# F

# HOW ECONOMIC MODELLING IS USED IN THIS REVIEW

The Authority requested assistance from Treasury and DIICCSRTE to provide input to its economic analysis for the Targets and Progress Review. The Treasury and DIICCSRTE undertook economic modelling of different climate change mitigation scenarios in close consultation with the Authority. The modelling was also used as a basis for the government's 2013 emissions projections (DoE 2013).

This appendix outlines how the modelling was used to inform different parts of this Review.

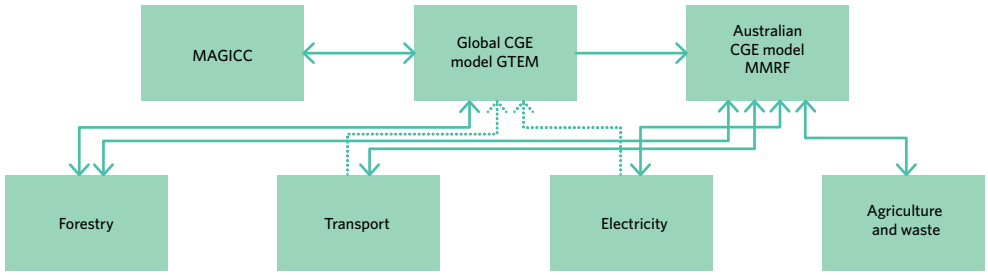
Treasury and DIICCSRTE (2013) and the consultants' reports on the electricity, transport and agriculture sectors are published on the Authority's website.

## APPENDIX F1 MODELLING APPROACH

The Treasury and DIICCSRTE modelling report uses a suite of models because no single model adequately captures the global, national, state and sectoral dimensions or focuses on all relevant aspects of mitigation policy in Australia.

The suite includes two top-down, computable general equilibrium (CGE) models developed in Australia—the GTEM and the Monash Multi-Regional Forecasting (MMRF) model. These are economy-wide models that capture the interactions between different sectors and among producers and consumers. The model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) is used to estimate atmospheric concentrations based on the emissions trajectories from the international scenarios. Sector-specific models for electricity generation (undertaken by ACIL Allen Consulting), transport (CSIRO), agriculture (CIE) and forestry and waste (DIICCSRTE) are used to complement the CGE models, enriching the understanding of the economy's likely response to climate change mitigation policy (Figure F.1). The Treasury and DIICCSRTE modelling report and consultants' reports provide further detail on the use of these models and their integration.

**FIGURE F.1:** HOW THE SUITE OF MODELS FITS TOGETHER




**Note:** A solid arrow indicates direct transfer of results as an input/output; a dashed arrow indicates use of results for calibration.
**Source:** Treasury and DIICCSRTE 2013

## APPENDIX F2 SCENARIOS

The modelling investigates the future economic and emissions outlook for Australia. As outlined in Chapter 10, assumptions about policy settings are especially challenging as Australia's are currently being revised. The modelling assesses the economic impacts of achieving different targets in the context of the current legislative settings. Assuming the carbon pricing mechanism is in place, a key uncertainty is the future level of the carbon price. Assumptions about the level of international action and the extent of international permit trading are important determinants of the level of Australia's carbon price. These assumptions also affect the prices of the goods Australia imports and exports, and have implications for energy exports in particular.

Two international action scenarios are modelled. They assume the world takes action to stabilise atmospheric concentrations of greenhouse gases at levels of either around 550 or 450 ppm $CO_2$-e in the long term. These international scenarios form the backdrop for the domestic modelling. Further detail is provided in Chapter 2 of the Treasury and DIICCSRTE modelling report.

Economic activity and emissions are projected for three scenarios with carbon pricing and the CFI, and for one scenario in which there is neither carbon pricing nor the CFI. The Australian carbon price scenarios are further outlined in Box 10.1 of Chapter 10 and the Treasury and DIICCSRTE modelling report.

The international scenarios form the backdrop for the domestic scenarios (Table F.1). The ambitious international action scenario forms the backdrop for the high scenario; the carbon price is sufficient to drive the cuts in global emissions required to give a 50 per cent probability of limiting warming to no more than 2 degrees. The medium international action scenario forms the backdrop to the medium and low scenarios; the lower carbon price drives more gradual cuts in global emissions, resulting in additional warming.

**TABLE F.1:** INTERNATIONAL AND DOMESTIC SCENARIOS MODELLED

| INTERNATIONAL ACTION SCENARIO | DOMESTIC ACTION SCENARIO |
|---|---|
| Ambitious action—stabilisation around 450 ppm $CO_2$-e | High scenario |
| Medium action—stabilisation around 550 ppm $CO_2$-e | Medium scenario* |
| Medium action—stabilisation around 550 ppm $CO_2$-e | Low scenario |
| Medium action—stabilisation around 550 ppm $CO_2$-e | No price scenario |

*Referred to as 'central' price scenario in the Treasury and DIICCSRTE modelling report.

The high, medium and low domestic action scenarios assume Australia has a fixed carbon price in 2012–13 and 2013–14, and then moves to a flexible price. A sensitivity analysis on the medium scenario is also modelled, with a fixed price in 2014–15 and a flexible price starting in 2015–16, in accordance with the current legislation. This changes emissions levels in 2014–15, which affects the cap calculations presented in Part E and Appendix E. However, it has no material impact on the economic results, so it is not used in the analysis in chapters 10, 11 and 12.

DIICCSRTE engaged consultants to undertake detailed modelling of Australia's electricity, transport and agriculture sectors. The consultants also undertook a range of sensitivity analyses for each sector. Further detail on this modelling is provided in the consultants' reports published on the Authority's website.

## APPENDIX F3
## EMISSIONS DATA

Historical and projected emissions for the period 1990 to 2030 are taken from the Treasury and DIICCSRTE modelling report.

In the modelling, historical emissions data for the period 1990 to 2011 are based on the National Greenhouse Gas Inventory report 2010–11 (DIICCSRTE 2013a); these have been converted to $CO_2$-e values using GWPs from the IPCC's Fourth Assessment Report (AR4) to permit simple comparison over the full period. Emissions in 2000 of 585.88 Mt $CO_2$-e are used as the basis for the emissions reductions targets and trajectories. For 2012, historical emissions are based on preliminary estimates of the National Greenhouse Gas Inventory, with the exception of waste and LULUCF emissions, which are modelled estimates. Historical emissions for LULUCF for the period 1990 to 2012 are adjusted to be consistent with the new accounting rules agreed for the second commitment period of the Kyoto Protocol. Emissions data for the period 2013 to 2030 are modelled estimates. Further details are provided in Box 6.1.

## APPENDIX F4
## AUSTRALIAN ACTION IN A GLOBAL CONTEXT

The modelling is used to inform part of the analysis of countries' targets presented in Chapter 4. The modelling is used for Figure 4.3 and in Appendix B to compare countries' 2020 targets with their projected BAU emissions. The BAU emissions are estimated from the GTEM reference case for some countries, and the domestic emissions for Australia are estimated from the no price scenario from MMRF. All Australian population estimates are from GTEM. Further information on the other data used for the comparison analysis can be found in Appendix B.

## APPENDIX F5
## FORM AND SCOPE OF GOALS

Net emissions reductions due to the election of optional land-use activities from bottom-up modelling undertaken by DIICCSRTE are used in chapters 7 and 11 and Appendix D to calculate the implications of land sector accounting changes for Australia's 2020 target.

The impact on the 2020 target is calculated as follows:

1. The total additional emissions reduction over 2013–2020 provided by land sector accounting changes (under Article 3.4 of the Kyoto Protocol including forest management) is calculated as the difference between the 2013 modelling projections with and without Article 3.4 including forest management (see Appendix B of the Treasury and DIICCSRTE modelling report).
2. Projected emissions reductions are identified from CFI projects in forest management, crop land management, grazing land management and revegetation. These are subtracted from the total additional emissions reduction in (1), giving 90 Mt $CO_2$-e of emissions reduction that would occur because of the Article 3.4 changes, regardless of policy incentives.
3. The resulting cumulative emissions reduction from (2) is converted to an equivalent strengthening in the 2020 target that would result in the same cumulative emissions reduction over the period 2013–2020.

This calculation is not affected by changes in global warming potentials since the 2012 projections, as the relevant emissions are carbon dioxide only.

## APPENDIX F6
## AUSTRALIA'S EMISSIONS BUDGET TO 2050

Calculations of Australia's emissions budget to 2050 outlined in Chapter 8 draw on the international modelling from GTEM and further information provided by Treasury. Details are in Appendix C.

## APPENDIX F7
## ECONOMIC IMPLICATIONS OF AUSTRALIA'S EMISSIONS REDUCTION GOALS

The modelling is a key input to the Authority's analysis of economic impacts. All domestic scenarios are used to assess the outlook for the Australian economy and domestic emissions, in the context of different levels of international action and carbon prices.

### F7.1 GNI ADJUSTMENT FOR THE HIGH SCENARIO

The modelling was used to estimate the GNI impacts of moving to a stronger target.

The scenarios reported in the Treasury and DIICCSRTE modelling report assumed a 5 per cent target for the central- (referred to as 'medium' in this Review) and low-price scenarios, and a 25 per cent target for the high-price scenario.

To assess the impact of moving from the minimum 5 per cent target to a 19 per cent target, the Authority requires GNI levels for a 5 per cent target for all price scenarios. The Authority adjusted the GNI results for the high-price scenario to remove the costs of achieving the stronger 25 per cent target, using the following method:

1. The cost of the additional imports was added back. A 5 per cent target requires fewer international emissions reductions to be purchased than a 25 per cent target. For example, in 2020 it requires 41 million fewer Kyoto units and 76 million fewer European Union allowances (EUAs) to be purchased. This increases GNI in 2020 by $5.9 billion.
2. The positive terms of trade effect was added back (this stems from lower international transfers associated with imports, and is the same effect described in Section 3.7.2 of the modelling report). This effect is 0.3 times the cost of imports, increasing GNI in 2020 by an additional $1.8 billion.

The additional revenue impact described in Section 3.7.2 of the modelling report is not included in the modelling scenarios and did not need to be removed for the Authority's estimate of the 5 per cent target.

This methodology was used to adjust GNI in each year of the flexible-price period. Throughout Chapter 10, the adjusted GNI for the high scenario is used.

## F7.2 CALCULATING THE GNI COSTS OF STRONGER TARGETS

Starting from the common 5 per cent target, the methodology discussed in Section 10.3.1 was used to calculate the impact of moving to stronger targets. The costs are based on the additional imports required to move from 5 per cent to the recommended target; specifically, the difference in annual caps for a 5 per cent and a 19 per cent target. Table F.2 shows the average annual GNI growth rate between 2013 and 2020 for each of the price scenarios.

**TABLE F.2:** AVERAGE ANNUAL GROWTH IN GNI PER PERSON 2013–2020

| TARGET | HIGH SCENARIO | MEDIUM SCENARIO | LOW SCENARIO |
|---|---|---|---|
| 5 per cent | 0.73% | 0.80% | 0.82% |
| 19 per cent including carryover | 0.67% | 0.78% | 0.82% |

## F7.3 ASSESSING THE IMPACT OF AUSTRALIA'S TARGET ON THE INTERNATIONAL CARBON PRICE

A central question in analysing the economic implications of Australia's emissions reduction goals under the current legislation is whether its choice of 2020 target would have an impact on the international carbon price. As outlined in Chapter 10, for this analysis we have assumed that Australia's decision to move to a stronger target would not have a material impact on the international carbon price.

Under the current legislative settings, limits on the use of Kyoto units and the ability to bank units for future use mean the Australian carbon unit price is expected to track the European price. The majority of stakeholders consider that Australia will have little or no impact, because changes in Australian demand would not be big enough to shift the European market. The European Union emissions trading system (EU ETS) covers roughly 2,000 Mt $CO_2$-e (European Commission 2013), while the Australian carbon pricing mechanism covers about 300 Mt $CO_2$-e, making the European market almost seven times bigger than the Australian market. Further, the European market currently has a substantial surplus of roughly two billion units, in part due to the sustained economic downturn. As a result, a stronger Australian target will reduce the supply of Australia's domestic units, but have only a small impact on aggregate demand for international units.

The Authority has consulted extensively on this question, including with market analysts and traders, and liable entities. Many stakeholders, including the Australian Industry Group and the Investor Group on Climate Change, indicated Australian carbon prices would be likely to follow European prices.

Some analysts consider that a stronger target in Australia would increase the international price. For example, in August 2013 Bloomberg New Energy Finance (BNEF) projected that Australia moving to a 15 per cent target could increase the Australian carbon unit price by an average of $7.80 (2020 Australian dollars) (€4.70) over the period 2016–20 when compared to its 5 per cent scenario (2013a). Under this scenario, BNEF forecast an Australian carbon unit price of $80.40 in 2020, compared to $71.60 in 2020 under a 5 per cent target (in 2020 Australian dollars).

Other stakeholders suggested that the European price is largely contingent on the outcomes of proposed EU ETS structural reform, and finalisation of Europe's emissions reduction goals for the post-2020 period. These reforms could change the underlying demand and supply balance for European allowances, in which case additional demand from Australia may have a modest price impact.

Even if Australia's target did have a price effect, the scale of the projected change would not be expected to materially change domestic economic activity or impacts on Australian businesses and households. Moreover, the scale of the projected change is small relative to the scale of uncertainty in the carbon price itself. In July 2013, analyst forecasts of the carbon price in 2020 ranged from roughly $6 to $80 (RepuTex 2013; BNEF 2013b)—a much wider range than any potential impact of a stronger Australian target on the international price.

The Authority has considered three carbon price scenarios spanning a wide range of possible future market conditions, which provide a robust basis to illustrate the potential costs. Table F.2 illustrates the GNI impacts for the different price scenarios, which show the potential range of impacts if Australia was to have an effect on the international price.

## F7.4 IMPACT OF THE TARGET IS DIFFERENT TO IMPACT OF THE CARBON PRICE

As discussed in Section 10.3.4, the impact of the target is different to the impact of the carbon price. There is a common misconception that stronger targets mean much higher economic costs, with greater distributional consequences. This is not the case under the current legislation, where the carbon price is not expected to be materially affected by the target.

In determining the economic impact of the target, both the policy choice and the level of the target are relevant. Under the current legislation, economy-wide costs are quite small; the economy continues to grow and incomes continue to rise, even with a strong target. However, under a different policy the impacts could be different. The results from the medium scenario, with illustrative 5 and 25 per cent targets, demonstrate the scale of potential effects.

## F7.4.1 POLICY CHOICE

Depending on Australia's policy choice, costs may not be very transparent (for example, raising general tax revenue can have diffuse effects) and may be higher than under the current legislation.

Current legislated policy applies a carbon price to certain emissions sources (including electricity generation, direct combustion, landfills and industrial processes). This increases the cost of these emissions-intensive activities and shifts the economy towards lower emissions activity.

The carbon price imposes costs at the individual commodity level (for example, higher electricity prices); the whole-of-economy level (for example, lower GDP growth) and household income level (for example, lower GNI per capita growth).

Table F.3 shows the scale of these effects, using the results from the no price scenario compared to the medium scenario (with a 5 per cent target).

**TABLE F.3: ELECTRICITY PRICES AND ECONOMIC IMPACTS WITH A 5 PER CENT 2020 TARGET IN DIFFERENT SCENARIOS**

| | ELECTRICITY PRICES (RESIDENTIAL RETAIL) | GNI PER CAPITA | GDP |
|---|---|---|---|
| **2012 levels** | Varies across markets | $62,350 | $1.475 trillion (2012) |
| **No carbon price** | Changes to residential retail electricity prices over the period 2012–2020 vary across jurisdictions, ranging from:<br>• 24% above 2012 levels in 2020 in Queensland (an increase of $50 per MWh) to<br>• 1% below 2012 levels in 2020 in Tasmania (a fall of $1 per MWh). | $66,700 (2020)<br>0.84% average annual growth to 2020 | $1.882 trillion (2020)<br>3.10% average annual growth (2012–2020) |
| **Medium scenario** | Changes to residential retail electricity prices over the period 2012–2020 vary across jurisdictions, ranging from:<br>• 35% above 2012 levels in 2020 in Queensland (an increase of $73 per MWh) to<br>• 7% above 2012 levels in 2020 in the Northern Territory (an increase of $18 per MWh). | $66,450 (2020)<br>0.80% average annual growth to 2020 | $1.877 trillion (2020); 0.31% lower than no price<br>3.06% average annual growth (2012–2020) |

**Note:** GNI per capita figures are rounded to the nearest $50.
**Source:** Climate Change Authority based on Treasury and DIICCSRTE (2013) and ACIL Allen Consulting (2013)

Removing the carbon price will unwind these economic impacts. Alternative policy will have its own impacts. More detail would be required to estimate impacts for the Direct Action Plan. If new policy was less efficient than a carbon price, the impact on GDP and GNI would be greater. Distributional effects, including the impact on electricity prices, would depend heavily on policy choice.

## F7.4.2 LEVEL OF THE TARGET

Under the current legislation, a stronger target is expected to lead to more imports of international emissions units. Australia is small compared to the global carbon market, so is not expected to have material impact on the carbon price. As a result, a stronger target is not projected to have material direct impact on the economy, liable entities or the prices of goods and services such as electricity. The main economic impact of the target choice arises from international transfers associated with imports, and lower government revenue from having fewer units to auction.

Table F.4 shows the scale of these effects using the results from the medium scenario, assuming a 5 and 25 per cent target.

**TABLE F.4:** ELECTRICITY PRICES AND ECONOMIC IMPACTS WITH A 5 AND 25 PER CENT TARGET IN THE MEDIUM SCENARIO

| | ELECTRICITY PRICES | GNI PER CAPITA | GDP |
|---|---|---|---|
| **2012 levels** | Varies across markets | $62,350 | $1.475 trillion (2012) |
| **5 per cent target** | Residential retail tariff in 2020 is about 10% higher than in the no price scenario (ACIL Allen Consulting 2013). Ranges from:<br>• 1.4% in Darwin-Katherine Interconnected System to<br>• 13% in Victoria. | $66,450 (2020)<br>0.80% average annual growth to 2020 | $1.877 trillion (2020)<br>3.06% average annual growth |
| **25 per cent target** | Same as for 5 per cent | $66,250 (2020)<br>0.76% average annual growth | Same as for 5 per cent |

**Note:** GNI per capita figures are rounded to the nearest $50
**Source:** Climate Change Authority based on Treasury and DIICCSRTE (2013) and ACIL Allen Consulting (2013)

# APPENDIX F8
# AUSTRALIA'S EMISSIONS OUTLOOK

The Review of Australia's emissions outlook and progress towards its medium- and long-term goals draws on the four scenarios from the modelling (no price, low, medium and high) to show the scale and source of emissions reductions that may be elicited with different price incentives. The sensitivity analysis from the bottom-up models is also used. The Authority's approach to reporting sectoral projections is outlined below.

## F8.1 INTEGRATING SECTORAL AND ECONOMY-WIDE MODEL PROJECTIONS

### F8.1.1 EMISSIONS LEVELS

The Authority has used emissions levels as reported in the Treasury and DIICCSRTE modelling report for all sectors for the period 2013 to 2030.

The approaches used to estimate sub-sector level emissions depend on the level of detail available from different models:

- for transport, agriculture and electricity (for example, emissions from coal-fired electricity generation), the Authority has used sub-sector ratios from the sectoral models to apportion emissions
- for all other sectors, sub-sector emissions are based on information from Treasury and DIICCSRTE modelling.

### F8.1.2 TIMEFRAME FOR PROJECTIONS

The Treasury and DIICCSRTE modelling provides emissions projections for the period 2013 to 2030. The sectoral models provide emissions projections from 2031 to 2050 for electricity, transport and agriculture.

As evident from the Treasury and DIICCSRTE modelling report and the consultants' reports, there are small differences between some of the projected emissions from the sectoral models and the projected sectoral emissions from MMRF. For consistency over time, and where appropriate, the Authority has derived emissions from electricity and transport for the period 2013 to 2050 by applying the growth rates from the sectoral models to the level of emissions in 2030 from the Treasury and DIICCSRTE modelling report. Other sector emissions and economy-wide emissions are not projected beyond 2030.

### F8.1.3 ADDITIONAL SUBSECTOR DETAIL

Some activity and any additional subsector details (for example, fuel shares) have been sourced from the sectoral models and the Treasury and DIICCSRTE:

- electricity supply mix is based on ACIL Allen Consulting (2013) using as-generated gigawatt hours for projections, and BREE (2013) for historical disaggregation
- transport fuel use and modal shares are based on Reedman and Graham (2013) for projections, and BITRE (2011) and BREE (2013) for historical disaggregation
- agriculture activity is based on CIE (2013)
- direct combustion activity is based on Treasury and DIICCSRTE emissions data and National Greenhouse Gas Accounts (DIICCSRTE 2013b) rebased to AR4 GWPs
- waste production activity is based on data sourced from DIICCSRTE.

## F8.2 ATTRIBUTING CHANGES IN EMISSIONS SINCE 2000 DUE TO CHANGES IN ACTIVITY OR EMISSIONS INTENSITY

The Authority developed an approach to attribute estimated changes in emissions over a period between simultaneous factors, such as between a change to activity level and a change to emissions intensity. The results are presented in Appendix D. This approach has been used for electricity and transport sectors only. For all other sectors, changes in emissions are based on absolute emissions changes and do not distinguish the contribution of changes in activity from changes in intensity.

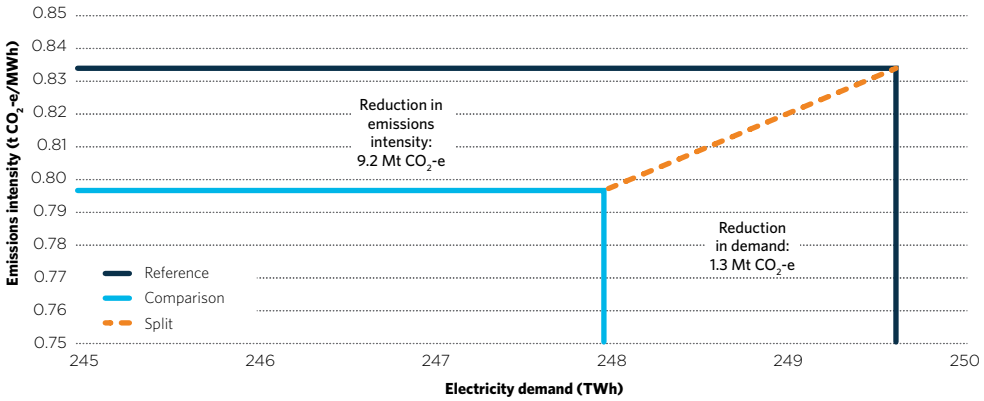
Activity levels and emissions intensity at the start and end of the period are used as reference points. The year 2000 is used as the primary start point, as it is the base year for Australia's national emissions reduction goals.

The method is designed to:

- facilitate analysis of the factors contributing to changes in emissions and highlight the largest contributors
- ensure all changes in emissions could be attributed to contributors without double-counting—and, as a result, be additive, so that:
  - the sum of changes attributed to each contributor is equal to the total change across all contributors
  - the sum of changes attributed to consecutive time periods is equal to the total change from the start to the end of the whole period.

Figure F.2 illustrates the method, apportioning a reduction in emissions between lower activity and lower emissions intensity.

**FIGURE F.2:** HOW CHANGES IN EMISSIONS ARE QUANTIFIED AND ATTRIBUTED




**Source:** Climate Change Authority

Figure F.2 compares demand and supply intensity in a given year against a reference year. The total change in emissions is represented by the area between the reference and comparison curves—in this example, 10.5 Mt $CO_2$-e. Part of the change is attributed to the small reduction in demand—1.3 Mt $CO_2$-e. The remainder is attributed to the reduction in supply-side emissions intensity—9.2 Mt $CO_2$-e.

## APPENDIX F9
## CAPS FOR THE CARBON PRICING MECHANISM

The caps calculations presented in Chapter 13 and Appendix E draw on the emissions projections from the modelling. Details of the scenarios used and associated calculations are provided in Appendix E.