity, as measured by GDP, remains unchanged when moving from the 5 per cent to a 15 per cent or 25 per cent target. This is because, under current policy settings, additional reductions would come predominantly from international sources. The impact on gross national income (GNI), which includes the purchases of emissions reductions from other countries, is very slightly larger as a result of moving to a stronger target: changing from a reduction of 0.48 per cent in 2020 in the 5 per cent scenario to 0.54 per cent in the 25 per cent reduction scenario. This is in the context of projected underlying growth in GNI of 27 per cent from 2013 to 2020.

The costs of achieving a stronger target are much lower than expected when the target range was originally set. The lower price outlook for international emissions permits and offset credits reduces both Australia's domestic economic impacts and the amount of money spent on international emissions units. This results in much lower macroeconomic costs in terms of both GDP and GNI. The Australian Treasury's 2011 modelling study showed a 0.9 per cent reduction in GDP and a 1.4 per cent reduction in GNI relative to the reference case for the 25 per cent target case, and the need to purchase around A$7.3 billion of international emissions units. Treasury's 2008 modelling of a 25 per cent scenario showed even greater macroeconomic costs and international transfers. By contrast, in our updated modelling of a 25 per cent target, the GDP impact at 2020 is 0.3 per cent, the GNI impact is 0.5 per cent, and the cost of purchase of international emissions units are A$2.2 billion.

Figure 2. **The macroeconomic costs of a stronger target are much lower than previously estimated**



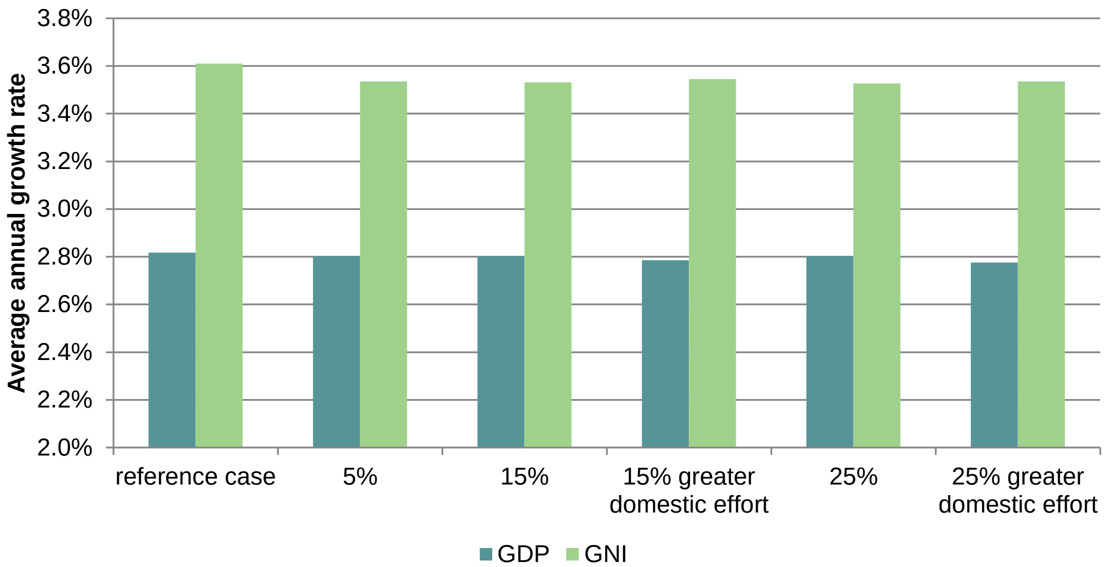
Note: Treasury's 2008 report reports GNI as GNP (gross national product). The two measures are very similar.

Source: *Vivid Economics based on modelling results from CoPS MMRF.*

A stronger target might call for greater domestic effort. Irrespective of the target level, under the relatively low current price outlook, the emissions levels in Australia as modelled would continue rising, up 7 per cent from 2012 levels in 2020. This is because any additional emission reductions would come from the purchase of international units. While this is a low-cost strategy for meeting a given target, greater domestic effort could better position Australia's economy for deeper cuts in the longer term. Furthermore, community expectations might call for a stronger target to be translated into stronger domestic action. It would also send a stronger signal of Australia's commitment to the international community.

Shifting the balance towards greater domestic effort and away from overseas emissions permits means a larger impact on domestic GDP, but reduces the impact on GNI. We construct "greater domestic effort" scenarios where domestic emissions levels fall by 4 per cent and 8 per cent respectively from 2012 to 2020, with the Australian carbon price significantly higher than assumed in the standard scenarios. In these scenarios, the impact on domestic GDP is increased by around half for the 15 per cent target, and almost doubled for a 25 per cent target. Nonetheless, the overall GDP impact is still moderate; an economy which achieves a 25 per cent target with more than half of the emissions reductions achieved domestically would still reach the same level of GDP as achieved without any climate policy just three months later. The impact on annual economic growth rates is very small. At the same time, the overall cost of purchasing international emissions units falls to less than half of that in the corresponding standard scenarios. Australia's GNI is modelled to be affected *less* in the "stronger domestic effort" scenarios than under the standard assumptions.

Figure 3. **Across all scenarios, the impact on average annual growth rates is barely discernible**



Note: *Note vertical axis starts at 2 per cent*

Source: *Vivid Economics based on modelling results from CoPS MMRF.*

Industry-level output changes are minor, and largely confined to a small number of industries that will continue growing in absolute terms. This is possible because of technological improvements and substitution away from high-emissions inputs towards low-emissions inputs. In a scenario in which emissions are reduced by 25 per cent by 2020, among Australia's 25 largest industries, only the coal, gas and electricity industry are modelled to experience output reductions of greater than 2 per cent, relative to the reference case. In absolute terms, these industries are modelled to keep growing with employment in the coal and gas industries expected to either remain stable or grow. For 9 out of the 25 largest industries it is projected that output value will actually increase relative to the baseline of no climate policy.

The macroeconomic impacts are differentiated between states. The largest overall impacts are in Queensland and New South Wales reflecting the higher proportion of coal mining and electricity generation from coal, but even here state level economic product is reduced by no more than 0.4 per cent in the standard scenarios. This is relative to a baseline of continued significant growth in all states and territories.

Acting now may save costs later. Adopting a more ambitious target to 2020 may require a less steep trajectory of emissions reductions in following decades. Deferring emission reductions to the future would allow Australia's emission reductions to take place when the country is richer. But early action to reduce emissions can reduce the risk of 'lock-in' of high carbon assets, which might otherwise mean higher costs in the medium to long run.

Many analyses find that that the cost of delay may be significant. Earlier Treasury modelling found that delayed action increases Australia's future mitigation costs, with a three year delay resulting in higher mitigation costs of 2 to 10 per cent in 2050. International academic analysis suggests that more ambitious early action can help to reduce total costs over time, and could drastically reduce the magnitude of future carbon prices. The International Energy Agency finds that if strong global mitigation is to be achieved, for every dollar of investment avoided by taking less action before 2020, an additional four dollars would need to be spent between 2021 and 2035 to compensate for the higher emissions.

The transformation to a low-carbon society will require a radical shift in technologies. To avoid dangerous climate change, rapid, extensive and widespread low-carbon innovation will be required, in a transformation that has been compared to the advent of information technology. Countries that are able to develop a comparative advantage in key technologies may see economic benefits. Australia may be able to develop intellectual property that will be valuable in a low-carbon future, for example in geothermal and other forms of renewable energy, biosequestration, as well as carbon capture and storage.

Australia may not be well positioned for a global low carbon economy at present, but stronger domestic emissions reduction action will help. The required change in technologies to realise a low-carbon future could be massively disruptive to existing patterns of international trade and comparative advantage. Continued and strengthened domestic mitigation action including through carbon pricing will be important in turning this threat into an opportunity.

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1 Introduction

This report informs the debate on the costs and benefits of Australia increasing its level of emission reduction ambition. Australia's current target, submitted to the Copenhagen Accord in 2010, commits Australia to an unconditional 5 per cent reduction in emissions from 2000 levels as well as more stringent targets in the event of greater global cooperation on mitigation. The Climate Change Authority (CCA) has recently announced the commencement of its statutory 'Caps and Targets Review' which, among other things, will provide independent recommendations on whether this target should be increased; as well as a cap for the first five years of the carbon pricing mechanism; and a national carbon budget.

The report provides two salient pieces of analysis that should be taken into account in this decision. This is in the context of the CCA's issues paper[1] which invites input from stakeholders to better inform its analysis and recommendations.

First, it presents new macroeconomic modelling analysis of the economic impact of Australia adopting a more ambitious emissions reduction target. This modelling takes account of recent changes in both economic and policy circumstances, in particular the decision made to link the Australia's Carbon Pricing Mechanism with that of the European Union Emissions Trading Scheme. This analysis uses the Monash Multi-Regional Forecasting (MMRF) model that has previously been used by the Australian Treasury in its own analysis. The modelling was conducted by the Centre of Policy Studies (CoPS) at Monash University.

A secondary, complementary analysis provides a brief review of the long-term benefits associated with taking more ambitious action on climate change in the near term. This includes an examination of the existing literature on the possible importance of avoiding high-carbon 'lock-in' as well as the potential benefits available to countries that acquire comparative advantage in low-carbon technologies.

[1] Climate Change Authority (2013) Caps and Targets Review, April.

2 Modelling the impact of more ambitious action

The cost of meeting more ambitious targets has fallen

We provide new modelling analysis on the macroeconomic impacts of Australia meeting different emission reduction targets. Our modelling shows that as a consequence of the change in policy settings, the macroeconomic context and the changes in international carbon price outlook, the costs of achieving a given emission reduction target is lower than it was thought to be back in 2009 when Australia first committed to a 5 per cent emissions reduction target by 2020. It further shows that the additional macroeconomic costs of moving from a 5 per cent to a 15 per cent or 25 per cent reduction target would be small under current policy settings, because the additional reductions would likely be achieved solely through purchases of relatively low-cost international permits.

We also model domestic emissions trajectories under greater domestic abatement effort. We show that under current policy settings, the amount of abatement achieved domestically would be less than under earlier assumptions of higher international prices, and absolute emissions would continue increasing from today's level. We model the effects of achieving a 15 per cent or 25 per cent target with greater domestic mitigation effort. While this would raise the Gross Domestic Product (GDP) costs of meeting the more ambitious emission reduction targets, as a result of higher domestic carbon prices and greater domestic mitigation action, the costs in terms of Gross National Income (GNI) would be reduced relative to relying on purchases of international emissions reductions[2]. The modelled macroeconomic costs remain below 0.1 per cent of GDP per year for a 25 per cent reduction target at 2020 even when the majority of emissions reductions occur domestically.

We begin by describing the modelling framework, then report results for standard scenarios of achieving a 5 per cent, 15 per cent or 25 per cent target along with sensitivity analysis, and then report results for scenarios where a greater share of the mitigation effort takes places domestically within Australia.

2.1 Modelling framework, scenarios and assumptions

Our modelling framework is similar to that used by the Australian Treasury in earlier analyses. We use the Monash Multi-Regional Forecasting (MMRF) model, a whole-of-economy model rich in industry detail that captures interactions between different sectors of the economy and among producers and consumers, and tracks emissions levels by economic sector and region.[3] Further details of the modelling

[2] GDP is a measure of the value of the economic activity taking place within a country. GNI is a measure of the income flowing to residents of a country; GNI adjusts GDP to take account of payments made and received from other countries.

[3] Adams, P.D., Dixon, J., Gieseke, J. and Horridge, M.J., 2011. 'MMRF: Monash multi-regional forecasting model: a dynamic multi-regional applied general equilibrium model of the Australian economy', Working Paper, Centre of Policy Studies, Monash University.

framework are provided in the Appendix. The model used is similar to that employed (alongside other models) in the Australian Treasury's 2008 and 2011 reports on modelling a carbon price.[4] The focus in the modelling for this report is domestic. We do not model carbon pricing in other countries or how changes in Australia's target might lead to indirect changes (in climate policy, for instance) in any other country.

The MMRF model has been updated for economic and policy developments. The Centre of Policy Studies at Monash University was commissioned to update the MMRF model and run specific modelling scenarios developed by Vivid Economics for this report. The model has been updated with economic and emissions data to 2012. In line with the earlier Treasury modelling, all emissions in the economy are assumed to be covered by the carbon price, while actual existing policy settings do not impose the emissions price on emissions from agriculture and forestry (except in a limited and indirect way through the Carbon Farming Initiative), parts of transport and some other emissions sources. The revenue from the carbon price is modelled to be shared between reductions in income tax, transfers to industry and any purchases of international emissions units. The allocation of permit revenue to households and industries is broadly similar to that in operation under the Clean Energy Future legislation. The earlier Treasury modelling assumed redistribution to households in a lump-sum fashion as opposed to tax cuts. The Renewable Energy Target is modelled in the policy scenarios, and not in the reference case.

The baseline has been updated. The outlook for economic growth and future emissions levels in the reference case without carbon pricing has been updated. This includes a slightly lower trajectory for future GDP growth than assumed in Treasury's previous modelling exercises, a lower growth outlook for electricity use and a higher growth outlook for output from the liquefied natural gas (LNG) industry. The reductions from the reference case needed to achieve a given emissions target at 2020 are slightly lower in our updated modelling than in the Treasury's 2011 modelling report.[5] All dollar figures relating to this report's modelling are given in 2012 Australian dollars. Results from policy scenarios are reported relative to the baseline, which is also referred to as reference case.

Our assumptions for international prices are in line with, or somewhat higher than, the current market outlook. We have updated assumptions about international permit prices to reflect the recent drop and subdued price outlook for EU emissions allowances (EUAs). Specifically, we assume that the EUA price and CER price are A$10/t and A$1/t in 2016 respectively, and that both rise by 10 per cent in real terms each year. This is above the level of forward markets for 2016 as of mid-May 2013 and in line with the Treasury's most recent price projection for Australia's carbon price in 2015/16 of $12.1/t[6]. It also implies a stronger annual rate of increase from 2016 onwards than is apparent in forward markets. In other words, it represents

[4] Australian Government (2008), *Australia's low pollution future: the economics of climate change mitigation*, Treasury; Australian Government (2011), *Strong growth, low pollution: modelling a carbon price*, Treasury.

[5] To achieve a 5 per cent reduction in net national emissions on 2000 levels by 2020, our modelling analysis suggests a 23 per cent reduction relative to the reference case is required; in the Treasury's 2011 modelling, a 24 per cent reduction was needed to achieve the same target.

[6] Combet G. (2013) *Clean Energy Future package working in Australia's interest,* Joint media release with the Deputy Prime Minister and Treasurer, the Hon Wayne Swan MP, 14th May 2013. Available at http://minister.innovation.gov.au/gregcombet/MediaReleases/Pages/CleanEnergyFuturepackageworkinginAustraliasinterest.aspx. Accessed 24th May 2013. The budget assumption is in nominal terms whereas our price assumptions are in 2012 dollars.

a significant recovery in the price outlook, either through policy change or a change in economic growth outlook for Europe. If market expectations prove correct then the actual macroeconomic impacts may be more benign than reported here. For the years 2013 to 2015, the domestic price is assumed to be as legislated under the ‘fixed price’ phase of the carbon pricing mechanism, rising from A$23 to A$25/t.

We model the existing limits on trading in CERs. We model the use of Certified Emissions Reductions (CERs) from the Clean Development Mechanism (CDM) up to 12.5 per cent of actual emissions from 2015. This is in line with the 12.5 per cent limit on the use of CERs by Australian liable entities under the current legislation, applying from mid-2015 when Australia’s carbon pricing mechanism turns into an emissions trading scheme with linkage to the EU ETS.

We model the government’s target range. We model a reduction in net national emissions (after international trading) of 5 per cent, 15 per cent and 25 per cent at 2020 relative to 2000, in line with the target range supported by both the Australian government and the current opposition.

We conduct sensitivity analysis on international prices. We model a 5 per cent reduction scenario where international prices are assumed to be the same as in the Treasury’s 2011 modelling report, about twice as high as assumed here for EUAs and without access to much cheaper CERs. We also model a 25 per cent scenario where the additional demand for emissions reductions from Australia increases the EUA price by one quarter, in order to test the sensitivity of macroeconomic impacts to possible increases in permit prices arising from increased Australian demand.

We also test the effect of greater domestic effort in achieving a 15 per cent or 25 per cent target. If a stronger target than the current 5 per cent target was agreed, it may be a consideration to combine this with a greater extent of domestic action to reduce emissions, rather than allowing the fulfilment of a stronger target purely by way of more purchases of international emissions units. We model scenarios where only half the amount of international emissions credits and permits of those used in the respective standard scenarios is used, with the domestic permit price increasing above the EUA price.

Table 1 below summarises the key modelling assumptions across the different scenarios.

Table 1. **We model five scenarios that vary according to the emission reduction target, domestic and international credit prices and restrictions on international trading**

Scenario family	Scenario description	Target (2020 relative to 2000)	International price from 2016-20 (A$2012/t$CO_2$e)	International trading of emissions units
Reference case	No emissions target	No emissions target	No domestic carbon price	No trading of emissions units
Standard scenarios	5% target	-5%	EUAs: A$10/t in 2016 rising to A$15/t in 2020 (rising 10%pa) Domestic price equal to EUA price. CERs: A$1.00/t in 2016 rising to $1.50/t in 2020 (rising 10%pa).	No restrictions on EUA use; CER use restricted to 12.5% of emissions
	15% target	-15%		
	25% target	-25%		
"Greater domestic effort" scenarios	15% target, greater domestic effort	-15%	International prices as per the standard scenarios. Domestic price determined in model to meet emissions target: at 2020, $38/t for 15 per cent target and $45/t for 25 per cent target.	EUA use limited to 50% of the amount used in the corresponding unrestricted scenario; CER use restricted to 12.5% of emissions
	25% target, greater domestic effort	-25%		
Sensitivity analysis	5% target, Treasury's 2011 price assumption	-5%	Price assumptions match those of "core policy scenario" in Treasury's 2011 modelling: A$31/t at 2020 for all international units, domestic price equal to international price	No restrictions on use of international units, no distinction between EUAs and CERs
	25% target, higher price	-25%	EUA prices 25% higher than in standard 25% scenario	As per standard scenarios

Note: *In all scenarios, the modelled carbon price during 2013-15 is in line with the fixed price as per current legislation (A$23/t rising to A$25/t).*
All policy scenarios include modelling the 2020 Renewable Energy Target (RET). The reference case does not include the RET.

Source: *Vivid Economics*

It is likely that in each scenario, accounting for forest related emissions will make for a smaller abatement task to reach Australia's emissions target, and lower macroeconomic costs, than modelled here. In all scenarios, we do not model emissions reductions and increased carbon sequestration from forest management, as well as deforestation, afforestation and reforestation. It is likely that even without carbon pricing, net emissions from these sources will significantly decrease over the period to 2020, and make it commensurately easier to achieve a given 2020 emissions target. It has been estimated that the cumulative abatement task to 2020 is reduced by 52 to 114 Mt as a result of reductions in net deforestation, and that forest management could reduce the abatement task by 96 Mt under conservative assumptions; additional reductions could arise from reforestation and afforestation.[7] It will be possible for Australia to account for deforestation, forest management and other land-related emissions and sequestration under the second period of the Kyoto Protocol. The cumulative abatement task (the difference between reference case emissions and the trajectory towards the target) for 2013-20 in our model is 685Mt for the 5 percent target, 894Mt for a 15 per cent target, and 1104Mt for a 25 per cent target. Thus including deforestation and forest management could reduce the abatement task for a 5 per cent target by between one fifth to one third, and more if reforestation and afforestation were included. In addition, the abatement task may be further reduced if accumulated surplus emissions units from the first period of the Kyoto Protocol were used, amounting to 101 to 107Mt.[8]

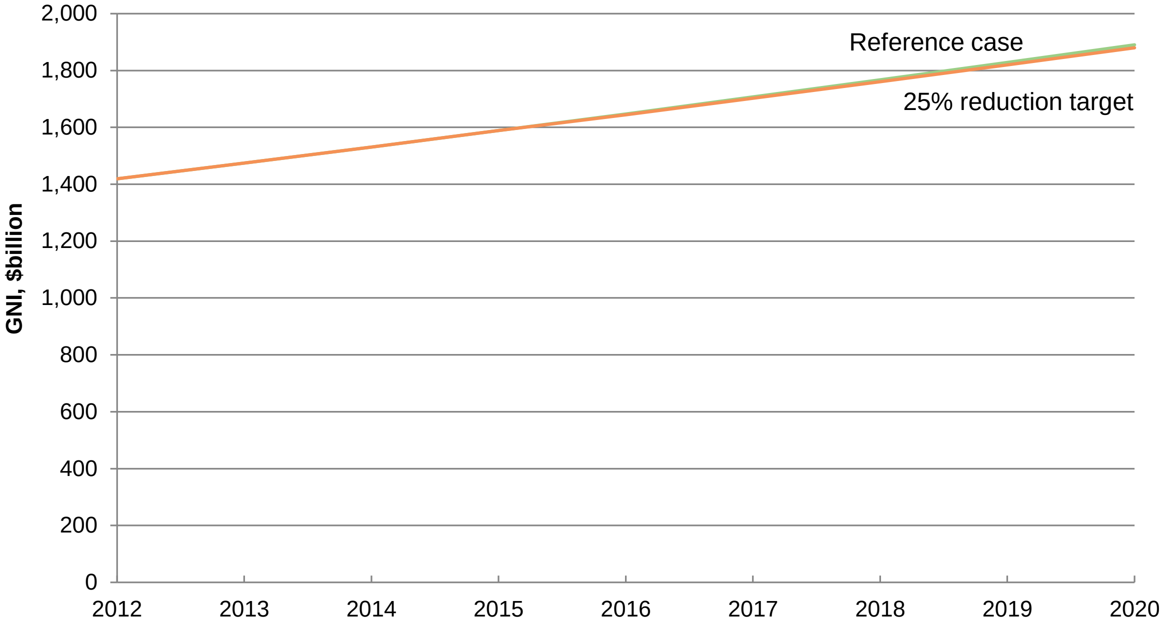
2.2 Macroeconomic costs of achieving Australia’s targets

The macroeconomic costs of achieving Australia’s 5 per cent emissions target are moderate. Achieving a 5 per cent national emissions reduction by 2020 in our modelling would result in GDP and consumption being 0.3 per cent lower in 2020 than in the reference case. This implies that the same level of GDP would be reached less than two months later than if no action was taken; the annual reduction in the pace of economic growth would be less than 0.05 per cent. Gross national income (GNI), which accounts for international payments, in particular the purchases of emissions reductions from other countries, is reduced by around 0.5 per cent relative to the reference case at 2020, implying that GNI would grow by just 0.1 per cent less per year than if there was no climate policy. GNI would still be 27 per cent larger in 2020 than in 2013 when achieving the 25 per cent target. This is illustrated in Figure 4 below where the trajectory for GNI over the period 2012-2020 shows very little difference between the reference case and the 25 per cent reduction target case.

[7] Macintosh, A. (2011) Are forest management reference levels incompatible with robust climate outcomes? A case study on Australia *Carbon Management* **2**:11; Macintosh, A. (2011) Durban Climate Conference and Australia’s abatement task, *CCLP Working Paper Series* 2011/2

[8] Macintosh, A. (2011) Durban Climate Conference and Australia’s abatement task, *CCLP Working Paper Series* 2011/2

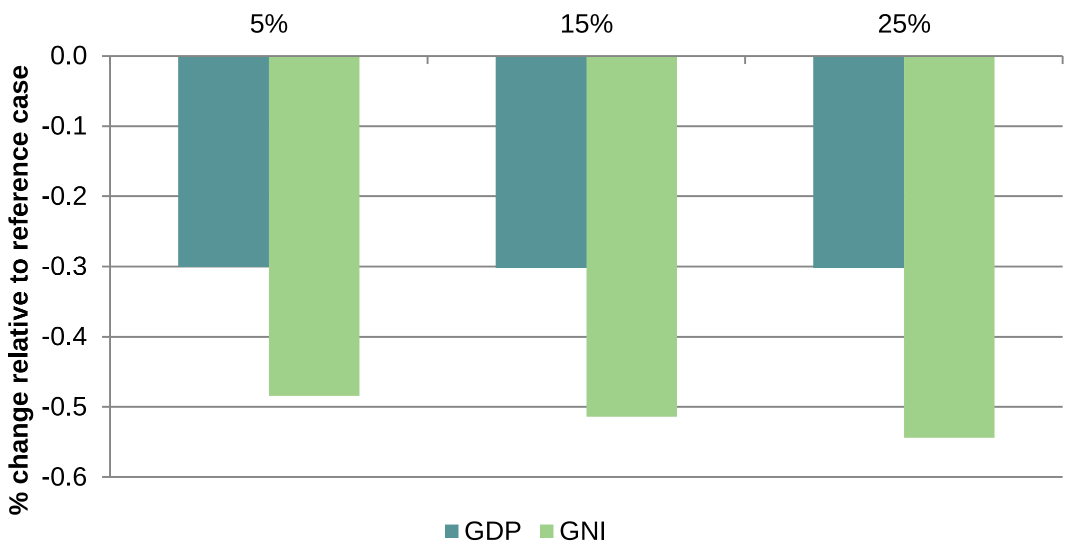
Figure 4. **The macroeconomic costs of achieving a 25 per cent reduction in emissions are very small compared to underlying economic growth**



Source: *Vivid Economics based on modelling results from CoPS MMRF.*

Moving to a stronger reduction target has very low additional macroeconomic costs. The level of domestic economic activity, as measured by GDP, remains unchanged when moving from the 5 per cent to a 15 per cent or 25 per cent target. This is because under current policy settings, it is likely that the more ambitious reductions would not induce much additional mitigation action in Australia, but would rather come predominantly from international sources, including Certified Emissions Reductions (CERs) from the Clean Development Mechanism (CDM) and EU Emissions Allowances (EUAs). The impact on GNI is very slightly larger as a result of moving to a stronger target: changing from a reduction of 0.48 per cent in 2020 in the 5 per cent scenario to 0.54 per cent in the 25 per cent reduction scenario.

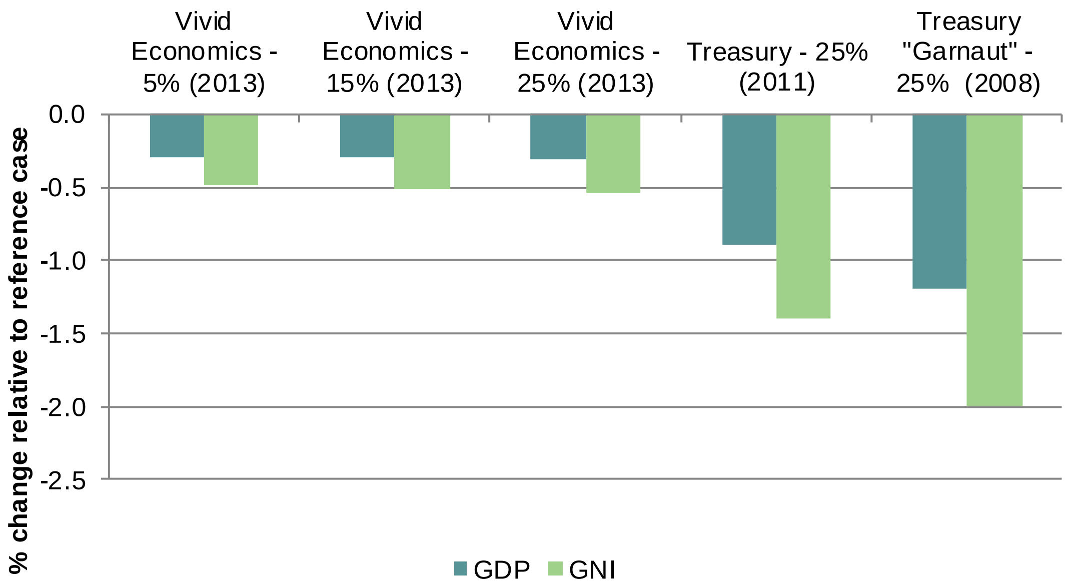
Figure 5. **The additional cost of achieving a stronger target is very small**



Source: *Vivid Economics based on modelling results from CoPS MMRF.*

The costs of achieving a stronger target are much lower than expected when the target range was originally set. The lower price outlook for international emissions permits and offset credits reduces both Australia's domestic economic impacts and the amount of money spent on international emissions units. This results in much lower macroeconomic costs in terms of both GDP and GNI. For example, the Australian Treasury's 2011 modelling study showed a 0.9 per cent reduction in GDP and a 1.4 per cent reduction in GNI relative to the reference case for the 25 per cent target case, and the need to purchase around A$7.3 billion of international emissions units. Treasury's 2008 modelling of the "Garnaut 25 per cent target" scenario showed even greater macroeconomic costs and international transfers. By contrast, in our updated modelling of a 25 per cent target, the GDP impact at 2020 is 0.3 per cent, the GNI impact is 0.5 per cent, and the cost of purchasing of international emissions units is A$2.2 billion (A$2 billion for EUAs, the rest for CERs).

Figure 6. **The macroeconomic costs of a stronger target are much lower than previously estimated**



Note: Treasury's 2008 report reports GNI as GNP (gross national product). The two measures are very similar.

Source: Vivid Economics based on modelling results from CoPS MMRF.

The modelling suggests that if extra Australian permit demand drove up the EU trading price this would only affect Australian costs to a minor extent. Increased demand for EUAs from Australia may increase the EUA price. It is unclear what the magnitude of the price effect might be, however it is likely to be relatively small given that Australia's ETS is less than one sixth the size of the EU ETS. To test the effect, we ran a sensitivity analysis where the EUA price is raised by one quarter in response to a shift from an Australian 5 per cent target to a 25 per cent target. This would be a very large price impact on the combined market. Compared to the standard 25 per cent scenario, the impact on Australia's GDP at 2020 changes from 0.30 per cent to 0.34 per cent. The impact on GNI changes from 0.54 per cent to 0.75 per cent, mostly as a result of greater costs of purchased permits.

The full set of these results is in Table 2 below.

Table 2. **The costs of achieving Australia's emissions targets are lower than previously estimated**

Modelling exercise	Scenario	% change in GDP relative to reference case, 2020	% change in GNI relative to reference case, 2020	Domestic carbon price at 2020	Amount of international permits purchased at 2020 ($MtCO_2$-eq)	Cost of purchasing international emissions units (A$billion)
Vivid Economics (2013)	5%	-0.30	-0.48	A$15/t	108	0.5
	15%	-0.31	-0.51	A$15/t	163	1.3
	25%	-0.31	-0.54	A$15/t	219	2.2
	5%, Treasury's 2011 price assumption	-0.37	-0.40	A$31/t	90	0.3
	25%, higher international price	-0.34	-0.75	A$18/t	234	2.9
Treasury (2011)	5% "core policy scenario"	-0.3	-0.5	A$29/t	94	2.7
	25% "high price scenario"	-0.9	-1.4	A$62/t	118	7.3
Treasury (2008)	5% "CPRS -5"	-1.2	-1.3	A$35/t	46	1.6
	15% "CPRS -15"	-1.2	-1.7	A$50/t	46	2.3
	25% "Garnaut -25"	-1.6	-2.0	A$60/t	100	6.0

Note: *Treasury (2011): data from Table 5.1 for MMRF model, carbon price in 2010 dollars. Treasury (2008): data from Tables 6.4 and 6.8 for MMRF model, carbon price in 2005 dollars. Treasury (2008) reported GNP rather than GNI; the two measures are very similar.*

"Vivid Economics (2013)": Modelling results from CoPS MMRF.

Source: *Vivid Economics*

2.3 Emissions and costs under greater domestic effort

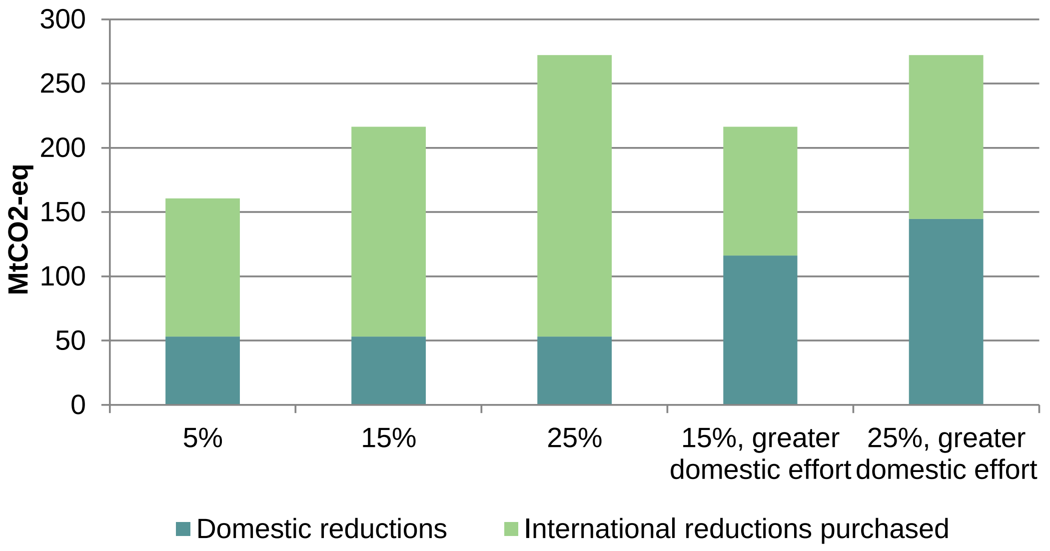
The lower market prices result in lower domestic abatement effort. In all of the scenarios presented above, the emissions levels in Australia as modelled would continue rising, up 7 per cent from 2012 levels in 2020. This is because the relatively low permit price in the EU ETS determines the Australian domestic carbon price, and results in only a relatively modest reduction in emissions relative to the reference case.[9] This occurs independently of the stringency of the target as all of the additional effort in the 15 per cent and 25 per cent scenarios is met by international permit purchases.

A stronger target might call for greater domestic effort. While meeting more ambitious targets from the purchase of international emission units is a low-cost strategy for meeting a given target, if Australia were to move to a more ambitious emissions target, there is a question as to whether this should also result in greater domestic effort. This could serve to better position Australia's economy for deeper cuts in the longer term, as discussed in Section 3 below. Furthermore, community expectations might call for a stronger target to be translated into stronger domestic action. It would also send a stronger signal of Australia's commitment to reduce emissions to the international community.

We model two scenarios where a stronger target is partly met by increased domestic abatement action. We construct "greater domestic effort" scenarios for the 15 per cent and 25 per cent target, by assuming that the amount of international emissions units used is explicitly restricted to be only half of that in the standard 15 per cent and 25 per cent targets. In turn, domestic abatement is increased. This is modelled by way of the Australian carbon price rising above the EUA price, to a level that fulfils the target at 2020. Additional domestic abatement could also be achieved through policy instruments other than carbon pricing. In both "greater domestic effort" scenarios, just over half of the total abatement would be undertaken domestically, compared to only one quarter and one fifth in the standard 15 per cent and 25 per cent scenarios.

[9] The emissions reductions relative to the reference case shown in Figure 4 also include the effect of the Renewable Energy Target.

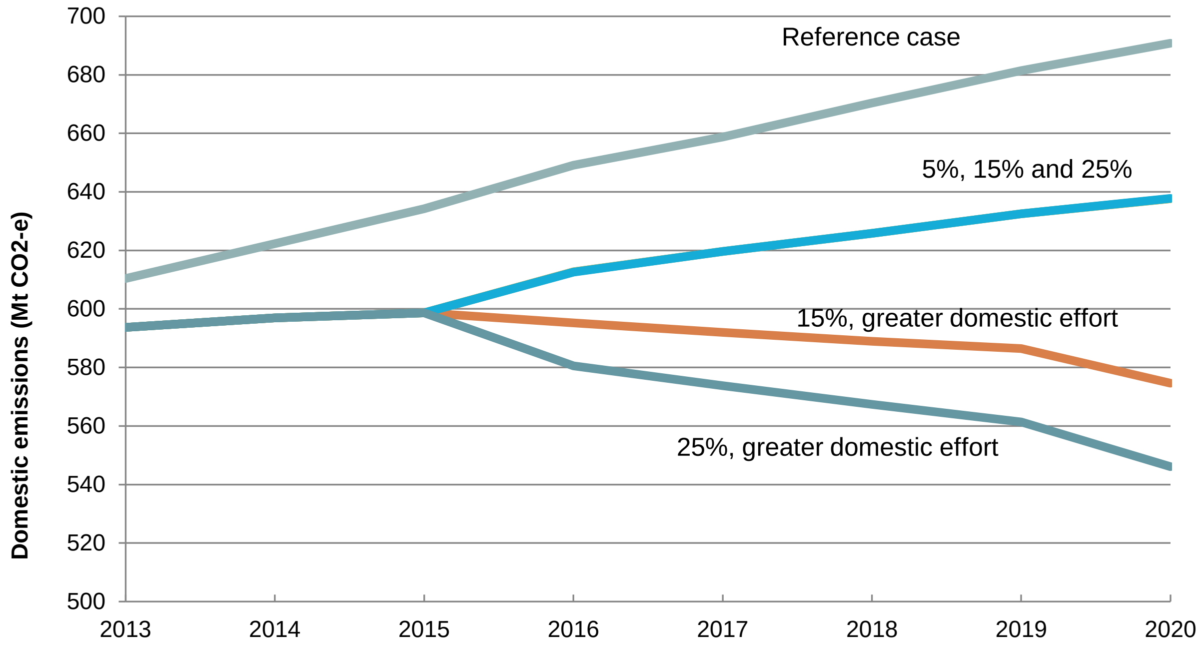
Figure 7. **The balance between domestic and international abatement differs strongly between scenarios**



Source: Vivid Economics based on modelling results from CoPS MMRF.

A higher domestic carbon price would achieve reductions in domestic emissions relative to current levels. Our "greater domestic effort" scenarios show domestic emissions levels falling by 4 per cent and 8 per cent respectively from 2012 to 2020. The Australian carbon price is significantly higher than assumed in the standard scenarios, namely A$38/t and A$45/t in the 15 per cent and 25 per cent "greater effort" scenarios respectively in 2020 (compared to the A$15/t in the standard scenarios). Greater domestic action could alternatively be achieved through policies other than the carbon price, though this is not explicitly modelled here and is likely to result in higher macroeconomic costs.

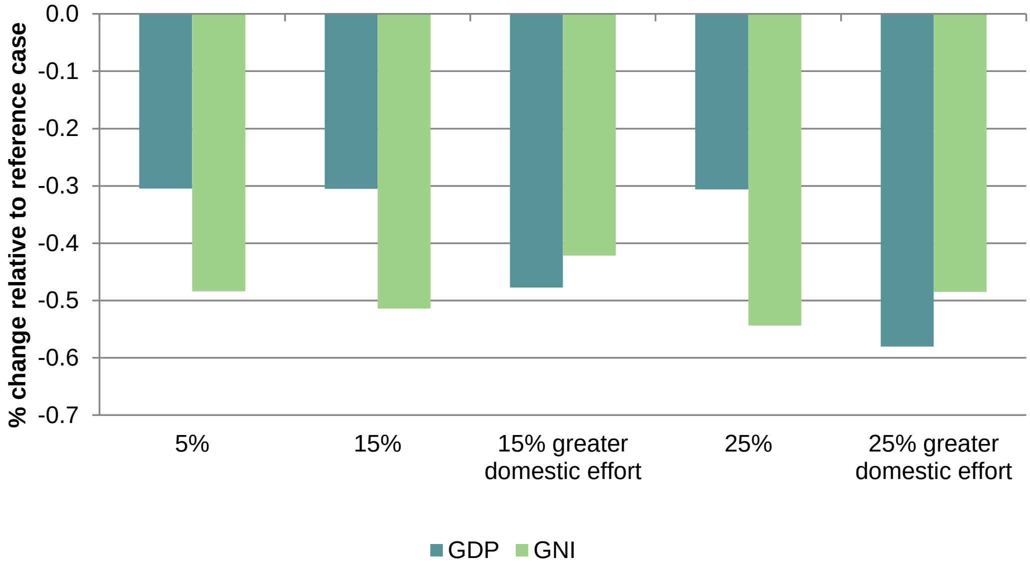
Figure 8. **Domestic emissions would rise unless more stringent targets were accompanied by a deliberate policy choice to encourage domestic abatement**



Source: *Vivid Economics based on modelling results from CoPS MMRF.*

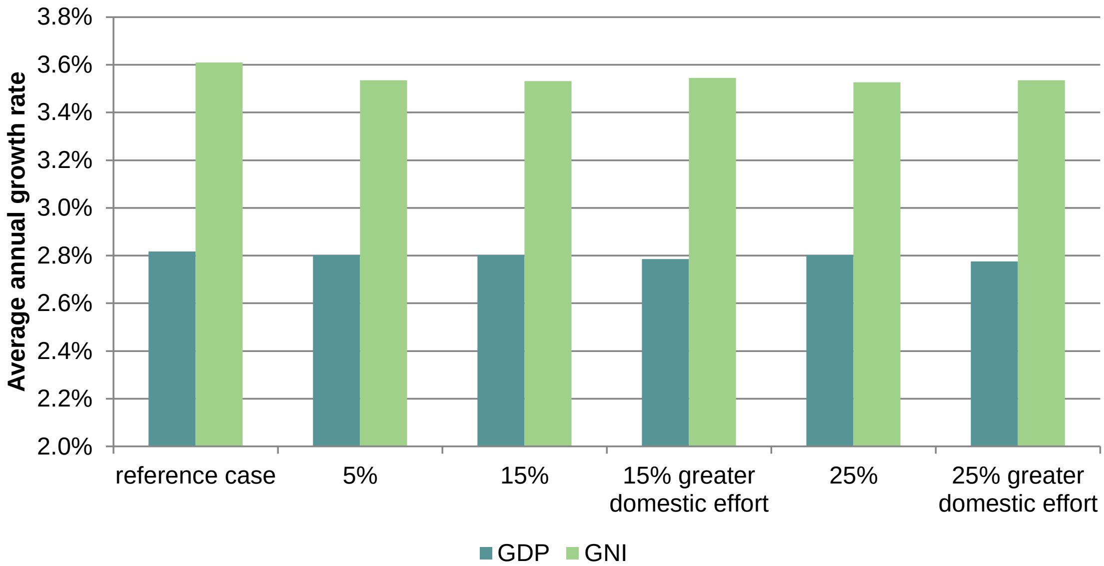
Shifting the balance towards greater domestic effort and away from overseas emissions permits means a larger impact on domestic GDP, but reduces the impact on GNI. In the "greater domestic effort" scenarios, the impact on domestic GDP is increased by around half for the 15 per cent target (from 0.31 per cent to 0.48 per cent), and almost doubled for a 25 per cent target (from 0.31 per cent to 0.58 per cent). Nonetheless, the overall GDP costs are low: amounting to less than 0.1 per cent a year for a 25 per cent target that has more than half of the emissions reductions achieved domestically. By 2020, the economy would achieve the same level of GDP as achieved without any climate policy just three months later. At the same time, the overall cost of purchasing international emissions units falls to less than half of that in the corresponding standard scenarios. This is reflected in the impact on Australia's GNI being *less* in the "stronger domestic effort" scenarios than under the standard assumptions. These results are shown below, first relative to the reference case baseline and then expressed in terms of the impact in annual average growth rates.

Figure 9. **Scenarios with greater domestic effort would result in greater GDP costs but lower GNI costs**



Source: *Vivid Economics based on modelling results from CoPS MMRF.*

Figure 10. **Across all scenarios, the impact on average annual growth rates is barely discernible**



Note: *Note vertical axis starts at 2 per cent*

Source: *Vivid Economics based on modelling results from CoPS MMRF.*

The full results comparing the "greater domestic effort" and standard scenarios in 2020 are shown in Table 3 below.

Table 3. **The 2020 key results show that increasing the proportion of emission reductions achieved domestically increases the domestic carbon price and GDP impact but reduces the GNI impact**

Scenario	Domestic emissions reductions (Mt)	International emissions reductions purchased (Mt)	Carbon price, $/tCO_2$-eq	Costs of international emissions purchases, A$ billion	Change in GDP relative to reference case, %	Change in GNI relative to reference case, %
5%	53	108	15	0.5	-0.30	-0.48
15%	53	163	15	1.3	-0.31	-0.51
15%, greater domestic effort	116	100	38	0.5	-0.48	-0.42
25%	53	219	15	2.2	-0.31	-0.54
25%, greater domestic effort	145	128	45	1.0	-0.58	-0.49

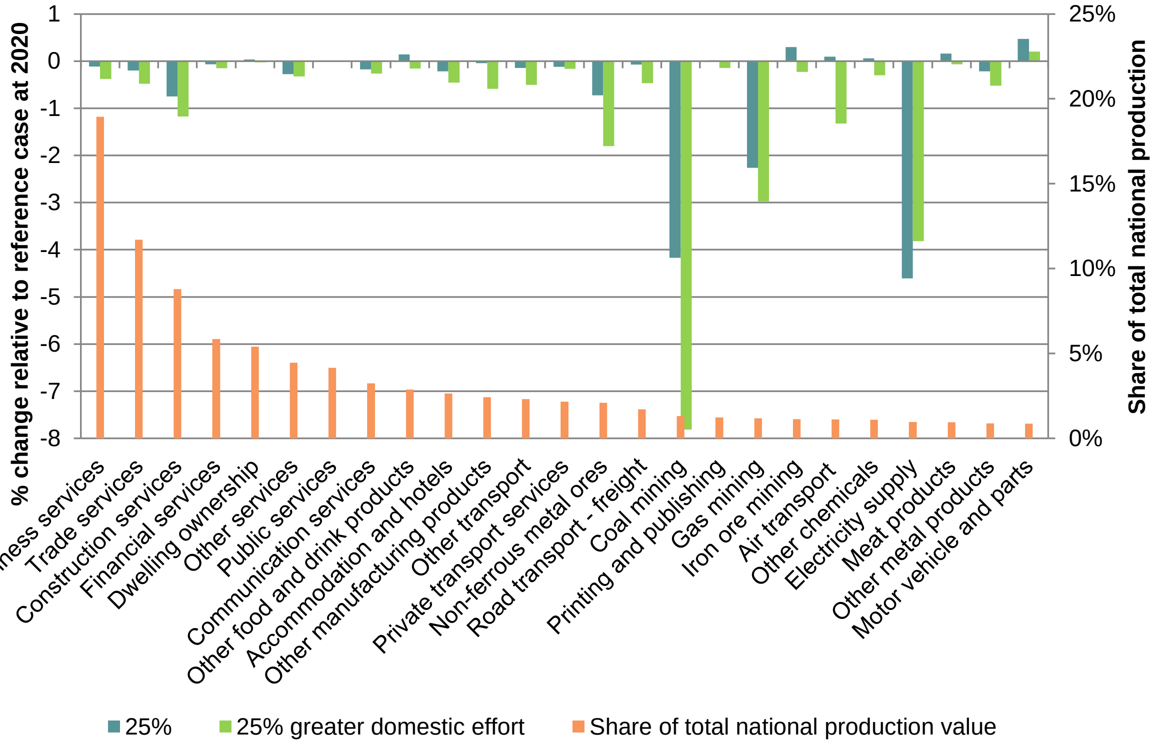
Source: Vivid Economics based on modelling results from CoPS MMRF.

2.4 Industry level and state level results

The modelling framework allows disaggregation of the economic impacts to the industry level and regional disaggregation by State. The model represents the Australian economy as 58 different industries. More so than for the national level results, it is important to keep in mind that the disaggregated results are indicative in nature. For instance, while based on current economic statistics, the MMRF model represents economic responses to a carbon price and other price changes in a homogenous manner for each industry. The model does not include detailed representations of the cost structures in particular plants and other idiosyncratic factors that may affect production decisions. As noted earlier, we also do not model the effect of other countries' climate policies on Australia. Below we show changes in industry production value relative to the reference case at 2020, in the standard 25 per cent scenario and the 25 per cent "greater domestic effort" scenario. The changes in the standard 5 and 15 per cent scenarios are the same as in the 25 per cent scenario, because the carbon price is the same.

Among the 25 largest industries, only the coal, gas and electricity industry are modelled to experience output reductions, relative to the reference case, of more than 2 per cent. The 25 largest industries shown in Figure 11 collectively account for ninety per cent of Australian industry output as represented in the model. The largest percentage reductions in output are in the coal industry, which sees output decline by 4 and 8 per cent relative to the baseline in the two scenarios respectively; followed by electricity which has approximately a 4 per cent reduction in both scenarios; and the gas industry where output falls by 2-3 per cent in the two scenarios. Each of these three industries accounts for less than 1.5 per cent of total national industry output value. In the standard 25 per cent reduction target scenario, nine experience increases in output value relative to the reference case and 11 out of the 25 largest industries experience reductions in value of production of less than 0.5 per cent.

Figure 11. **Changes in industry production value are small for most of Australia's large industries**

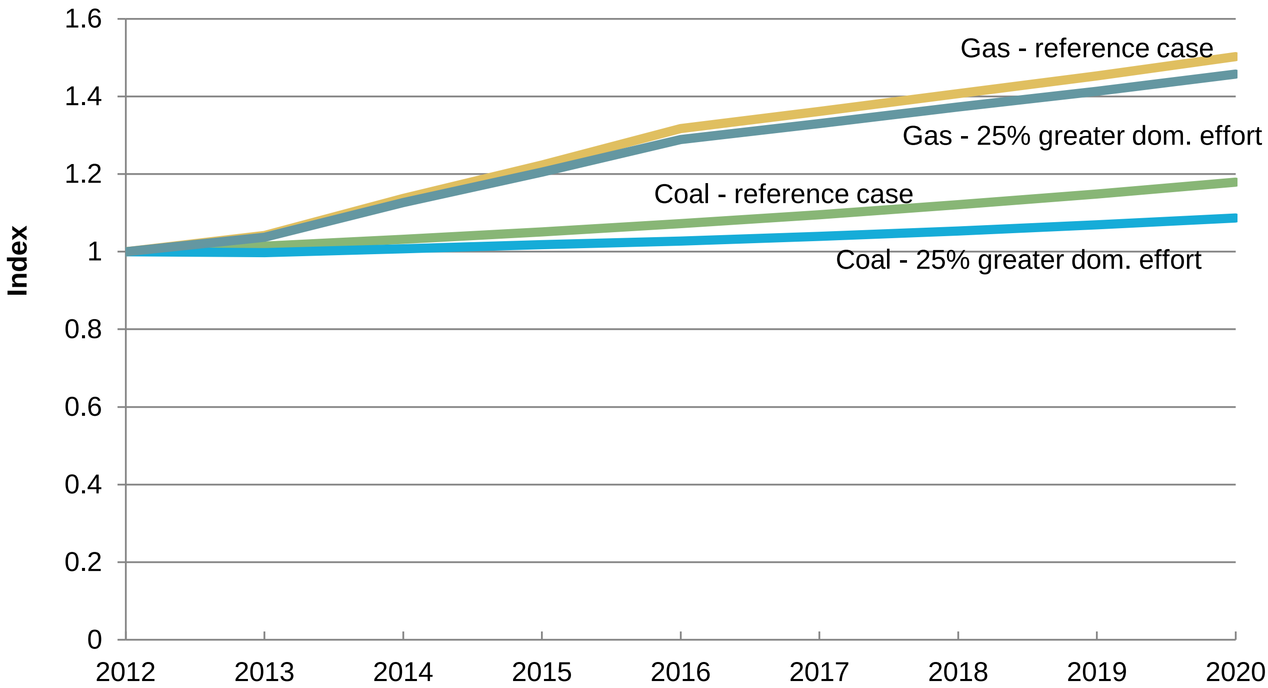


Source: *Vivid Economics based on modelling results from CoPS MMRF.*

Changes in output as a result of more ambitious action will take place in industries that are benefitting from an absolute growth in output. All industries except hydroelectricity increase their output over time in the reference case, on average at the rate of GDP growth (assumed to be 2.9 per cent per year on average from 2012 to 2020). The coal industry for example is projected to grow its production value by 18 per cent (adjusted for inflation) between 2012 and 2020, the gas industry by 50 per cent, and the electricity supply industry by 13 per cent. The modelled reductions of output value even under a 25 per cent "stronger domestic effort" scenario would thus result in continued growth in output value in absolute terms. This is shown for the coal and gas sectors in Figure 12 below. Similarly, in this scenario, absolute employment levels in the coal industry remain virtually unchanged over the period 2013-2020, while employment in the gas sector grows by more than 8 per cent over the same period. However it needs to be noted that only domestic climate policies are modelled here, we do not analyse the effects that other countries' policies may have on demand for Australian exports.

Reductions in emissions are achieved while the economy and value of industry output continues growing strongly. This is possible because of technological improvements and substitution away from high-emissions inputs towards low-emissions inputs.

Figure 12. **Even the most strongly affected industries experience growth in output value over time, under a 25 per cent "stronger domestic effort" scenario**



Source: *Vivid Economics based on modelling results from CoPS MMRF.*

It is likely that most sectors will experience smaller declines in output than would have been anticipated in earlier modelling exercises. Although we have not undertaken a detailed comparison of these sectoral results with those from earlier studies, it is likely that the pattern of lower costs seen at the macroeconomic level in section 2.2 above, would be replicated at a sectoral level. This would be both as a direct result of the lower carbon price and also because the lower carbon price would be likely to imply smaller increases in electricity prices than previously expected (although electricity impacts have not been explicitly modelled).

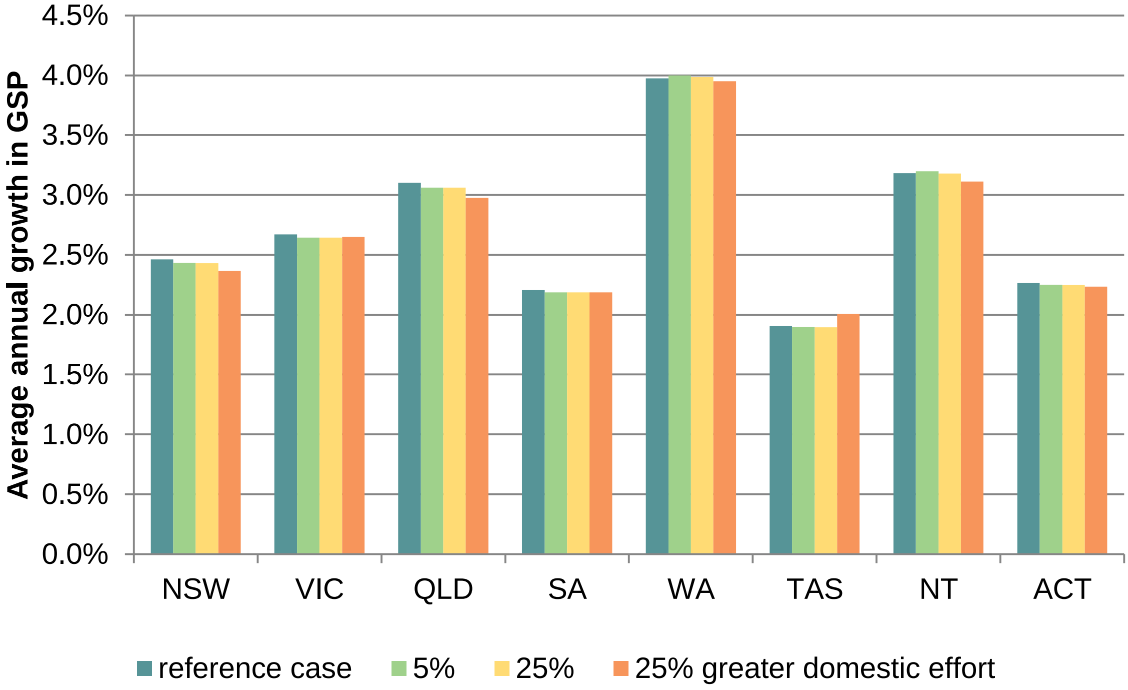
The regional macroeconomic impacts are differentiated between states. Under the standard 25 per cent target scenario, the real Gross State Product (GSP) for all states or territories is modelled to be reduced by no more than 0.4 per cent relative to the reference case at 2020. All states see annual growth in GSP of between 1.9 and 4.0 per cent, in real terms. In this scenario, the largest overall impacts are in Queensland (QLD) and, to a lesser extent, New South Wales (NSW), reflecting the higher proportion of coal mining and electricity generation from coal in these economies; but even here the effects are merely to reduce state level economic product by 0.4 per cent relative to the baseline.

The economy of the Australian Capital Territory (ACT) is almost entirely service oriented, but the disproportionate importance of energy-intensive providers of private transport and space heating for residential and commercial means that it also experiences a moderate negative impact. By contrast, Tasmania (TAS) sees much more modest declines in output under the 25 per cent standard scenario as result of an absence of coal-fired generation or gas and coal mining coupled with a high proportion of forestry and agricultural production which do relatively well under the government's plans (emissions from land use are assumed to be excluded from all schemes across all years). There is a negligible impact on GSP in the Northern Territory (NT) due to the importance of agriculture, while Western Australia (WA) sees a modest increase in GSP relative to the reference case as a result of an over-representation of gas-fired generation and natural gas production.

Macroeconomic impacts in the "greater domestic effort" scenario are more differentiated. In this scenario, even though all states continue to see an absolute increase in modelled GSP of at least 15 per cent between 2013 and 2020, the higher carbon price results in relatively stronger impacts in NSW and Queensland state product. Even so, the reductions relative to the reference case do not exceed 1 per cent at 2020. All other states' GSP is reduced by less than national GDP, and Tasmania's GSP increases relative to the reference case. Underlying these results is that the higher local carbon price affects the electricity generation sector proportionately more than it affects other industries. Most of the loss in fossil-fuel generation is projected to come from black coal generation across NSW and QLD. This electricity production is replaced by other forms of renewable generation. By contrast, as Tasmania has an over-representation of renewable energy production, its share of national GDP increases by a relatively significant amount.

In assessing state level results, it should be kept in mind that we do not model international carbon pricing and any impacts that this may have on commodity exports, such as coal (in itself, Australia's higher carbon price would be unlikely to have a significant impact on the price of such commodities which will instead be determined by international supply and demand conditions).

Figure 13. **State-level macroeconomic impacts are modest**



Source: *Vivid Economics based on modelling results from CoPS MMRF.*

3 The benefits of taking more aggressive early action

This section reviews the potential benefits of more aggressive emissions reduction activity. The previous sections reviewed that the costs of taking more aggressive action have fallen significantly in recent years and that there is a growing number of countries pursuing emission reduction activity. This final section briefly complements this analysis by looking at some of the potential advantages from more aggressive action today, especially more aggressive domestic mitigation action. In particular, it focusses on two issues.

- First, it considers whether a stronger emissions reduction trajectory to 2020 may be beneficial in lowering the overall costs of Australia achieving deep reductions in emissions, with the current government's 2050 target of reducing emissions by 80 per cent as a reference point. The Climate Change Authority states in its Issues Paper that it takes the 80 per cent target as a 'given' reference point for its review, however it can be argued that other – possibly deeper – reductions targets would be shown as appropriate in an analysis of principles-based global mitigation effort sharing.

- Second, it provides a brief review of the literature on the possible technological opportunities available to Australia from a global low-carbon future and discusses the importance of domestic carbon pricing as a means to realise these opportunities.

3.1 Can early action reduce long-term costs?

Adopting a more ambitious target to 2020 may require a less steep trajectory of emissions reductions in following decades. Three key factors will influence how the profile of emission reductions towards a target affects total costs.

- First, deferring emission reductions to the future would allow Australia's emission reductions to take place when the country is richer and where the relative impact of a given cost increase is correspondingly lower. This effect is captured by discounting future costs.
- In addition, if emission reductions were deferred to further in the future this implies that the cumulative emission reductions required by Australia would be smaller; although this impact will be negated if domestic policy and/or future international agreements place limits on a country's cumulative emissions[10].
- On the other hand, early action to reduce emissions can reduce the risk of 'lock-in' of high carbon assets in short-term, which might otherwise mean that carbon prices in the medium to long run have to be higher. This is likely to be particularly significant in a context in which there are strict limits on the use of international credit purchases, making the ease of achieving domestic emission reductions more important.

[10] In this context, it is noteworthy that the Caps and Targets review will recommend a budget for emissions in the period 2013-2020 and possibly beyond.

It has not been possible to undertake detailed new modelling work on this subject within the scope of this research. It may, however, be a fruitful focus of any modelling work undertaken by the Climate Change Authority.

Earlier Treasury modelling work indicates that the cost of delay may be significant. This found that delayed action increases future mitigation costs and specifically states that:[11]

> *'Delaying global action by 3 years adds around 20 per cent to the first year entry mitigation cost; a further three years adds a further 30 per cent to the first year mitigation cost. […] Depending on countries' emission reduction targets and the ability to source permits from other countries, a 3-year delay of mitigation action results in higher mitigation costs of 2 to 10 per cent in 2050.'*

Recent academic modelling also points to the benefits of early action by Australia. Jakob et al (2012)[12] use three different models to look at the question of whether countries/regions will find it cheaper to take early action towards a given target, given the behaviour of other countries and regions. This analysis includes Australia within an 'other Annex 1' grouping of countries, and also provides results for EU, US, China, India and Rest of Non-Annex 1.This analysis suggests that more ambitious early action can help to reduce total (discounted[13]) costs in high emission regions, often even if other regions choose not to take early action. In particular, some of the key modelling findings include the following:

- For the rest of Non Annex 1 region (including Australia), two of the three models suggest that taking action from 2010, in conjunction with other Annex 1 countries, would result in lower total discounted costs than if the region decided to defer taking action until 2020. It therefore seems likely that taking more aggressive action between 2010 and 2020 would also help reduce total costs.
- All three models suggest that it would make more sense for the EU to take action in the period 2010-2020 even if every other region in the world was not taking action. Indeed, two of the three models suggest that early action by the EU could more than halve the total costs of reaching its long term target.

The authors conclude that:

> *'For the majority of regions, even though appealing from the short term perspective, delaying action on climate policy does not turn out to decrease long run consumption losses. Even though late movers have the advantage of laxer reduction commitments regarding their cumulative emissions … this effect is*

[11] Australian Government (2011), *Strong growth, low pollution: modelling a carbon price*, The Treasury.

[12] Jakob, M, Luderer, G., Steckel, J. Tavoni, M, Monjon, S. (2012) Time to act now? Assessing the costs of delaying climate measure and benefits of early action, *Climatic Change,* 114: 1, pp 79-99

[13] The analysis uses a discount rate of 3 per cent.

countered by increased future mitigation costs arising from the build-up of long lived carbon intensive infrastructure.'

Such a conclusion is corroborated by a range of studies that have looked at the issue of lock-in from a global perspective. This includes both policy and academic studies.

The International Energy Agency (IEA) declares that delaying action is a 'false economy'. Its analysis suggests that every $1 of investment avoided by taking less action before 2020, an additional $4.3 would need to be spent between 2021 and 2035 to compensate for the higher emissions while keeping to a 450ppm global budget[14].

The rapid low-carbon investment required with delayed action could only be delivered by substantially higher carbon prices in the future. A recent *Nature* paper, based on a wide array of different modelling runs, suggests that, to have a 60 per cent chance of staying below 2˚C, a global carbon price of US$27/t$CO_2$ would be needed in 2012 but that this would increase by almost three and a half times, to US$93/t$CO_2$, if action was delayed until 2020. It reports that achieving this goal while delaying action to 2030 is physically infeasible[15.]

3.2 Can Australia realise opportunities to gain comparative advantage in new sectors?

The transformation to a low-carbon society will require a radical shift in technologies. To avoid dangerous climate change, rapid, extensive and widespread low-carbon innovation will be required across the globe. Although the nature of the innovation process makes it impossible to predict exactly which technologies will emerge, renewables, carbon capture and storage (and possibly other forms of carbon sequestration), and vehicle technology are all likely to require both fundamental changes and significant scale-up.[16] Placing these changes in a historical context, a number of commentators[17] have suggested that the impact could be as transformative as the industrial revolution or the advent of information technology. This idea is captured in Figure 14 below.

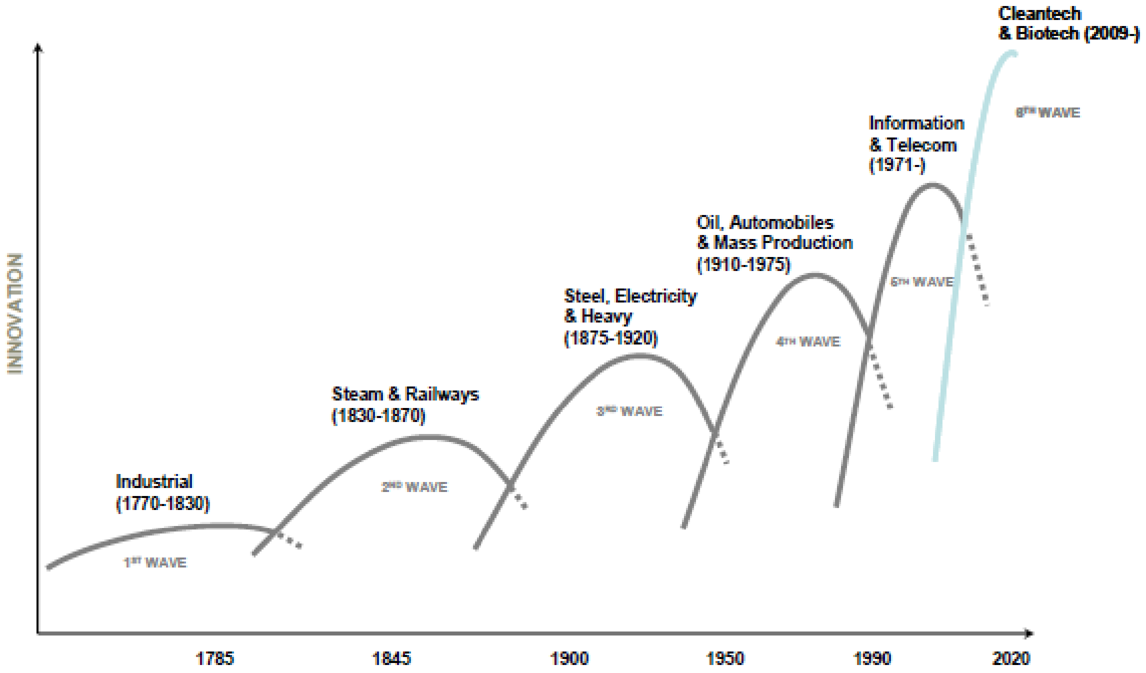
[14] IEA (2011) World Economic Outlook

[15] Rogelj, J., McCollum, D.L., Reisinger, A., Meinshausen, M. & Riahi, K. (2013) Probabilistic cost estimates for climate change mitigation, *Nature* doi:10.1038/nature11787

[16] Barrett, S (2009) The Coming Global Climate-Technology Revolution, *Journal of Economic Perspectives,* **23**:2, pp53-75

[17] Stern, N (2010) China's growth, China's cities and the new global low-carbon industrial revolution, Policy Brief, Grantham Research Institute, London School of Economics; Perez, C. (2010) Technological revolutions and techno-economic paradigms' Cambridge Journal of Economics **34**, 185-202

Figure 14. **The low-carbon technology transformation may be as radical as the advent of the steam engine and railways**



Source: *Stern (2010) China's growth, China's cities and the new global low-carbon industrial revolution*

The transition has already begun. For instance, the annual amount of patents related to clean energy has grown more than twice as fast as the average of all patents over the last fifteen years.[18]

This structural change will be disruptive; creating winners and losers. This form of structural change will cause expansion in some sectors – and within parts of certain sectors – and a scale back in other activities. It already appears that the 'green race' is likely to alter the present competitiveness landscape.[19] As such, those countries that are able to develop a comparative advantage in key technologies, or intellectual property development in those technologies, may see an improvement in their terms of trade and higher real incomes; whereas if the scale-back in brown sectors, is combined with rigidities in real wages and/or a lack of skills and production, then there is likely to be a (temporary) drop in output and employment.

[18] Veefkind, V. Hurtado-Albir, J. Angelucci, K. Karachalios, K. and Thumm, N. (2012) A new EPO classification scheme for climate change mitigation technologies, *World Patent Information*, 34, 106-111.

[19] Fankhauser, S., Bowen, A. Calel, R., Dechezlepretre, A., Grover, D, Rydge, J. and Sato, M. (2012) Who will win the green race? In search of environmental competitiveness and innovation, Grantham Research Institute on Climate Change and the Environment Working Paper No. 94

There are a number of technologies where Australia may be particularly well-positioned to develop intellectual property that will be valuable in a low-carbon future. For instance, the Garnaut review update[20] mentions three specific areas which there is a national interest for Australia supporting:

- Carbon Capture and Storage (CCS) where the report notes that '*the proximity of carbon dioxide sources to sites for geological storage with enormous potential resources make this technology particularly suited to further exploration and research in Australia*'
- Geothermal energy where it anticipates that Australia should have *'strong research skills in fields required for innovation …based on its history of internationally competitive mining and related engineering and construction'*
- Biosequestration where the report discusses that *'Australia's strength in agricultural and biological research provides a clear comparative advantage for low-emissions innovation in the land sectors'*. It further notes that the economic gains from biosequestration could *'enhance the role of the rural sector in Australia's economy'*.

In the longer term, Australia might become a supplier of renewables based fuels to the region, especially if technology to make liquid synthetic fuels using solar power eventuates.

Australia may not be well-positioned in the low-carbon/green growth race at present. This report has not been able to undertake a detailed review of the risks and opportunities posed to Australia by these changes (although such a study would be valuable). However, it is striking that a recent study found that Australia only accounted for 0.9 per cent of the world's high-value low-carbon inventions between 2000 and 2005. This placed it 26th in the world, behind Germany (1st), Japan (2nd), USA (3rd), South Korea (6th) and China (10th).[21] This is broadly consistent with the findings of The Climate Institute's *Global Climate Leadership Review*[22], which placed Australia in 17th out of the 19 G20 countries in terms of preparedness for a low-carbon world. Economies that are reliant on high carbon commodities and technologies face a potential threat to these sources of economic prosperity. Australia as a large exporter of fossil fuels is in this category.

Stronger domestic emissions reduction action, such as discussed in section 2.3, will help in exploiting opportunities for low carbon growth. The existence of public policy support, such as feed-in tariffs or tradeable certificate regimes, has been a critical driver in renewable innovation activity globally [23], although sometimes at relatively high cost. Another study has shown that countries with more stringent energy and CO_2 regulations have been more successful at exporting related technologies. [24] At the same time, to exploit

[20] Garnaut, R. (2011) The Garnaut Review 2011: Australia in the global response to climate change, Cambridge University Press.

[21] Dechezlepretre, A., Glachant, I. Hascic, I., Johnstone, N. and Meniere, Y. (2011) Invention and transfer of climate change-mitigation technologies: a global analysis, *Review of Environmental Economics and Policy* **5** (1): 109-130

[22] The Climate Institute (2013) Global Climate Leadership Review. Available at: http://www.climateinstitute.org.au/global-climate-leadership-review-2013.html Accessed 22nd May 2013.

[23] Johnstone, N. Hascic, I. and Popp, D. (2010) Renewable energy polices and technological innovation: evidence based on patent counts, *Environmental Resource Economics*, 45: 133-155

[24] Costantini, V. and Crespi, F. (2008) Environmental regulation and the export dynamics of energy technologies, Ecological Economics **66** (2-3), 447-460.

these opportunities, additional public policy support explicitly targeting innovation market failures will likely be needed, which will be more efficient if it remains technology neutral.

In summary, the required change in technologies to realise a low-carbon future could be massively disruptive to existing patterns of international trade and comparative advantage. Although Australia may not be well placed to benefit from this disruption at present, continued and strengthened mitigation action including through carbon pricing will be important in turning this threat into an opportunity.

Appendix

In this appendix we give a brief description of the MMRF model. More details are given in Adams and Parmenter (2013).[25]

MMRF is a dynamic, multi-sector, multi-region model of Australia. It distinguishes 58 industries, 63 products and 8 regions representing the states and territories. Each regional economy is a fully-specified bottom-up system that interacts with other regional economies. Three industries produce primary fuels (coal, oil and gas), one produces refined fuel (petroleum products), five generate electricity and one supplies electricity to final users. The five generation industries are defined according to primary source of fuel: coal, gas, oil, hydro, other renewables. Apart from Grains and Petroleum products, industries produce single products. Grains produces grains for animal and human consumption and biofuel used as feedstock by Petroleum products. Petroleum products produces gasoline (including gasoline-based biofuel blends), diesel (including diesel-based biofuel blends), LPG, aviation fuel, and other refinery products (mainly heating oil).

General equilibrium core

The nature of markets

MMRF determines regional supplies and demands of commodities through optimising behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital. Labour supply at the national level is determined by demographic factors, while national capital supply responds to rates of return. Labour and capital can cross regional borders in response to relative regional employment opportunities and relative rates of return.

The assumption of competitive markets implies equality between the supply price (the price received by the producer) and marginal cost in each regional sector. Demand is assumed to equal supply in all markets other than the labour market. The government intervenes in markets by imposing *ad valorem* sales taxes on commodities. This places wedges between the prices paid by purchasers and the prices received by producers. The model recognises margin commodities (for example, retail trade and road transport) that are required for the movement of commodities from producers to purchasers. The costs of margins are included in purchasers' prices of goods and services.

Demands for inputs used in the production of commodities

MMRF recognises two broad categories of production inputs: intermediate inputs and primary factors. Firms in each regional sector are assumed to choose the mix of inputs that minimises the costs of production for their levels of output. They are constrained in their choices by a three-level nested production technology. At

[25] Philip D. Adams and Brian R. Parmenter (2013), "Computable General Equilibrium Modelling of Environmental issues in Australia: Economic Impacts of an Emissions Trading Scheme" in P.B. Dixon and D. Jorgenson (eds) *Handbook of CGE Modelling, Vol. 1,* Elsevier B.V.

the first level, intermediate-input bundles and a primary-factor bundle are used in fixed proportions to output. These bundles are formed at the second level. Intermediate-input bundles are constant-elasticity-of-substitution (CES) combinations of domestic goods and goods imported from overseas. The primary-factor bundle is a CES combination of labour, capital and land. At the third level, inputs of domestic goods are formed as CES combinations of goods sourced from each of the eight domestic regions, and the input of labour is formed as a CES combination of inputs from nine occupations.

Domestic final demand: household consumption, investment and government

In each region, the household buys bundles of goods to maximise a utility function subject to an expenditure constraint. The bundles are CES combinations of imported and domestic goods, with domestic goods being CES combinations of goods from each domestic region. A Keynesian consumption function determines aggregate household expenditure as a function of household disposable income (HDI). Capital creators for each regional sector combine inputs to form units of capital. In doing so, they minimise costs subject to a technology similar to that used for current production, with the main difference being that they do not use primary factors directly. Regional governments and the Federal government demand commodities from each region.

Foreign demand

Each regional sector faces its own downward-sloping foreign demand curve. Thus, a shock that reduces the unit costs of an export sector will increase the quantity exported but reduce the foreign-currency price. By assuming that foreign demand schedules are specific to product and region of production, the model allows for differential movements in foreign-currency prices across domestic regions.

Regional labour markets

The response of regional labour markets to policy shocks depends on the treatment of three variables – regional labour supplies, regional unemployment rates and regional wage differentials. In this work, regional wage differentials and regional unemployment rates are set exogenously and regional labour supplies are determined endogenously (via interstate migration or changes in regional participation rates). Under this treatment, workers move freely (and instantaneously) across state borders in response to changes in relative regional unemployment rates. With regional wage rates indexed to the national wage rate, regional employment is demand determined.

Physical capital accumulation

Investment undertaken in year t is assumed to become operational at the start of year t+1. Under this assumption, capital in industry i in region q accumulates according to:

$$K_{i,q}(t+1) = (1 - DEP_{i,q}) \times K_{i,q}(t) + Y_{i,q}(t), \qquad (1)$$

where $K_{i,q}(t)$ is the quantity of capital available in industry i in region q at the start of year t, $Y_{i,q}(t)$ is the quantity of new capital created in industry i in region q during year t, and $DEP_{i,q}$ is the rate of depreciation for industry i in region q. Given a starting value for capital in t=0, and with a mechanism for explaining investment, equation (1) traces out the time paths of industries' capital stocks.

Investment in year t is explained via a mechanism of the form

$$\frac{K_{i,q}(t+1)}{K_{i,q}(t)} = F_{i,q}\left[\frac{EROR_{i,q}(t)}{RROR_{i,q}(t)}\right], \qquad (2)$$

where $EROR_{i,q}(t)$ is the expected rate of return in year t, $RROR_{i,q}(t)$ is the required rate of return on investment in year t, and $F_{i,q}$ is an increasing function of the ratio of expected to required rate of return. In this work, it is assumed that investors take account only of current rentals and asset prices when forming expectations about rates of return (static expectations).

Lagged adjustment process in the national labour market

The simulations reported here are year-to-year recursive-dynamic simulations, in which it is assumed that deviations in the national real wage rate from its basecase level increase through time in inverse proportion to deviations in the national unemployment rate. That is, in response to a shock-induced increase (decrease) in the unemployment rate, the real wage rate declines (increases), stimulating (reducing) employment growth. The coefficient of adjustment is chosen so that effects of a shock on the unemployment rate are largely eliminated after about ten years.

Environmental enhancements

A number of key environmental enhancements of MMRF are necessary to facilitate modelling of the scenarios in this paper.

Energy and emissions accounting

MMRF tracks emissions of greenhouse gases according to: emitting agent (58 industries and the household sector); emitting region (8); and emitting activity (9). Most of the emitting activities are the burning of fuels (coal, natural gas and five types of petroleum products). A residual category (activity emissions) covers non-combustion emissions such as emissions from mines and agricultural emissions not arising from fuel burning. The resulting 59 × 8 × 9 array of emissions is designed to include all emissions except those arising from land clearing. Emissions are measured in terms of carbon-dioxide equivalents, $C0_2$-e. Note that MMRF accounts for domestic emissions only; emissions from combustion of Australian coal exports, say, are not included, but fugitive emissions from the mining of the coal are included.

Carbon taxes and prices

MMRF treats the price of emissions as a specific tax on emissions of CO_2-e. On emissions from fuel combustion, the tax is imposed as a sales tax on the use of fuel. On activity emissions, it is imposed as a tax on production of the relevant industries. In MMRF, sales and production taxes are generally assumed to be *ad valorem*, levied on the basic (that is, pre-tax) value of the underlying flow. Carbon taxes, however, are specific, levied on the quantity emitted by the associated flow.

Inter-fuel substitution

To allow for fuel-fuel and fuel-factor substitution that a carbon tax would be expected to induce, we (i) introduce inter-fuel substitution in electricity generation using the “technology bundle” approach; and by introducing a weak form of input substitution in sectors other than electricity generation to mimic “KLEM substitution”.

Electricity-generating industries are distinguished based on the type of fuel used. There is also an end-use supplier (*Electricity supply*) in each region and an industry (*NEM*) covering the six regions that are included in Australia’s National Electricity Market: New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA), the Australian Capital Territory (ACT) and Tasmania (TAS). Electricity flows to the local end-use supplier either directly in the case of Western Australia (WA) and the Northern Territory (NT) or via *NEM* in the remaining regions.

Purchasers of electricity from the generation industries can substitute between the different generation technologies in response to changes in generation costs. Such substitution is price-induced, with the elasticity of substitution between the technologies typically set at around 5. For other energy-intensive commodities used by industries, MMRF allows for a weak form of input substitution. In most cases, a substitution elasticity of 0.1 is imposed. Thus, if the price of cement rises by 10 per cent relative to the average price of other inputs to construction, the construction industry will use 1 per cent less cement and a little more labour, capital and other materials. For important energy goods (petroleum products, electricity supply, and gas) the substitution elasticity in industrial use is 0.25. Being driven by price changes, this input substitution is especially important in an ETS scenario where outputs of emitting industries are made more expensive.

The National Electricity Market

The National Electricity Market is a wholesale market covering nearly all of the supply of electricity to retailers and large end-users in NSW, VIC, QLD, SA, ACT and TAS. Final demand for electricity in each of these regions is determined within the CGE-core of the model in the same manner as demand for all other goods and services. All end users of electricity in these six regions purchase their supplies from their own-state *Electricity supply* industry. Each of the *Electricity supply* industries in these six regions sources its electricity from the industry *NEM*, which does not have a regional dimension; it is a single industry that sells a single product (electricity) to the *Electricity supply* industry in each of the six regions. *NEM* sources its electricity from generation industries in each *NEM* region. Its demand for electricity is price-sensitive.

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Company Profile

Vivid Economics is a leading strategic economics consultancy with global reach. We strive to create lasting value for our clients, both in government and the private sector, and for society at large.

We are a premier consultant in the policy-commerce interface and resource- and environment-intensive sectors, where we advise on the most critical and complex policy and commercial questions facing clients around the world. The success we bring to our clients reflects a strong partnership culture, solid foundation of skills and analytical assets, and close cooperation with a large network of contacts across key organisations.