Chapter 2: Framework for analysis

Key points

The Treasury has used a suite of models to undertake a comprehensive modelling exercise comparable to that undertaken in 2008.

The impacts of carbon pricing are assessed at the global, national, state, industry and household levels.

The analysis provides information on one element necessary for evaluating climate change policy: the costs of taking action. To form policy judgements, this modelling analysis needs to be evaluated alongside the detailed analysis of the economic and social impacts of climate change itself and the benefits of reducing global emissions.

Modelling results need careful explanation and interpretation. Statistics and numbers can mean different things when reported in different contexts.

The modelling is robust to a range of assumptions. Sensitivity analysis across various components in the suite of models has been undertaken and shows aggregate economic costs are similar across a range of plausible assumptions.

2.1 Rationale for pricing carbon — using a market based mechanism

There is clear scientific advice that the climate is changing and that there is a real risk greenhouse gas emissions from human activity are a major cause. Scientific advice also indicates it is likely we can avoid the worst impacts by reducing emissions.

Countries have moved and will continue to move to reduce their emissions through a variety of policy mechanisms. The Productivity Commission (2011) found most countries they examined have adopted a large and diverse range of emission reduction policies.

The Productivity Commission also found, when firms and consumers make the decisions, rather than governments, the cost of reducing emissions is lower.

Explicitly pricing carbon ensures all companies and individuals either explicitly or implicitly factor into decisions the cost of greenhouse gas emissions. Companies and individuals do not need to make complex calculations about the emission intensity of particular goods, as the price of the goods will reflect that key information.

Over time, as prices reflect the emission content of goods, producers and consumers will have an incentive to find ways to reduce emissions. For instance, electricity producers will look to reduce the use of emission-intensive fossil fuels to generate electricity and consumers will be encouraged to use less electricity.

A stable market-based framework also will support investment by providing businesses with greater policy certainty over time.

2.2 Modelling framework

Climate change operates over very long timeframes, with significant time lags between greenhouse gas emissions and resulting impacts. Consequently, quantitative analysis of carbon pricing and climate change mitigation must take a long-term view. This report provides projections to 2050.[1] This difficult exercise requires assumptions for a wide range of economic, social and environmental variables which can change in unpredictable ways.

This report uses economic models to make long-term projections and analyse the effect of emission reductions on the Australian economy. Economic models mathematically represent how the economy operates and how various agents respond to changing signals.

Economic models are useful for exploring the costs of climate change mitigation, as they ensure internally consistent long-term projections of economic activity and the resulting greenhouse gas emissions. While these models have their limitations, they integrate, in a comprehensive manner, economic and other data with economic theory about how the world responds to changing circumstances.

The models are used to estimate greenhouse gas mitigation costs to Australia by comparing two global action scenarios (where no new policies to reduce emissions are introduced in Australia) with policy scenarios where a domestic carbon price mechanism is introduced. The global action scenarios continue current Australian policies, extrapolate past economic trends and incorporate known information and assumptions about future developments, including international action to reduce emissions. The difference between each domestic policy scenario and the corresponding global action scenario represents the impact of the domestic policy.

2.2.1 Suite of models

No single existing model adequately captures all the global, national, state, industry and household dimensions or focuses on all relevant aspects of climate change policy in Australia. Most Australian studies of climate change mitigation policy focus on one of these dimensions — that is a particular sector (for example, electricity generation) in isolation from the broader national economy, or on the national economy but without a consistent global analysis. In contrast, Treasury's analysis uses a suite of models to create a holistic framework for climate change mitigation modelling across the five dimensions.

This section briefly describes the range of models used in this report (the appendices provide more detail).

1 All results in this publication, unless otherwise indicated, are in Australian financial years, ending 30 June of the year quoted.

The modelling centres on two top-down computable general equilibrium (CGE) models developed in Australia: the Global Trade and Environment model (GTEM) and the Monash Multi-Regional Forecasting (MMRF) model. These whole-of-economy models capture interactions between different sectors of the economy and among producers and consumers.

GTEM, developed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and extended by Treasury, is a global model which provides insights into Australia's key international trading partners (Pant, 2007; and Australian Government, 2008). The version of GTEM used disaggregates the world into 13 geographic regions and 19 industrial sectors.

To examine whether emission trajectories from the international global action scenarios derived in GTEM meet specified emission targets around 2100, the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) is used to estimate the atmospheric concentrations of the trajectories (Raper et al, 1996; Wigley and Raper, 1992; and Wigley and Raper, 2001). MAGICC is calibrated against more complex climate models and used in the IPCC's Fourth Assessment Report (Solomon et al, 2007). GTEM covers emissions of 7 gases, including both low and high global warming potential gases from various sources and sinks. As the global action scenarios project emission paths only to 2050, projections of emissions beyond 2050 for the estimation of concentrations by MAGICC are based on emission trends before 2051 and draw on post 2050 emissions information from the Garnaut scenarios in previous Treasury modelling (Australian Government, 2008). World carbon price paths are set so the atmospheric concentrations of the emission paths from the model broadly match the environmental targets.[2]

MMRF, developed by the Centre of Policy Studies at Monash University, models the Australian economy (Adams et al, 2011). It is rich in industry detail.

Several bottom-up sector-specific models for electricity generation and road transport sectors complement the CGE models. In addition, comprehensive analysis of emissions covered under the Carbon Farming Initiative (CFI) was undertaken and incorporated into the Australian macroeconomic modelling. Detailed analysis of these emission-intensive sectors enriches the understanding of the economy's likely response to climate change mitigation policy, particularly in the short-to-medium term.

Given the importance and inherent uncertainty about the evolution of the electricity generation sector, two detailed bottom-up models of the sector were used by ROAM Consulting and by SKM MMA part of the Sinclair Knight Merz Group. Using two models provides a natural hedge against the inherent uncertainty of economic modelling. These highly detailed models provide analysis of the Australian electricity generation sector, with projections for levels of generation, total capacity (installed), emissions (of carbon dioxide equivalent), energy use (fuel use), wholesale and retail electricity prices and the profit streams of generators (important for asset values and financing). Results are generally provided at the generator level or by the unit within each generator, giving insights into the transformation of the electricity generation sector.

ROAM Consulting and SKM MMA models aim to represent actual market conditions as closely as possible. They have economic relationships between individual generating plants in the system;

2 There are scientific uncertainties in determining the exact sensitivity of the climate to increases in greenhouse gas concentrations. For example, for a doubling of carbon dioxide, the Intergovernmental Panel on Climate Change Fourth Assessment Report gives a best estimate of an increase in global temperature of 3 degrees Celsius. However, the range is likely between 2 and 4.5 degrees Celsius with the possibility of substantially higher values not excluded.

each power plant is divided into generating units defined by their individual technical and cost profiles. The models incorporate a range of fuel types, including brown and black coal, natural gas and renewables (including hydro, biomass, solar, wind and geothermal), technology such as carbon capture and storage, and differences between natural gas technologies (such as combined cycle gas turbines and the less efficient open cycle gas turbines).

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) models the Australian road transport sector. CSIRO uses a partial-equilibrium model of the Australian energy sector, the Energy Sector Model (ESM), with detailed transport sector representation (Graham and Reedman, 2011; and Graham et al, 2008). The model has an economic decision-making framework, based around the cost of alternative fuels and technologies.

The road transport sector model evaluates the uptake of different technologies based on cost competitiveness, practical market constraints, current excise and mandated fuel mix legislation, greenhouse gas emission limits, existing plant and vehicle stock in each state, lead times in new vehicles or plant availability, and the degree of flexibility in the existing fleet.

The potential for abatement under the CFI scheme for agriculture, land use change and legacy waste sectors was analysed by the Department of Climate Change and Energy Efficiency (DCCEE). The abatement estimates are based on a top-down approach using marginal abatement cost curves constructed to be consistent with previous bottom-up estimates published by DCCEE.

ABARES model the impact of the CFI on the Australian forestry sector[3]. Their framework is spatially explicit and involves analysing the opportunities for carbon sequestration provided by forestry on cleared agricultural land. The net present value of returns from forestry investments is compared with the projected agricultural land value to estimate the potential area of clear agricultural land that is competitive for forestry within each spatial grid cell.

Treasury's Price Revenue Incidence Simulation Model (PRISMOD.IO) models the impact of a carbon price on a range of prices. PRISMOD.IO is a large-scale highly disaggregated model of the Australian economy capturing the flows of goods between industries and final consumers. The 2011 version of PRISMOD.IO is based on data from the Australian Bureau of Statistics *Australian National Accounts, Input-Output Tables 2005-06* (ABS, 2009) and 2005-06 emissions data from the 2009 National Inventory Report (DCCEE, 2011a). PRISMOD.IO is linked with PRISMOD.DIST to obtain household price increases, including the consumer price index.

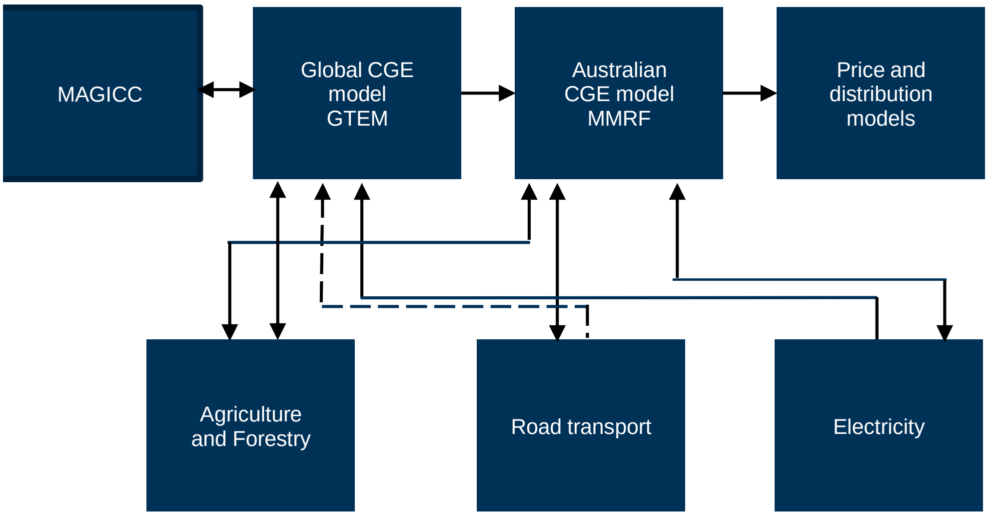
Treasury's Price Revenue Incidence Simulation Model and Distribution Model (PRISMOD.DIST) analyses the distributional implication for households. This static micro simulation model examines the distributional effects of government policies on spending by different households. The 2011 version of the model is based on data from the *Household Expenditure Survey 2003-04* (ABS, 2006b).

3 The Lawrence Berkeley National Laboratory used its Generalized Comprehensive Mitigation Assessment Process (GCOMAP) model for the forestry sector overseas in the 2008 modelling (Sathaye et al, 2006 and 2008). As the international carbon prices were broadly similar, these detailed estimates were incorporated into the GTEM model as they were in 2008, with some adjustment for the timing of the carbon price. GCOMAP simulates how forest land users respond to changes in prices in forest land and products and carbon prices. GCOMAP calculations of net change in emission stocks associated with land use change and forestry are incorporated into GTEM.

2.2.2 Integrating the models (refer to details in Appendix A)

The results from each model are drawn together into an integrated set of projections that are broadly consistent at the macroeconomic level and sufficiently detailed in key sectors. They provide insights into the likely transformation of the Australian economy under carbon pricing.

Chart 2.1: Integrating the suite of models



Note: Solid arrow indicates direct transfer of results as an input/output. Dashed arrow indicates use of results for calibration. GTEM does not take input from the agriculture model but does take input from the forestry sector.
Source: Treasury.

GTEM models the global economy to provide the international economic and emissions context for the Australian economy (MMRF), which in turn is informed by the bottom-up modelling of the electricity generation, road transport, agriculture and forestry sectors.

Linking economic models with different economic structures is not straightforward. Care is needed to obtain internally consistent results. For example, MMRF and GTEM have internally consistent, but different, assumptions about the supply responsiveness of various Australian industries. MMRF requires assumptions about world demand for Australian goods. This required careful linking to ensure the shift in the world demand curve is appropriatly inputted into the MMRF model. Similarly, the bottom-up electricity and transport supply-side models link iteratively with MMRF to ensure consistency.

2.3 Understanding the results

As with all modelling assessments, the modelling results require careful explanation. It is sensible to undertake alternative scenarios and sensitivity analysis to evaluate the robustness of the key messages obtained from the modelling analysis.

2.3.1 Scenario modelling

The analysis in this report estimates the cost of reducing emissions through carbon pricing by modelling various scenarios. Scenario modelling does not predict what *will* happen in the future.

Rather it is an assessment of what *could* happen, given the structure of the models and input assumptions.

Scenarios are an analytical lens through which to view a problem; they do not factor in all elements of the 'real world'. In particular, the scenarios do not assess the impact of climate change on the economy. Scenarios guide understanding of policy impacts, relativities of different policy options and the extent that parts of the economy (technology, preferences and so on) need to shift from current trends to achieve particular outcomes, given the model's assumptions.

Input and policy assumptions are particularly important. Many variables affect the estimated cost of responding to carbon pricing. The future path of these variables is not known. However, values are required for the modelling analysis, so assumptions must be made.

The Treasury developed these assumptions, through research, through consultation with stakeholders and domestic and international experts, and on the basis of expert consultancies. While they are intended to be plausible central estimates within a range of uncertainty, other analysts could well form different judgements.

The inherent difficulty in developing assumptions and undertaking simulations is compounded by the long timeframes required for this analysis. Generally, more caution is needed in interpreting results that are well into the future. As the timeframe expands, assumptions are more speculative. Just as modellers in 1972 could not have easily foreseen today's widespread internet use and China's economic transformation, modellers today are unlikely to accurately foresee all potentially relevant developments in the world of 2050.

2.3.2 Economic measures of cost

The modelling encompasses several measures of economic cost.

It focuses on gross national income (GNI)[4] as the high level measure of economic welfare impact rather than gross domestic product (GDP). GNI reflects changes in GDP, the terms of trade and international income transfers. Reducing greenhouse emissions in the least-cost way may involve transfers of income between economies, and influence nations' terms of trade. In that context, GNI is a better measure of welfare, as it excludes income accruing to overseas residents, thereby depicting the current and future consumption possibilities available to Australians. It measures what a nation can afford to buy.

Different measures indicate the output of an industry or economy. Two common definitions are gross value added (GVA) and gross output. GVA measures the returns accruing to the owners of primary factors such as land, labour and capital used in production. GDP is the sum of GVA across industries, plus taxes less subsidies on products. Gross output is the value of an industry's output and measures turnover or activity. The most appropriate measure of output will vary. GVA indicates an industry's contribution to economic activity, as it excludes the value of intermediate inputs from other industries. Gross output is the focus of this report as emissions are created during production.

4 GNI, aggregate primary income of Australians including income received from non-residents, was previously known as Gross National Product (GNP). The ABS has used the term GNI since 1998, to better reflect what the variable measures.

All gross world product (GWP) and regional gross domestic product (GDP) statistics are in 2010 US dollars, using 2005 purchasing power parity weights.[5]

2.3.3 Presentation of results

Results need careful interpretation. Statistics and numbers can mean different things when reported in different contexts.

Research indicates the economic costs of reducing emissions are widely misunderstood and public attitudes towards action on climate change are significantly affected by how impacts and costs are communicated. A 2008 survey (conducted before previous Treasury modelling) found 25 per cent of Australian respondents believed that significantly reducing greenhouse gas emissions would result in incomes falling from current levels, despite economic modelling unanimously finding that emission reductions are consistent with continuing strong trend economic growth and increases in average incomes. Associated research finds clear communication that avoids this misunderstanding results in significantly higher support for policy action. Avoiding misunderstanding by making it clear that average incomes rise, but rise less than they would without policy action, also reduces opposition to policy action by around a third (Hatfield-Dodds and Morrison, 2010).

Other analysis finds people who are only weakly engaged on policy issues tend to withdraw their support when public debate becomes complex or highly contested, and these issues interact with communication and framing issues. This often hollows out expressed support, as evident in responses to the Australian debate around the release of the Stern Report in late 2006 (Morrison and Hatfield-Dodds, 2011).

This occurs around climate policy issues, despite the underlying science becoming more certain in its predictions (Leviston et al, 2011; and Garnaut, 2011a). The recent Lowy Institute poll (Hanson, 2011), for example, finds both an increase in the share of people willing to pay an additional $20 per week or more for electricity as part of climate change action, and a significant reduction in people who are willing to pay $1 to $10 per week, between the years 2008 and 2011. The same survey question in June 2011 found more than 30 per cent of Australians believe that significantly reducing greenhouse gas emissions would result in incomes falling from current levels, in direct contradiction of economic modelling results, while around 60 per cent believe that incomes would continue to rise (Hatfield-Dodds, 2011).

Comparing results with a hypothetical future such as a reference scenario is a common and reasonable way to explain how a policy will influence the economy in isolation from other events.

However, such results must not be interpreted as suggesting policy will have an absolute impact relative to the *current* world. For example, if cutting interest rates would raise economic growth by 1 per cent relative to what otherwise would have been, this should not be interpreted as saying the economy would necessarily rise 1 per cent from its current level, if interest rates were cut. The statement is only relative to how the economy would have evolved in the absence of a cut.

To help and enrich understanding of the economic implications of pricing carbon, this report presents a range of measures when reporting high level results.

5 See the discussion in Box 2.7 of Australian Government (2008).

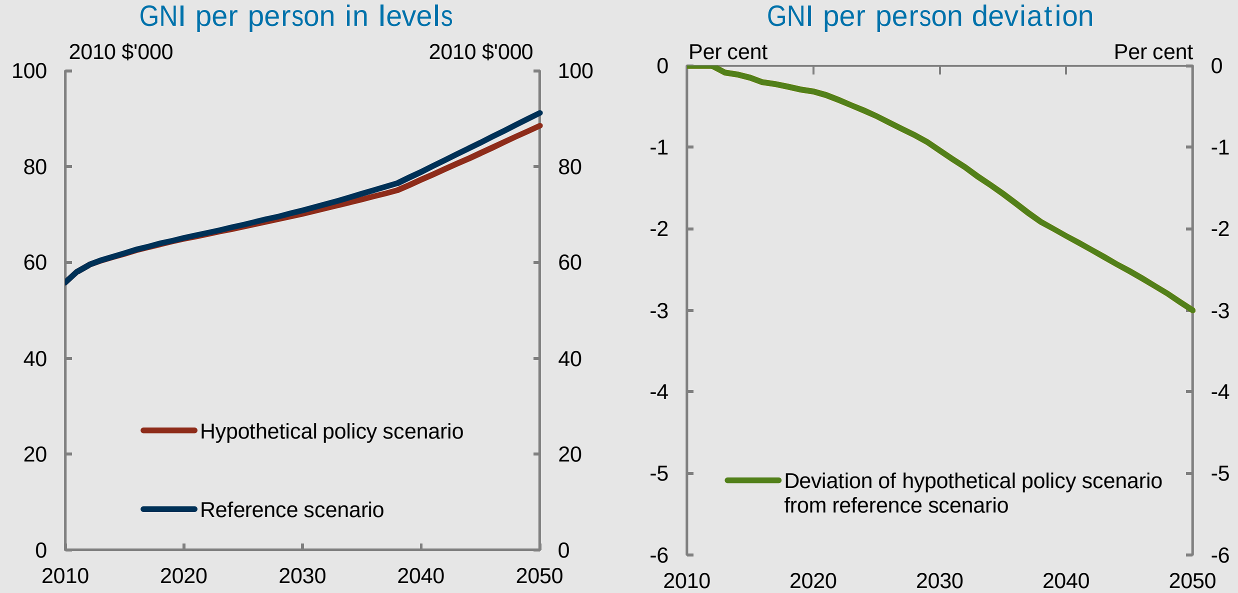
Box 2.1: Alternative ways to report on modelling — a hypothetical example

The same modelling results, reported differently, can convey different impressions to non-experts. For instance, the chart below (left) shows the impact on GNI per person in a reference scenario and in a hypothetical carbon price scenario. In the former, GNI per person grows from around $56,000 in 2010 to $91,000 by 2050 in today's dollars. The chart below (right) shows the percentage deviation from the reference scenario, and sometimes is reported as a 'loss' when it only indicates that GNI per person growth is slightly weaker than the reference scenario of ongoing income per person growth.

These six statements all report the same result and describe the 'cost' of the hypothetical policy scenario relative to the reference scenario.

- GNI per person growth is 0.1 of a percentage point per year lower over 40 years in the policy scenario than in the reference scenario.
- GNI per person is around $2,700 ($2010) lower in 2050 in the policy scenario than in the reference scenario.
- GNI per person is 3.0 per cent lower in 2050 in the policy scenario than in the reference scenario.
- The cumulative GNI per person loss is around $40,000 ($2010) over 40 years in the policy scenario compared to the reference scenario.
- The cumulative GNI per person loss is 1.4 per cent of total GNI per person over 40 years in the policy scenario compared to the reference scenario.
- GNI per person is 1.5 times its 2010 level in 2046 in the hypothetical scenario (instead of in 2044 in the reference scenario), a delay of 2 years.

Chart 2.2: Real GNI per person scenarios



Note: All results in this publication, unless otherwise indicated, are in Australian financial years, ending 30 June of the year quoted.
Source: Treasury.

This report focuses on the costs of mitigation, not the net benefits of action, and the choice of discount rates is not important for interpreting the results.[6] The modelling shows the costs of mitigation as they happen in a relevant year. However, if the modelling results were to be used to judge the importance of future costs from today's perspective, alternative discount rates would alter that analysis.

Carbon prices can be reported in different units. Nominal carbon prices include the impact of inflation on prices. When a carbon price is reported in nominal terms, such as $20 in 2013, this is the actual nominal price of an emission in 2013 using the dollars available in 2013. Often, to adjust for inflation, carbon prices are in base year or 'real' prices: for example, a carbon price of $21 in 2014, in 2010 prices. This reflects the purchasing power of $21 in 2010 dollars. Carbon prices in this report are reported in both real and nominal terms, depending on the context, and are clearly labelled.

2.3.4 Model limitations and uncertainty

Economic models approximate the complex real world and consequently have limitations that affect the interpretation of results. Despite this, models examine complex issues rigorously and consistently across long timeframes.

The models are aggregated to different extents. Aggregation necessarily simplifies the real economy by accommodating data and computing power limitations. In industries where businesses are reasonably homogenous, with similar patterns of inputs and emission intensity, this simplification has little effect. But in industries where firms have different, sometimes dramatically different, patterns of inputs and emission intensity varies widely, this simplification reduces the accuracy of the modelling and results.

The models exclude the risks and impacts of climate change itself. Mitigation policy improves the efficiency of the economy by pricing the 'externality' involved — a form of market failure as those emitting do not bear all the costs of climate change associated with emissions. The effect of carbon pricing needs to be considered in the context of broader benefits of mitigation action, including the economic benefits of reduced risks and impacts of climate change (Stern, 2007; Garnaut, 2008; Bollen et al, 2009; Tol, 2009; Aldy et al, 2010; and Garnaut, 2011b).

The CGE models generally are used to focus on the longer term economic adjustment costs of carbon pricing or other changes in the economy (such as high terms of trade). They capture short-term adjustment costs and transition paths less well. That is why they are supplemented with bottom-up models and other insights from partial analysis. MMRF assumed that capital, labour and emission intensity improvements take time to respond to changes in the economy, and these transition costs are captured in the analysis. GTEM assumes labour and capital adjust perfectly across industries, and it does not capture as many of the transition costs as would be experienced in the real world. Thus, GTEM more robustly explores the post-transition economy.

The models do not capture market failures caused by asymmetric information, strategic interaction between agents, public goods (goods for which the consumption by one individual does not preclude the consumption by others) and externalities.

6 Garnaut (2011b) discusses how discount rates can be useful for weighing up costs and benefits and how to choose the discount rate.

The models do allow for learning to make some technologies cheaper over time. For example, renewable technologies for electricity generation are subject to learning-by-doing, thus their capital costs fall with their output, which leads to a greater uptake of renewable technologies in the electricity generation sector. Economy-wide technological improvements are generally exogenous in the models. The sensitivity analysis, particularly in the electricity generation sector, explores alternative technology assumptions to check the robustness of key results.

The models do not capture transaction costs in reducing emissions, such as through regulating emission trading schemes. In the real world, implementing and monitoring emission markets has transaction costs, and identifying mitigation opportunities has search costs. Similarly, providing information could cheaply and easily reduce some transaction costs and such complementary measures are not explored in the modelling.

The models do not capture the potential co-benefits of climate change mitigation policy. Some co-benefits occur between mitigation and other environmental objectives, such as the simultaneous reduction in local and regional air pollution, together with carbon reduction from less coal burning.

The modelling reflects some forms of uncertainty by undertaking sensitivity analysis. It shows the modelling is robust to a range of assumptions and that aggregate economic costs are similar across a range of plausible assumptions.

The modelling also accounts for near-term electricity generation investments, which reflect the implications of current uncertainty about climate change mitigation policy. In the longer term, to the extent that uncertainty may reduce investment (Deloitte, 2011), the modelling may understate investment, possibly affecting the projected mitigation costs.