CLIMATE CHANGE AUTHORITY

POLICY OPTIONS FOR AUSTRALIA'S ELECTRICITY SUPPLY SECTOR – SPECIAL REVIEW RESEARCH REPORT

MODELLING COMMISSIONED FOR THIS REVIEW

Appendix C.1 Electricity sector modelling

Modelling approach

This section provides an overview of the electricity sector modelling the Authority commissioned Jacobs to undertake to help inform the Authority's policy recommendations in the Special Review. Jacobs' full modelling report is available on the Authority's website.

To facilitate a like-for-like comparison of policies, the modelling constrains each policy scenario to achieve the same cumulative emissions over 2020–2050, and uses common input assumptions. In the seven core scenarios, the emissions budget was set at a level consistent with the world taking action to limit global warming to no more than 2 degrees. A weaker emissions budget (consistent with 3 degrees) was examined as part of the sensitivity analysis. This scenario is included merely for the purpose of testing model sensitivity and does not reflect the Authority's endorsement of a three degree temperature increase as a policy objective.

The modelling covers the National Electricity Market (NEM) and the Wholesale Electricity Market (WEM) of Western Australia which currently make up about 94 per cent of Australia's electricity demand (AECOM 2013, p. 4). Section 1.3 of Jacobs' Modelling Report (Jacobs 2016c) provides further details on the modelling approach.

It is important to note that the modelling does not aim to predict future outcomes; rather it is intended to provide high-level insights to inform policy choice. To do this, the modelling makes a range of assumptions and simplifications. Some assumptions omit features that are important for short-term outcomes in the electricity sector, but are small in absolute terms over the longer time horizons that are the focus of this work, so excluding them does not materially affect the comparative projections. Some other assumptions, such as the level of electricity demand, and the availability and costs of electricity generation technologies, are important for the results. In these cases, the impact of varying the assumption is explored through sensitivity analysis. In general, the level of uncertainty around the projections increases over the modelling horizon. Jacobs' modelling is 'partial' rather than 'general' equilibrium, so it does not incorporate the second-round or 'indirect' effects[1] of these policies on the wider economy. These effects were considered for two scenarios—see Section 3.3 and Appendix C.3 of this report. Section 1.4 of Jacobs' modelling report (Jacobs 2016c) provides further guidance on interpreting the modelling.

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[1] Examples of second-round or indirect effects include interactions of the policies with the taxation system, the substitution of goods between industries and the movement of workers around the economy.

The proposed policies, modelling assumptions and approach were released for public feedback in the May 2015 consultation paper *Modelling illustrative electricity sector emissions reduction policies* (Jacobs 2015), which was published on the Authority's website.

Scenarios and sensitivities

Jacobs modelled seven individual policy scenarios and a reference case. Table 3 in Chapter 3 explains these policies in more detail. These policies are broadly representative of those proposed and discussed for the sector in recent years.

The policy scenarios were compared to a reference case which incorporates the current Renewable Energy Target (both the Large-scale Renewable Energy Target (LRET) and Small-scale Renewable Energy Scheme (SRES)) and state-based policies affecting the sector (current at the time of modelling).[2] It is important to note that the reference case is not a projection of the sector under a 'business as usual' future, but designed so that differences between the reference and policy cases are due to the policies, rather than the policies and other features. To achieve this, both the reference case and policy cases assume strong global action to reduce emissions, with the reference case assuming no new policies in the Australian electricity sector. Each policy scenario:

- assumes policies are announced in 2017–18 and start in 2019–20, so results match the reference case to 2018–19, but deviate thereafter. In practice, reaction and build times may be longer than presumed as investors and stakeholders consider the uncertainties, and labour and resource availability may constrain how quickly new builds can occur.
- like the reference case, includes the current LRET and SRES trajectories from 2020 to 2030.
- assumes all prospective zero- and low-emissions technologies—including nuclear—are available to achieve the emissions budget.
- excludes the sector from the Emissions Reduction Fund's safeguard and crediting mechanisms.
- omits the use of offsets from other sectors, or international permits or credits in meeting the emission budget for electricity generation. The ability to surrender such units can reduce compliance costs and is an important potential design feature of some of the policies analysed. However, if offsets or international permits or credits were included in the modelling, the results could be dominated by expected future offset or unit prices and would be less informative about the relative effects of the policies themselves. The economy-wide modelling (Appendix C.3) incorporates some use of international permits or credits.
- generally applies the same design for policy features such as coverage thresholds, limits on banking and borrowing of permits, and so on (specific design features are in Table 8). This helps ensure that differences in results are driven by material differences between the policies.
- is tested to ensure it meets current standards for electricity system reliability. Jacobs subjected modelled plant entry to current NEM and WEM output-based probabilistic reliability standards, as well as conducting an additional deterministic test.

Jacobs also tested the performance of combinations and the robustness of individual policies to changes in key assumptions. Table 7 sets out the key questions explored and the policy scenarios investigated in each case. As with all of the modelled scenarios, the sensitivities have been chosen to

[2] This includes the Australian Capital Territory's current 100 per cent renewable energy target and supporting auctions, but doesn't include Victoria's renewable energy target of 40 per cent by 2025, or Queensland's renewable energy target of 50 per cent by 2030.

assist in comparing the performance of policies only and should not be interpreted as policies that the Authority would recommend.

Table 7 Relationship between modelling questions, sensitivities and policies

Questions	Explore through	Scenarios	Key assumptions and design
How do individual policies compare on key metrics when meeting the same cumulative emissions budget?	Core scenarios: modelling each policy separately with common inputs and a common emissions budget	All	Strong global action, affecting fuel prices and technology learning rates (2 degrees) Policies calibrated to meet 2 degree emissions budget Technology availability (constant across all scenarios except technology sensitivity): • CCS and geothermal can be deployed from 2030 • Nuclear can be deployed from 2035
Will combinations of policies perform better than individual policies?	Policy combinations	Cap and trade and low emissions target Cap and trade and regulated closures Regulated closures and low emissions target	Strong global action affecting fuel prices and technology learning rates (2 degrees) The first policy in each combination is fixed; the other varies so the combination meets the 2 degree emissions budget. When fixed: • Carbon price consistent with likely chance of 3 degrees warming • Regulated closures of all coal capacity by 2030 (regulated closures limited to coal-fired generators)
Does a large shift to distributed generation and storage change the relative performance of policies? If actual electricity demand is lower than projected, does this change the relative performance of policies?	Sensitivity: low demand (higher penetration of PV and storage; lower underlying electricity demand)	Reference case Cap and trade Low emissions target (planned but not run: LET targets exceed electricity demand)	Strong global action, affecting fuel prices and technology learning rates (2 degrees) Uses policy parameters from the core modelling scenarios (that is, policy parameters are an input not an output as per most other runs) Lower electricity demand sourced from AEMO and IMO Faster reductions in battery storage costs Relaxed upper bounds on share of households and businesses that can install PV
If actual electricity demand is higher than projected, does this change the relative performance of policies?	Sensitivity: high electricity demand (electrification of other sectors and increased penetration of electric vehicles)	Reference case Cap and trade Low emissions target	Strong global action, affecting fuel prices and technology learning rates (2 degrees) Uses policy parameters from the core modelling scenarios (that is, policy parameters are an input not an output as per most other runs) High electricity demand based on ClimateWorks Australia et al. (2014) for NEM and Independent Market Operator (2015) high demand scenario for the WEM
Does changing costs and/or availability of key large-scale technologies change the relative performance of policies?	Sensitivity: technology sensitivity	Reference case Cap and trade Low emissions target Renewable energy target	Strong global action, affecting fuel prices and technology learning rates (2 degrees) Policies calibrated to meet 2 degree emissions budget No nuclear, CCS or geothermal deployment Faster reductions in battery storage costs
Would less ambitious emissions targets change the relative performance of policies?	Sensitivity: weaker emissions budget	All	Weaker global action, affecting fuel prices and technology learning rates (3 degrees) [3] Policies calibrated to meet 3 degree emissions budget

Source: Climate Change Authority.

[3] This scenario is included merely for the purpose of testing model sensitivity and does not reflect the Authority's endorsement of a three degree temperature increase as a policy objective.

Further details on the scenarios and sensitivities are available in Sections 2.2 and 2.3 of Jacobs' Modelling Report (Jacobs 2016c).

Key inputs and assumptions

Table 8 provides an overview of the key modelling assumptions. Another standard assumption adopted in the modelling is that investors have 'perfect foresight'. That is, the future paths of all variables are known with certainty. Investment decisions, for example, are made with complete knowledge of future fuel and capital costs. The impacts of uncertainty on policy choice are considered through sensitivities and the Authority's qualitative evaluation.

For further details on the modelling assumptions see Appendix C of Jacobs' modelling report (Jacobs 2016c).

Table 8 Key modelling assumptions for core scenarios

Modelling assumption	Description
General assumptions	
Emissions budget	In order to facilitate a like-for-like comparison of policies, the modelling constrains each policy scenario to achieve the same cumulative emissions over 2020–2050. The emissions budget is set at a level consistent with the world taking action to limit global warming to no more than 2 degrees, and covers both direct (emissions from combustion of fuels in electricity generation) and indirect emissions (emitted during processing and supply of fuel to power stations).
Electricity demand	The core electricity demand projection for the modelling is based on the series from the Department of the Environment's 2014–15 emission projections (DoE 2015a). These official projections use a total electricity demand series developed by pitt&sherry (2015) and ACIL Allen Consulting (2015).
Commodity prices (coal and gas) and technology costs	From 2020, commodity prices and technology costs based on consistent backdrop involving concerted global action to limit global warming to no more than 2 degrees.
Policy-specific assumptions	
Cap and trade	Applies to all generators, full auctioning of permits, no banking or borrowing of permits.
Emissions intensity scheme	Applies to all generators, emissions intensity baseline declines linearly from 2020, unlimited banking of permits, borrowing limit of 10 per cent of permits.
Renewable energy target	Eligibility limited to new large-scale renewable generators and brownfield projects on existing sites. New LRET trajectory additional to the existing LRET.
Low emissions target	Eligibility includes all generators with emissions below 0.6 t CO_2-e/MWh (the baseline). Eligible generators with above-zero emissions earn partial certificates in proportion to their emissions intensity relative to the baseline. Target additional to the existing LRET.
Contracts for difference	Eligibility limited to new renewables, new fossils with CCS, CCS retrofits and nuclear. Twenty year contracts; tariff payed through an energy-based customer levy.
Regulated closures	Applies to coal-fired and gas generators. Aged-based closure of coal generators that do not undergo CCS retrofit. Gas generators subject to an annual emissions limit of 2,200 t CO_2-e/MW capacity. No new coal without CCS.
Absolute baselines	Applies to all generators with above average emissions intensities. No new coal or gas without CCS.

Source: Climate Change Authority.

Technology costs

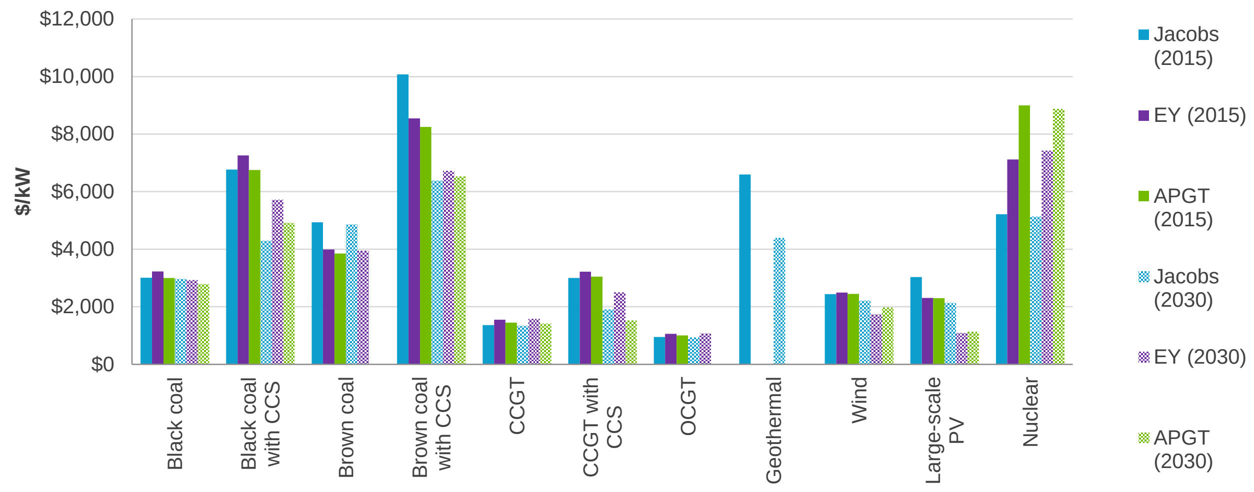
This section compares Jacobs' technology costs with those from two other recent studies:

- The Australian Power Generation Technology (APGT) study steered by CO2CRC, CSIRO, Australian Renewable Energy Agency, Australian Government: Department of Industry and Science, and Anlec R&D using consultants including the Electric Power Research Institute.
- Modelling for South Australia's Nuclear Fuel Cycle Royal Commission conducted by Ernst & Young (EY).

Figure 23 compares selected capital costs for technologies in both 2015 and 2030 across all three studies. Capital costs for all technologies—except for nuclear—are projected to fall in real terms over time due to 'learning by doing' as installed capacity increases; learning rates are slower with mature technologies. The capital costs across all three studies are broadly similar with the exception of nuclear, brown coal and large-scale solar generators.

- Relative to Jacobs, the 2015 capital cost of a brown coal plant is around 20 per cent lower in the APGT and EY studies.
- Jacobs' nuclear capital costs were about half that suggested by the APGT study; nuclear costs in the EY study are midway between the two. Further discussion of Jacobs' nuclear cost assumptions is in Appendix C.4.6 of Jacobs' modelling report (Jacobs 2016c).
- Jacobs' capital costs for large-scale solar are around 25 per cent higher in 2015 and around 50 per cent higher in 2030 than the APGT and EY studies.

Figure 23 Technology capital cost comparison



Note: All studies adopt costs consistent with 2 degrees global action scenario. In addition to the capital costs above, the EY report also publishes overnight capital costs for nuclear that include project development and licensing costs.
Source: Climate Change Authority based on APGT 2015; Jacobs 2016c; Ernst & Young 2016.

Key estimated impacts

The following section summarises the key estimated impacts of the different policy scenarios on:

- share of generation by technology type
- emissions from the electricity sector
- wholesale and retail electricity prices, and household spending
- generator profits

- cost to society, including resource costs and cost of abatement.

This summary compares results of the individual policies under the 2 degrees emissions budget. The complete set of modelling results—including policy combinations and sensitivities—are available in Jacobs' modelling report.

The seven policy scenarios may be classified into three broad categories:

- 'market mechanisms'—cap and trade and the emissions intensity schemes. These policies put a price on emissions to change the relative price of high- and low-emissions generation.
- the 'technology pull' policies—RET, low emissions target and contracts for difference. These policies change the generation mix by subsidising renewable and/or low-emissions generation.
- the 'regulatory' policies—regulated closures and absolute baselines. These policies change the generation mix by reducing output from high-emissions generators through regulation.

Generation mix

Meeting the 2 degrees emissions budget causes large changes in the mix of generating plants in Australia (Table 9). In the reference case, which assumes no new climate policies, coal-fired power remains the dominant source of generation. In the policy scenarios, however, coal generation and capacity is projected to reduce rapidly, reaching near zero between 2025 and 2040 (depending on the policy scenario).

Table 9 Share of generation by technology type, 2 degrees, 2030 and 2050

Scenario	2030				2050			
	Coal	Gas	Renewable	Other low emission	Coal	Gas	Renewable	Other low emission
Reference	63%	12%	24%	0%	53%	28%	19%	0%
Cap and trade	3%	41%	46%	10%	0%	8%	65%	27%
EI scheme	5%	24%	52%	19%	0%	6%	69%	25%
RET	16%	9%	74%	0%	4%	15%	81%	0%
Low emissions tgt	20%	5%	70%	5%	1%	5%	72%	22%
Contracts for diff	19%	6%	72%	2%	2%	6%	73%	19%
Reg closures	0%	32%	66%	2%	0%	21%	62%	17%
Abs baseline	21%	3%	76%	1%	0%	1%	71%	28%

Note: Rows may not sum up to 100 due to rounding. 'Other low-emission' is gas CCS and nuclear (coal CCS was available but not deployed in any scenario).
Source: Jacobs 2016c.

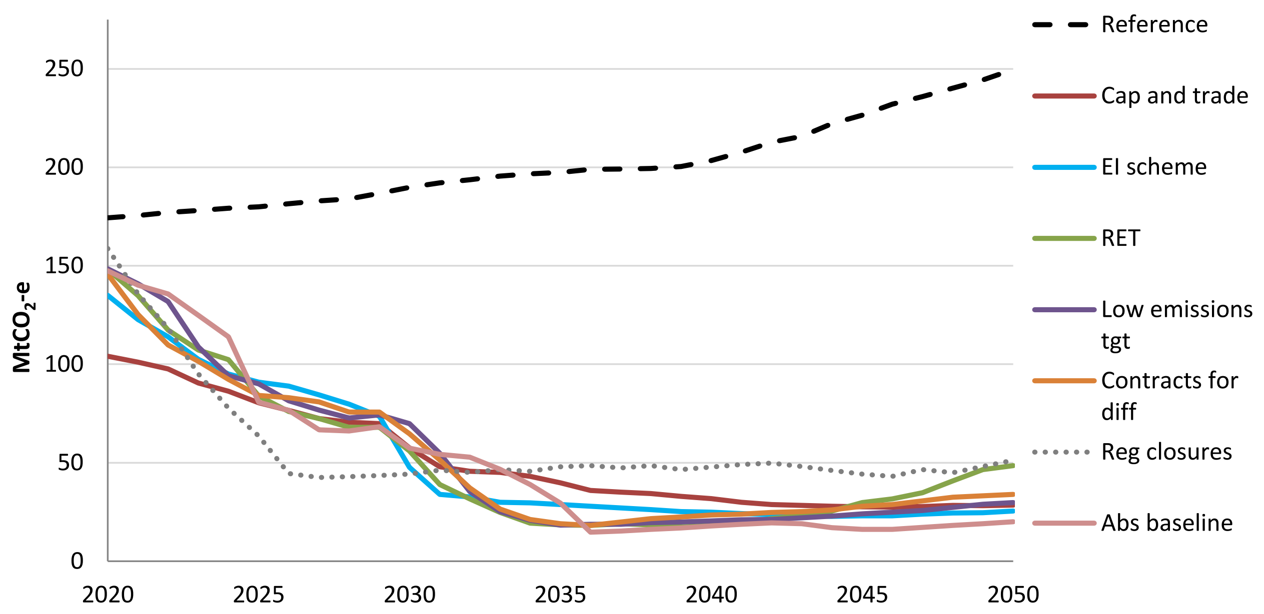
In all the policy scenarios, the lower share of coal generation is largely replaced with renewable energy and other low-emissions generation. Renewable energy is projected to make up between 60 and 80 per cent of the generation mix by 2050. The level of renewable energy is highest in the technology pull scenarios due to these policies directly providing a subsidy for renewable technologies. Renewable generation is lower in the market mechanism scenarios, where gas generation increases in the early years, and low emission technologies such as CCS and nuclear increase their share later. Small-scale solar PV is adopted at high levels across all scenarios including the reference case.

Current reliability standards are met in all policy scenarios despite increasing shares of intermittent renewable generation. After 2030 gas-fired peaking plants are projected to have an important role providing reserve capacity to meet these requirements.

Emissions

Each policy was required to meet the demanding emissions budget. Annual emissions were allowed to vary across policies so long as the overall emissions budget was met, however emissions and emissions intensities are projected to fall sharply in the 2020s in all policy scenarios (Figure 24 and Figure 25). This indicates that even though the costs of low-emissions technologies fall over time, early action is required to meet the emissions budget. If action is delayed for too long, the emissions intensity of the generation fleet would stay high for too long and the emissions budget would be exceeded. This relatively rapid change in intensity is consistent with other studies that have explored strong decarbonisation of Australia's electricity sector (ClimateWorks Australia et al. 2014; CCA 2014c; TCI 2016).

Figure 24 Emissions by policy scenario, 2 degrees, 2020–2050

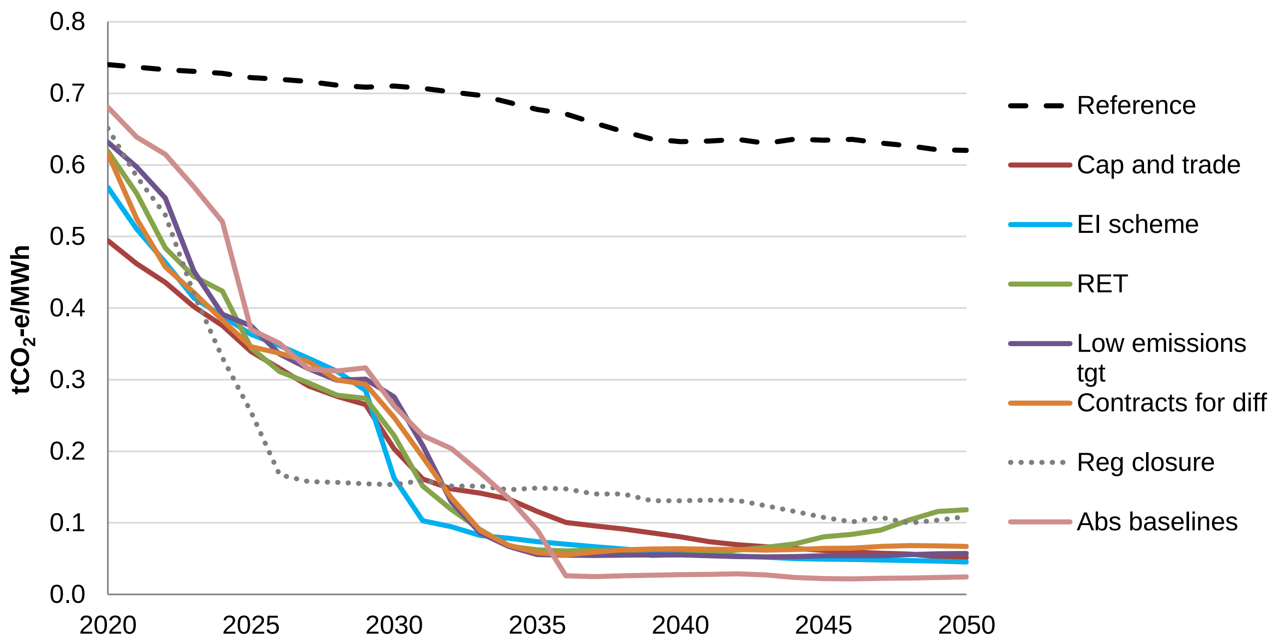


Note: Emissions from the NEM and WEM. Emissions comprise direct emissions (from combustion of fuels in electricity generation) and indirect emissions (emitted during processing and supply of fuel to power stations). The regulated closures policy breaches the emissions budget by about 200 Mt CO_2-e or 15 per cent.
Source: Jacobs 2016c.

In the absence of new policies, emissions are projected to be substantially higher in the reference case than in the policy scenarios. Emissions in the reference scenario grow by around 1.2 per cent per year, which is lower than the rate of growth in demand for that scenario. The emission intensity of generation falls slightly due to the increasing projected share of gas-fired generation.

Regulated closures is the only scenario that does not achieve the budget; cumulative emissions exceed the budget by about 15 per cent (227 Mt CO_2-e). Even with rapid closure of all coal by 2027, emissions are not projected to fall to the same level as the other policy scenarios. This is because, in the absence of other policy mechanisms, coal is replaced with a large amount of gas-fired generation rather than renewables.

Figure 25 Emissions intensity by policy scenario, 2 degrees, 2020–2050



Note: Emissions intensity of the NEM and WEM. Emission intensity is based on direct emissions (from combustion of fuels in electricity generation) and electricity demand. The regulated closures policy breaches the emissions budget by about 200 Mt CO_2-e or 15 per cent.
Source: Climate Change Authority based on Jacobs 2016c.

Prices

This section provides an overview of the projected effects of the policy options on wholesale and retail prices.

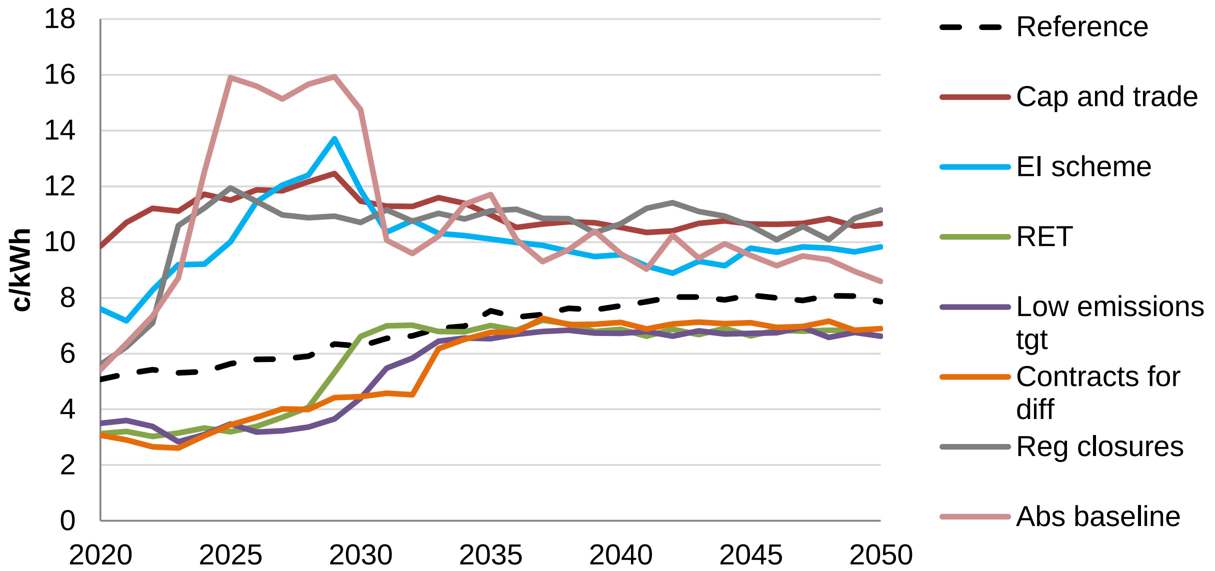
The type of mitigation policy has a large effect on projected wholesale electricity prices (Figure 26). For the policy scenarios, wholesale prices:

- are generally the highest in the cap and trade scenario. This reflects the impact of the carbon price on the dispatch costs of fossil fuel plants.
- also rise in the emission intensity scenario but are 12 per cent lower than the cap and trade scenario in present value terms. This is because of the production subsidy provided by free allocation of permits up to the baseline.
- also rise for the regulatory scenarios as they restrict dispatch of low cost but high-emissions plant. In the absolute baselines policy there is a price spike from 2024 to 2030.[4]
- are below or around the reference scenario prices for the technology pull policies. These policies provide a subsidy to generators with low operating costs, suppressing wholesale prices over the modelling period.

For further detail about how different policies affect wholesale prices see Box 2 in Chapter 2.

[4] For this period wholesale prices are projected to be higher than under any other policy. Over 2024–2030 new renewables are required to replace the declining output from existing plant. These renewables cause sharp increases in wholesale prices because they have only a short window to recover enough of their fixed costs before lower-cost technologies (gas CCS and geothermal) can be deployed from 2030. That is, the projected price spike is a function of the modelled policy design (declining limits on existing above-average emissions-intensity plants) combined with assumptions about the availability of new technologies and investors' knowledge of and expectations about future technologies and prices.

Figure 26 Average wholesale electricity price by policy, 2 degrees, 2020–2050



Note: Prices are volume weighted using average hourly prices weighted by hourly generation proportions. Volume weighted prices are calculated for each region of the NEM and the WEM and a system wide average is derived by weighting each regional price by the ratio of each region's energy demand to total demand. The regulated closures policy breaches the emissions budget by about 200 Mt CO_2-e or 15 per cent.
Source: Jacobs 2016c.

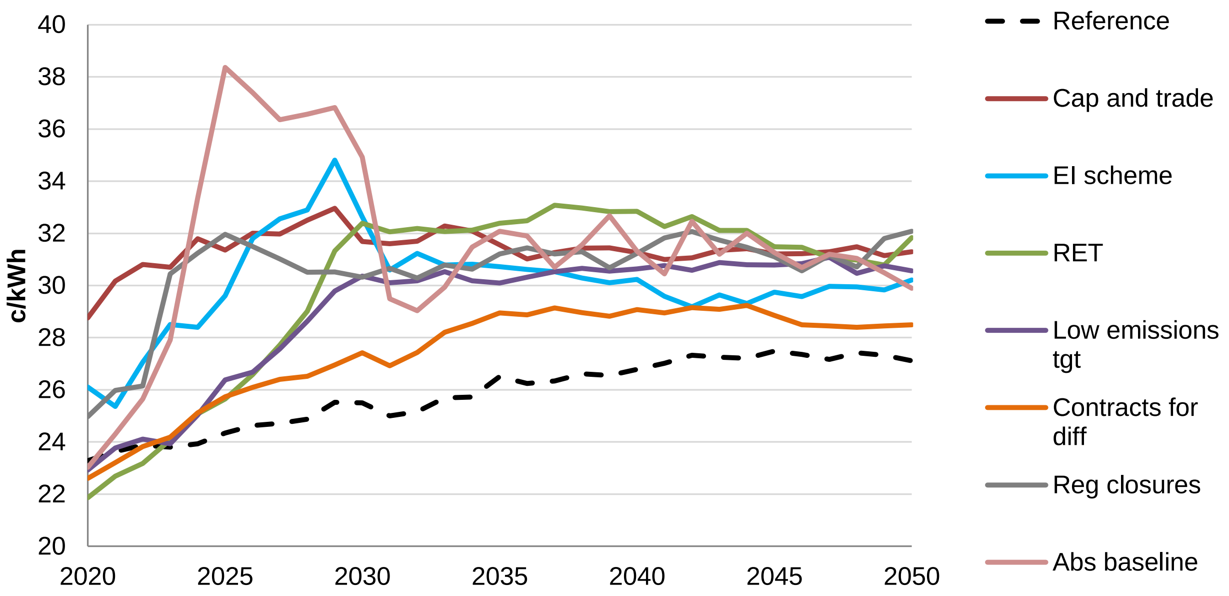
Retail prices are made up of the costs of generating, transmitting, distributing and selling electricity to end users (Section 2.5.2). Climate polices affect only some of these components:

- Market mechanisms and regulatory policies raise wholesale prices, but leave other components unaffected.
- Technology pull policies lower wholesale prices, but raise the retail components of prices as the costs of subsidising technology are borne by retailers and passed on to consumers. In the core policy scenarios, the second effect dominates and overall retail prices are projected to rise.
- Climate policies do not materially affect network costs, which in in 2014–15 made up 47 per cent of residential customer bills (AEMC 2015b).

For all policies, achieving Australia's long-term emissions reduction goals is likely to increase consumer electricity prices; these impacts can be addressed in a range of ways. In Jacobs' modelling average retail prices are projected to be about five to 25 per cent higher in the policy scenarios than in the reference scenario (Figure 27).[5] Projected changes in electricity costs are the product of projected changes in retail price and electricity consumed. Jacobs' modelling uses estimates from Australian data on how electricity demand responds to changes in price to project changes in electricity demand. Average annual residential electricity spending is projected to increase by between $50 and $200 per year depending on the policy (Figure 28). Electricity spending as a share of household income is projected to remain around 2.2 per cent for the reference case and averages between 2.3 per cent and 2.6 per cent in the policy scenarios over the period to 2050 (Jacobs 2016c). As noted above, these projections exclude policies such as energy efficiency measures which could be implemented alongside electricity sector climate policy and can improve electricity affordability even with increased electricity prices. Other recent modelling suggests the largest influences on future electricity affordability may be network infrastructure costs rather than climate action (CSIRO National Outlook p.16).

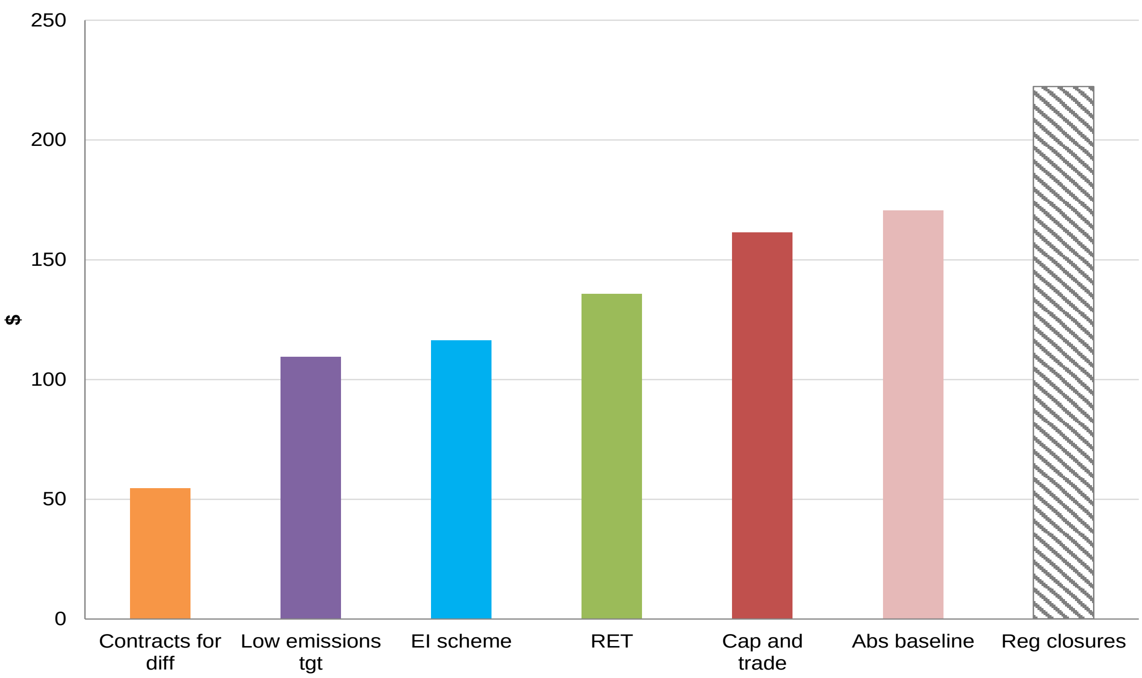
[5] This is calculated as the percentage difference between the present value of prices in the policy and reference case.

Figure 27 Average residential retail price by policy, 2 degrees, 2020–2050



Note: Prices are volume weighted using average hourly prices weighted by hourly generation shares. Volume weighted prices are calculated for each region of the NEM and WEM and a system wide average is derived by weighting each region price by the proportion of each region's energy demand to total energy demand. The regulated closures policy breaches the emissions budget by about 200 Mt CO_2-e or 15 per cent. The cap and trade scheme raises revenue which could be used to assist consumers with higher electricity prices; for other policies assistance could be drawn from general revenue.
Source: Jacobs 2016c.

Figure 28 Average annual residential customer spending, relative to reference, 2 degrees, 2020–2050



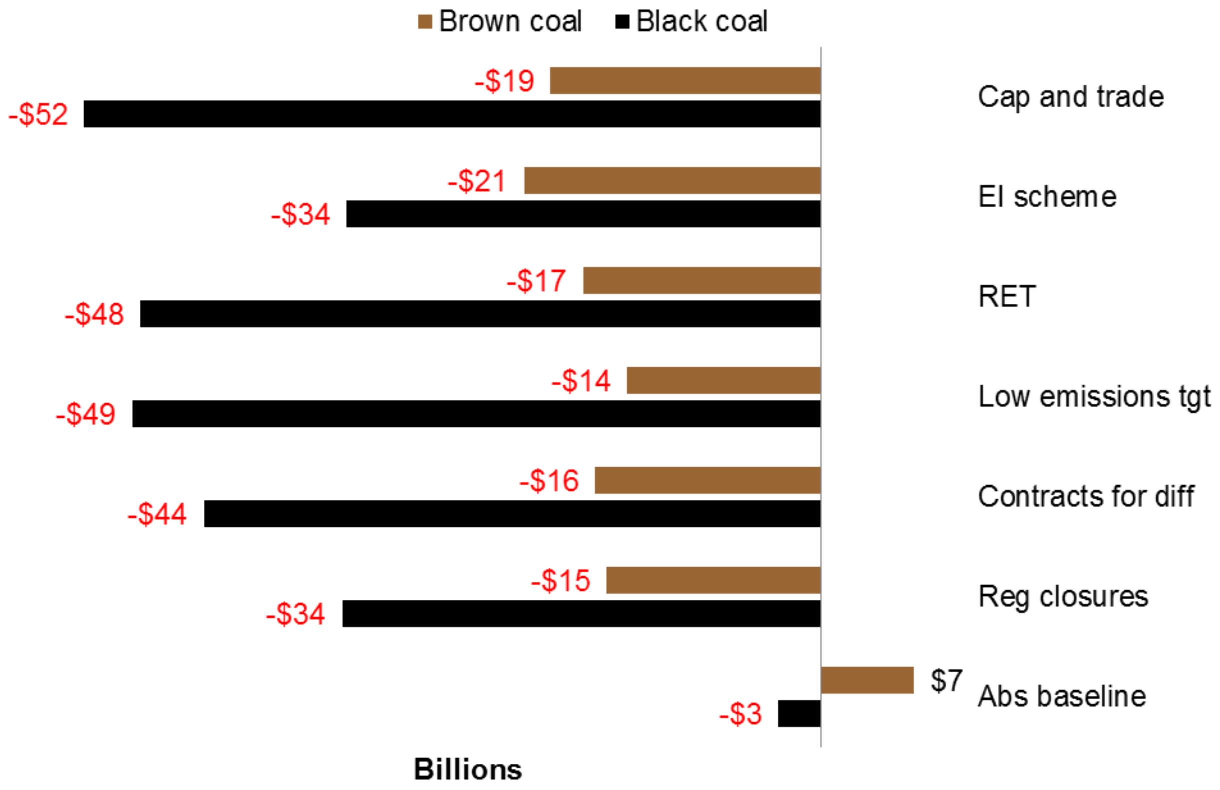
Note: Figures relative to reference case calculated by subtracting the reference case spending from the policy case spending. The regulated closures policy breaches the emissions budget by about 200 Mt CO_2-e. The cap and trade scheme raises revenue which could be used to assist consumers with higher electricity prices, for other policies assistance could be drawn from general revenue.
Source: Climate Change Authority based on Jacobs 2016c.

Generator profits

Gross profits are the difference between total revenue and all operating costs. Gross profits for incumbent coal generators are projected to be lower than the reference case in all policies under the 2 degree emissions budget except in the absolute baselines scenario (Figure 29). Incumbent coal generators can have higher profits relative to the reference case in this scenario because:

- there are no additional costs to generation from the policy
- the wholesale price of electricity is relatively high (Figure 26).

Figure 29 Difference in NPV of gross profits for incumbent coal generators, relative to reference, 2 degrees, 2020–2050



Note: NPV of gross profits calculated with seven per cent discount rate and discounted to 2020 levels. Gross profit is a concept related to costs, and for a generator is the difference between total revenue, which consists of pool revenue, contract revenue and certificate revenue (where applicable), less all operating costs, including fuel costs, fixed and variable operating costs and emissions costs. Gross profits for reference case are adjusted for new entrants using a generation to capacity ratio. The regulated closures policy breaches the common cumulative emissions budget, so the change in profits may not be directly comparable with other policies. The reference case assumes strong global action to reduce emissions, and no additional climate policies in the Australian electricity sector. Revenue raised under the cap and trade scheme is not redistributed in the modelling. For further information on interpreting gross profits measures, see Appendix C.3.3 of Jacobs' modelling report (Jacobs 2016c).
Source: Climate Change Authority based on Jacobs 2016c.

The closure of coal generators creates opportunities for investment in new low-emissions generators (Figure 17 in Section 4.1.2), which could be taken up by new or existing businesses. Overall, between 2020 and 2050 the NPV of cumulative gross profits in the sector increases by around 10 to 110 per cent relative to the reference case, depending on the policy.

Incumbent hydro generators generally increase gross profits under all policies. Hydro generators benefit the most under market mechanisms and regulatory scenarios from the increased wholesale price, and under the emissions intensity scheme through revenue earned from permits. In the technology pull policies, hydro generators receive lower wholesale prices, but benefit from price spikes resulting from higher penetration of intermittent generation. Incumbent gas generators benefit in a similar way to incumbent hydro generators, particularly in the 2020s before other non-intermittent generators are assumed to become available.

Further information on gross profits is in Appendix C.3.3 of Jacobs' modelling report (Jacobs 2016c).

Resource cost and cost of abatement

The resource costs presented in Jacobs' modelling represent the direct net cost of the policy to society as a whole, before accounting for indirect costs, and before considering the benefit of emissions reductions achieved by the policy. Resource costs comprise:

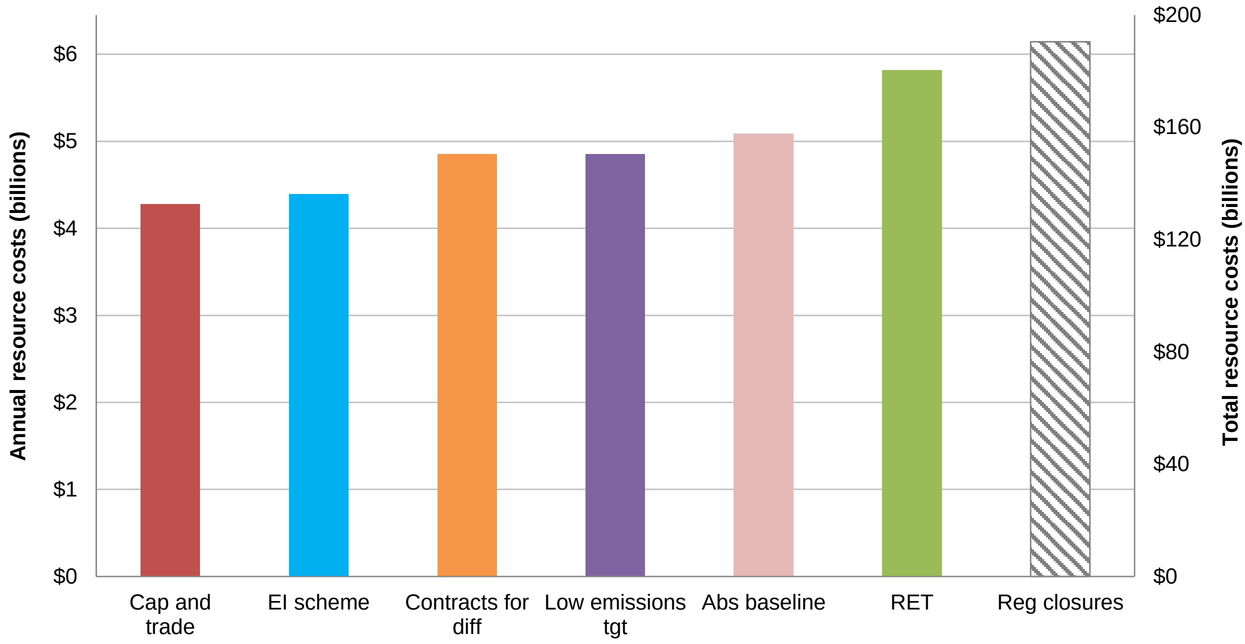
- fuel costs including any delivery (transmission or transport) costs
- variable operating and maintenance costs
- fixed operating and maintenance costs
- capital costs for new plant (both large-scale and distributed generation), large- and small-scale battery storage and interconnector upgrades
- decommissioning costs
- an adjustment to costs to account for changes in demand.

Further information on resource costs is in Appendix B.3 of Jacobs' modelling report (Jacobs 2016c).

The modelling projects that market mechanisms are the lowest cost (Figure 30). This is because market mechanisms create an incentive for generators and households to find the lowest cost ways to reduce emissions rather than prescribing particular emissions reduction activities.

The technology pull and the regulatory policies were all higher cost than the market mechanisms modelled. The technology pull policies have relatively high resource costs because they largely provide direct incentives for one type of emissions reduction activity in the electricity sector—building new zero- or low-emissions plants. This means that other and potentially cheaper emissions reductions are not directly targeted. Similarly, the regulatory policies are focussed on one type of emissions reduction activity—reducing output from high-emissions generators—and are less effective in targeting other emissions reduction opportunities in the sector.

Figure 30 Resource costs relative to the reference scenario, 2 degrees, 2020–2050



Note: Each bar represents the net present value of the change in resource costs relative to the reference case, adjusted for the reduction in demand due to the increase in electricity prices. This is equivalent to the present value of the welfare costs of the policy relative to the reference case before emissions reduction benefits are considered, discounted at the social discount rate of seven per cent. Annual resource cost (left axis) calculated by dividing the total resource cost (right axis) by the number of years. The regulated closures policy breaches the emissions budget by about 200 Mt CO_2-e or 15 per cent.
Source: Jacobs 2016c.

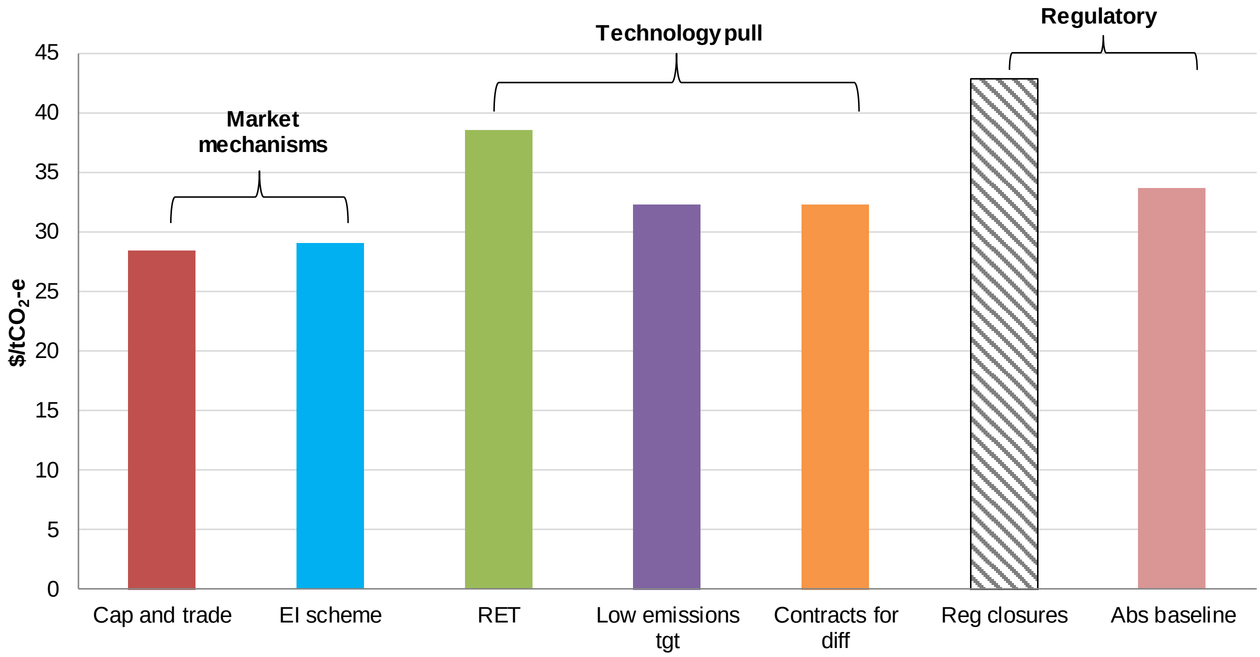
The average cost of abatement measures the cost effectiveness of a policy. It is calculated by dividing the present value of resource costs relative to the reference scenario by the emissions reductions achieved by the policy. Policies with a lower cost of abatement are more economically efficient. All policy scenarios—except regulated closures—achieved similar levels of cumulative emissions, so rankings by average cost of abatement are similar to rankings by resource costs (Figure 31). There are three points to note about the average cost of abatement calculations shown here:

- While experts take different views on whether future emissions reductions should be discounted or not, the Authority's approach is not to discount the emissions reductions. The rationale for this approach is that, within the emissions budget and over the timeframes and volumes of emissions reductions considered, a tonne of emissions reductions in the future is as valuable as a tonne now. The approach to calculating the average cost of abatement was examined as part of an independent peer review of the modelling conducted for the Authority by HoustonKemp (Appendix C.2), which found the approach was appropriate (HoustonKemp 2016, p. 13).
- The estimates cover costs in the electricity sector only; the economy-wide modelling (Appendix C.3) investigates total economic costs for three scenarios examining different market mechanisms. It is not possible to calculate a cost of abatement in the economy-wide modelling as all scenarios have the same level of emissions; by contrast, abatement in the electricity sector modelling can be measured by comparing the reference case with the other scenarios.
- The average cost of abatement is not the same as the level of a carbon tax or the price of permits in a cap and trade or emissions intensity scheme. While all are measured in dollars per tonne of emissions, the rate of a carbon tax or price of permits is the price liable entities pay for emissions under these particular policies. If liable businesses can reduce emissions at a lower cost per tonne

by changing their processes or practices than by paying the carbon tax or permit price, they can do so. This means that the tax or permit price measures the *marginal* cost of abatement: the cost of the last (and most expensive) unit of emissions reductions required to meet the policy. The average cost of abatement considers the average cost per tonne of emissions reductions, taken across all of the emissions reductions achieved under the policy over a given time period. For example, it includes the changes businesses make by finding ways of reducing emissions rather than paying the tax or permit price.

Further explanation of the cost of abatement methodology is in Appendix B.3.3 of Jacobs' modelling report (Jacobs 2016c).

Figure 31 Average cost of abatement by policy, 2 degrees, 2020–2050



Note: Average cost of abatement over 2020–2050 using a seven per cent discount rate for resource costs. Emissions not discounted. Accounts for the reduction in welfare from a fall in electricity demand resulting from increased retail electricity prices. The regulated closures policy breaches the common cumulative emissions budget by about 200 Mt CO_2-e or 15 per cent, so the cost of abatement here is not directly comparable with other policies.
Source: Climate Change Authority based on Jacobs 2016c.

Appendix C.2 Peer review of modelling

To test the robustness of Jacobs' modelling, the Authority commissioned an independent peer review by HoustonKemp. The scope of the peer review was to:

- assess the implementation of the emissions reduction policies in Jacobs' modelling, providing an opinion on whether the instructions provided to Jacobs, or their translation into the modelling, may have resulted in some policies being more or less advantaged relative to others
- review the sources and approach used to determine the main input assumptions for the electricity modelling.

HoustonKemp's review of the modelling was informed by materials provided by the Authority, including a draft of Jacobs' modelling report and detailed modelling results. Overall, HoustonKemp found that:

> *Based on our consideration of these materials, in our opinion the approach to comparing emissions reduction policies is sound, and the input assumptions used in Jacobs' modelling are generally appropriate. Our overall view is that the modelling has been conducted to a high*

standard of rigour and that the critical policy comparisons drawn by the report are robust (HoustonKemp 2016, p. 1).

HoustonKemp suggested several minor areas for improving the modelling exercise. Where feasible, Jacobs updated the modelling results and modelling report; these changes are outlined in Jacobs' response to the peer review. Detailed findings and recommendations of the peer review are outlined in the HoustonKemp report, which is available along with Jacobs' response at www.climatechangeauthority.gov.au.

Appendix C.3 Economy-wide modelling

Modelling approach

This section provides an overview of the economy-wide computable general equilibrium (CGE) modelling performed by Victoria University for the Authority, with input from Jacobs for the electricity sector.

As with the electricity sector modelling described in Appendix C.1, this modelling helped to inform the Authority's policy recommendations in the Special Review. The Authority recognises that electricity sector policies will have effects on the broader economy that are not captured by electricity sector modelling. These 'indirect' effects include 'tax interaction effects' that arise when emissions reduction policies cause less labour or capital to be used in the economy, and effects arising from how revenue raised by policies is returned to the economy. The economy-wide modelling builds on and extends the Authority's electricity sector modelling to assess whether these indirect effects could change the relative ranking of the market mechanisms examined in the electricity market modelling. These policies were chosen because differences in indirect effects could significantly affect their relative cost effectiveness.

The focus of this modelling is to examine the relative cost effectiveness of different policy options. It is not intended to examine the total economic cost of Australia adopting an emissions reduction policy relative to it not doing so, which was an important element of several past modelling exercises.

To ensure that differences in modelled cost between different scenarios are due to differences in policy design, each policy is compared on a like-for-like basis. To achieve this, the modelling:

- uses common input assumptions across scenarios, varying only a few key policy parameters to simulate the effect of different policies
- ensures each scenario achieves the same level of net national emissions and therefore a common emissions budget. This means that Australia's economy-wide emissions, net of purchases of international permits or credits, is the same in each year. This is slightly different to how the electricity sector modelling was undertaken, which used a common emissions budget within the Australian electricity sector for all policies modelled.

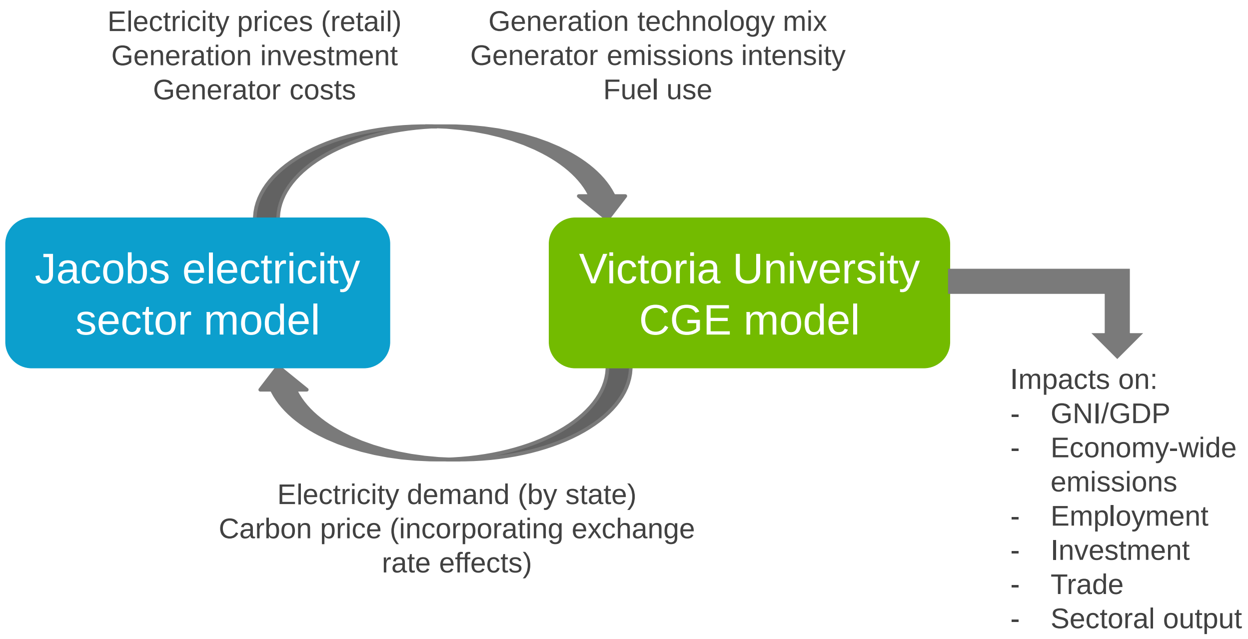
To isolate the economy-wide effects of electricity sector policies from impacts arising in other emitting sectors, the economy-wide modelling applies the same emissions reduction policy (a cap and trade scheme with lump sum revenue recycling) in other emitting sectors in all scenarios (Table 4 in Chapter 3).

As with the Authority's electricity sector only modelling, the economy-wide modelling does not aim to predict future outcomes; rather it is intended to provide high-level insights to inform policy choice. The modelling makes a range of assumptions and simplifications in order to represent the entire Australian economy. All assumptions suffer from some degree of uncertainty, but by holding them constant across all scenarios their effect on comparisons of cost effectiveness between policies will generally be negligible. In some cases simplifications could have a material impact on the Authority's assessment of cost effectiveness; in particular the simplified representation of the tax system and how workers respond to changes in real wages could affect the relative ranking of different policies. Nevertheless, the modelled scenarios give credible indications of how policy choice may be affected by considering indirect costs and benefits alongside direct costs. Importantly, the modelling provides limited insight into distributional effects for households, and so its insights into the cost effectiveness of different policies should be considered alongside potential equity impacts.

Victoria University's economy-wide modelling also required Jacobs to undertake new electricity sector modelling, as the detailed electricity sector effects of different policies could only be picked up with sectoral modelling. Jacobs' modelling generally used the same methodology as that described in Appendix C.1. The two models were iterated to ensure that both models described a consistent picture of the economy, particularly through the interaction between electricity prices and electricity demand. As shown in Figure 32, the Jacobs model provided electricity price series for the Victoria University model, which in turn provided estimates of electricity demand to the Jacobs model. This iterative process was continued until the degree of change in those variables was small, indicating consistency across the two models.

More detail on the modelling approach is provided in modelling reports by Jacobs and Victoria University, available on the Authority's website at www.climatechangeauthority.gov.au.

Figure 32 Iterative modelling using CGE and electricity sector models



Source: Climate Change Authority.

Scenarios

Victoria University modelled three scenarios:

- a cap and trade scheme with lump sum revenue recycling ('cap and trade (lump sum)')
- a cap and trade scheme with revenue recycling through tax cuts ('cap and trade (tax cuts)') and
- an emissions intensity scheme.

These scenarios were chosen to illuminate two indirect effects of particular interest:

- The change from the cap and trade (lump sum) to cap and trade (tax cuts) scenario illustrates the indirect economic benefit of recycling revenue through tax cuts rather than through lump sum payments to households.
- The change from the cap and trade (lump sum) to emissions intensity scheme scenario illustrates that the indirect cost of the tax interaction effect can be reduced by using an emissions intensity scheme to keep electricity prices lower than would prevail under a cap and trade scheme.

As the focus of the modelling was to examine the relative cost effectiveness of different policy options, rather than the total economic cost of Australia adopting an emissions reduction policy relative to not doing so, one of the three policy scenarios served as the reference case. The cap and trade (lump sum) scenario was chosen because the other two scenarios were expected to perform better. Table 4 in Chapter 3 provides an overview of the scenarios.

Key inputs and assumptions

Carbon price

Each of the three scenarios involves a market mechanism where emitters can purchase emissions permits from the government, other emitters, or other countries at the same prevailing international carbon price. As discussed above, emitters outside the electricity sector also face this carbon price.

In all three scenarios, the Authority adopted a common international carbon price, expressed in United States dollars consistent with global efforts with a likely chance of limiting temperature increases to 2 degrees. The international carbon price converted to slightly different Australian dollar carbon price series in each scenario within the Victoria University CGE model. This was a very similar carbon price series to the series used derive the emissions budget in the electricity sector only modelling.

The use of a common carbon price across both the cap and trade and emissions intensity scenarios varies from the approach in the electricity sector only Jacobs modelling. In that modelling the carbon price in the cap and trade scenario was lower than the certificate price in the emissions intensity scenario. The alternative approach was adopted because, in a world of strong action to reduce emissions, Australia would be likely to face the same effective global carbon price irrespective of whether it adopted a cap and trade scheme or an emissions intensity scheme.

Net national emissions budget

Adopting the same carbon price means that emissions from Australia's electricity generation sector, and other sectors, may vary between the CGE modelling scenarios. This differs from the electricity sector only modelling, where each policy was designed to achieve a fixed emissions budget within the Australian electricity generation sector.

In order to allow a like-for-like policy comparison, scenarios must be set up so that differences in costs are due to differences in policy design rather than in their level of emissions reductions. This is achieved by assuming Australia can purchase international permits or credits at the prevailing carbon price to achieve a common net national emissions budget, that is, a common level of national emissions net of purchases of international permits or credits.

Australia's net national emissions budget was established based on Australia's total domestic emissions in the cap and trade (tax cuts) scenario. Accordingly, trade in international permits or credits was very low in this scenario and higher in other scenarios. This emissions budget does not reflect any

Authority view of Australia's 'fair share' of a global emissions budget, but was adopted to simplify comparisons between scenarios.

Macroeconomic assumptions

Table 10 summarises key macroeconomic assumptions made by Victoria University for its economy-wide modelling. Further detail on these assumptions and on the Victoria University Regional Model (VURM) is provided in the accompanying modelling report (Adams 2016, available at www.climatechangeauthority.gov.au).

Table 10 Overview of macroeconomic assumptions, economy-wide modelling

Model element	Description and relevant assumptions
Regional structure	Australia's eight states and territories are modelled as economies in their own right, with linkages through trade and movements of labour and capital
Sectoral representation	The primary VURM database incorporates 84 separate economic sectors, which are aggregated to 72 in this modelling. Interrelationships between sectors are calibrated based on the 2009–10 ABS input-output tables.
Demographic assumptions	Based on the Australian Government's March 2015 Intergenerational Report (Treasury 2015).
Total factor technological progress (total factor productivity)	In the cap and trade (tax cuts) scenario, total factor productivity improvement is uniform across all industries necessary to achieve a targeted real GDP growth rate. This total factor productivity improvement rate is then held constant across all other scenarios.
Labour market assumptions	In the cap and trade (tax cuts) scenario, real wages are determined by the balance between labour supply, which is determined by demographic assumptions, and labour demand. In all other scenarios the real after-tax wage is 'sticky' in the short-term but flexible in the long-run. This means that short-run changes will primarily affect employment levels, and long-run changes will primarily affect wages. The exception to this are changes to labour tax rates, which affect before-tax and after-tax wages differently, and can therefore cause long-run differences in employment levels between scenarios. Labour is assumed to be mobile between states and territories to maintain constant regional differences in unemployment rates.
Budget balance	In each scenario the fiscal balance to GDP ratio is fixed at 2014 levels for all jurisdictions. The balancing variable is a lump sum payment to or from the representative household in each region.
Trade with the rest of the world	The rest of the world buys Australian exports based on a downward sloping demand schedule. The foreign demand schedule is calibrated in the cap and trade (tax cuts) scenario to achieve the terms of trade assumption in that scenario (see below), and are held constant in other scenarios. Australia sells imports at fixed foreign currency prices which are constant across all scenarios and consistent with the terms of trade assumption in the cap and trade (tax cuts) scenario.
Terms of trade	In the cap and trade (tax cuts) scenario, Australia's terms of trade is calibrated to a historically normal level, allowing for fixed fuel price assumptions (see below). The terms of trade can then vary from that level if changes to Australian exports result in changes to global commodity prices.
Fuel prices	US dollar prices for internationally traded crude oil, steam coal and natural gas are based on Climate Change Authority analysis of the IEA's 2014 World Energy Outlook.

Source: Climate Change Authority based on Adams 2016.

Electricity modelling inputs to economy-wide modelling

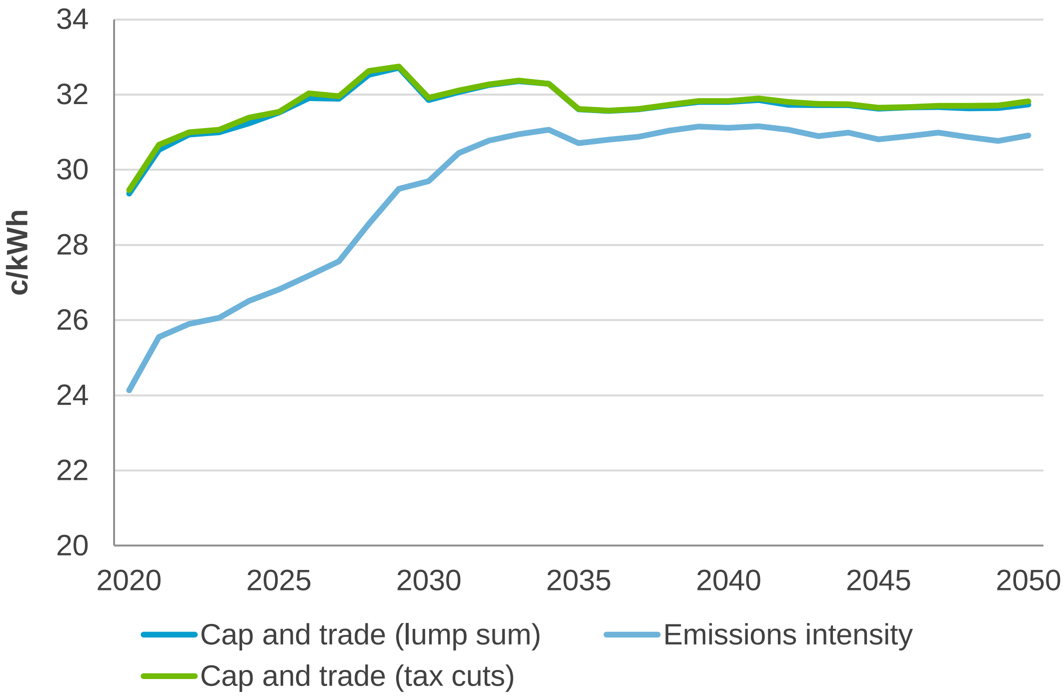
Retail electricity prices are a key output of Jacobs' electricity sector modelling. An important difference between the emissions intensity scenario and the two cap and trade scenarios is that the former has lower wholesale and retail electricity prices. This is because the allocation of permits to electricity generators effectively subsidises their output, lowering wholesale and retail electricity prices. This results in changes in the level of output in a range of economic sectors; in particular sectors that use large amounts of electricity would tend to have higher output under an emissions intensity scheme than a cap and trade scheme.

Jacobs' electricity modelling produces three retail electricity price series for three different types of energy users:

- residential
- small and medium enterprises (SME) and
- industrial.

Jacobs produced price series for each user type in each region.[6] Victoria University matched these price series to the different industry sectors in each region within VURM, as outlined in its report. Figure 33 shows average residential electricity prices for each scenario; electricity prices for SME and industrial users are detailed in Jacobs' modelling report.

Figure 33 Average residential electricity prices by scenario, economy-wide modelling, 2020–2050



Note: Prices are a load-weighted average of prices in the NEM and WEM.
Source: Jacobs 2016d.

Jacobs also modelled a range of details about how the share of different generation technologies changes in response to emissions reduction policies. Differences in the generation technology share flow through to a range of impacts in VURM, such as investment, employment and profits for different generation types in different regions. Table 11 shows that technology shares are remarkably similar across the three scenarios. This in turn indicates that the differences between the scenarios will

[6] Energy users in the Australian Capital Territory are assumed to have the same electricity prices as those in New South Wales. Jacobs did not model the Northern Territory (NT) explicitly; the NT electricity sector was modelled within VURM. Victoria University assumed that all Western Australian users face the electricity prices modelled by Jacobs for the WEM, which in practice only covers the south-western portion of the state.

primarily stem from differences in electricity prices and the use of carbon revenue, rather than from differences in the composition of the electricity generation sector.

Table 11 Share of generation by technology type by scenario, economy-wide modelling, 2030 and 2050

Scenario	2030				2050			
	Coal	Gas	Renewable	Other low emission	Coal	Gas	Renewable	Other low emission
Cap and trade (lump sum)	4%	37%	47%	12%	0%	8%	69%	24%
Cap and trade (tax cuts)	4%	38%	46%	13%	0%	8%	69%	23%
Emissions intensity scheme	3%	38%	47%	13%	0%	8%	68%	24%

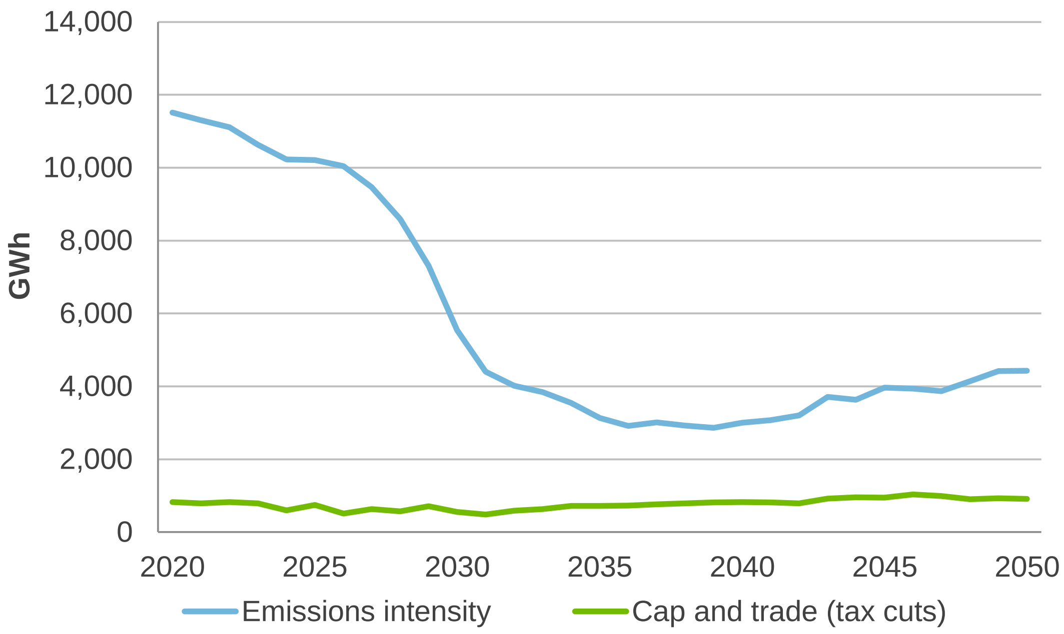
Note: Rows may not sum up to 100 due to rounding. 'Other low emission' is gas CCS and nuclear (coal CCS was available but not deployed in any scenario).
Source: Jacobs 2016d.

Economy-wide modelling results

Electricity demand

Electricity demand is higher in the emissions intensity scenario than the two cap and trade scenarios (Figure 34). This is because electricity prices are lower in the emissions intensity scenario, particularly in the early years of the scheme when the emissions intensity target is higher. Electricity demand is slightly higher in the cap and trade (tax cuts) scenario than the cap and trade (lump sum) scenario because tax cuts stimulate economic activity, and therefore increase electricity demand. Other policies to promote energy efficiency could be put in place to realise the demand-side emissions reductions.

Figure 34 Change in electricity demand, economy-wide modelling, relative to cap and trade (lump sum) scenario, 2020–2050



Source: Adams 2016.

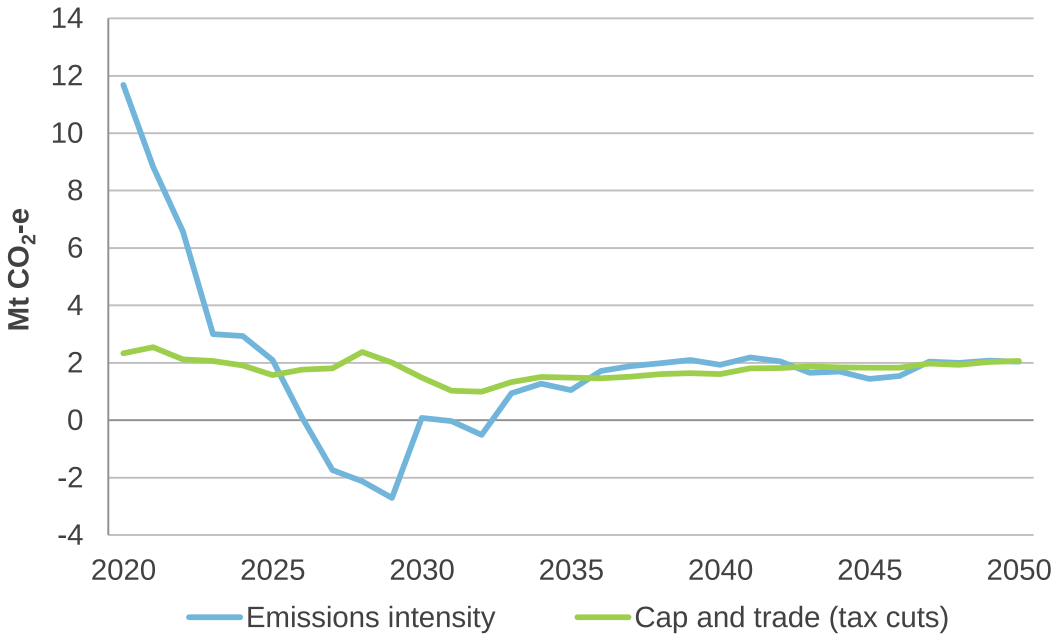
Emissions

Higher electricity demand results in generally higher Australian emissions in the emissions intensity and the cap and trade (tax cuts) scenarios than in the cap and trade (lump sum) scenario (Figure 35). Emissions grow both due to higher electricity demand and due to increased output in a range of energy and emissions-intensive sectors. Emissions under the emissions intensity scenario briefly fall below the cap and trade (lump sum) scenario as the higher electricity demand in that scenario brings forward investment in new low-emissions generators, but this effect is only temporary. As is discussed above, differences in domestic emissions between scenarios are offset by changes in purchases of international permits or credits to achieve a common net national emissions budget across all three scenarios.

Personal and company income tax rates

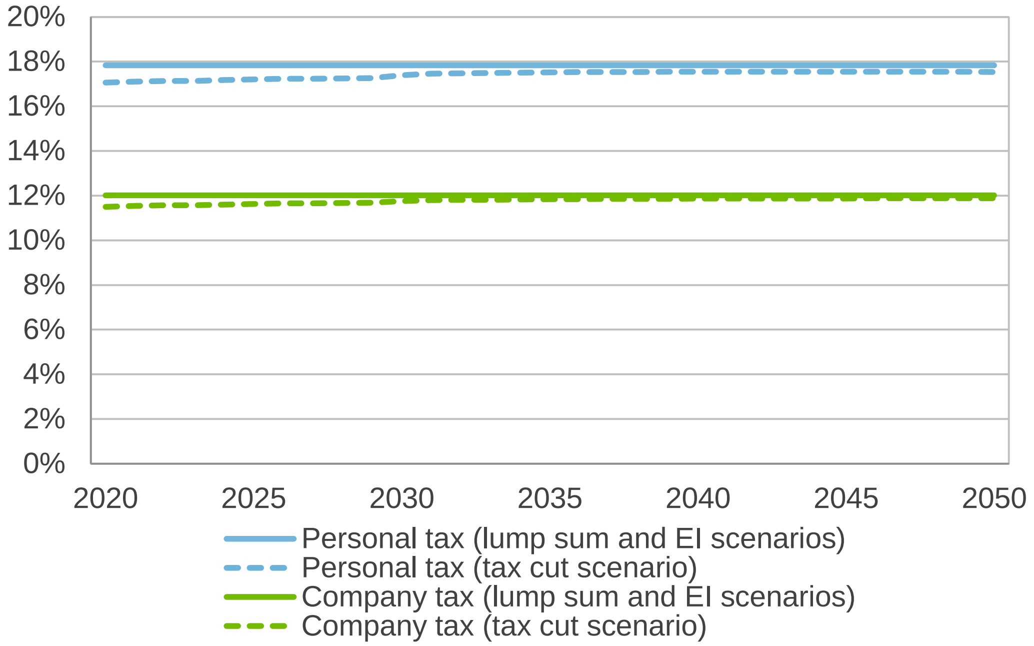
Personal and company income tax rates in the emissions intensity and cap and trade (lump sum) scenarios are held constant from 2020 to 2050. The cap and trade (tax cuts) scenario uses all revenue raised by selling permits to electricity generators to apply equivalent percentage cuts to both personal and company income taxes (Figure 36).

Figure 35 Change in Australian domestic emissions, economy-wide modelling, relative to cap and trade (lump sum) scenario, 2020–2050



Note: Net national emissions are constant between scenarios. Therefore this chart could also be interpreted as showing differences in purchases of international permits or credits relative to the cap and trade (lump sum) scenario.
Source: Adams 2016.

Figure 36 Personal and company income tax rates by scenario, economy-wide modelling



Note: Personal income tax is represented in the modelling as a single flat rate, as shown, rather than as a tiered system as occurs in practice. The company tax rates shown are effective rates on the total capital base, and differs from the statutory company tax rate due to differences between the taxable and the actual capital base (for example, due to depreciation or other deductions).
Source: Adams 2016.

Economy-wide effects

The Authority has primarily used gross national income (GNI) to assess the cost effectiveness of different policy options, as GNI is a better (albeit imperfect) measure of Australia's economic welfare than gross domestic product (GDP). Unlike GDP, GNI excludes income accruing to foreign residents, and takes into account changes in Australians' purchasing power due to changes in the terms of trade, and so better depicts the potential living standard of Australians.

Table 12 summarises the overall cost effectiveness of three policy options modelled. These results show that:

- The relative performance of cap and trade and emissions intensity schemes depends on how revenue from the cap and trade scheme is recycled. A cap and trade scheme with all revenue recycled through tax cuts is likely to be somewhat more cost-effective than an emissions intensity scheme, while a cap and trade scheme with lump sum revenue recycling is likely to be the least cost-effective of the three.
- An emissions intensity scheme reduces tax interaction effects relative to a cap and trade scheme. Compared to the cap and trade (lump sum) scenario, an emissions intensity scheme can increase GNI by around 0.15 per cent over 2020–2050 by muting the impact on electricity prices relative to a cap and trade scheme, which in turn stimulates investment and activity in a range of electricity-using sectors.

- Recycling revenue through tax cuts delivers benefits, as is illustrated by comparing the two cap and trade scenarios. Recycling revenue through tax cuts can increase GNI by around 0.33 per cent over 2020–2050 relative to doing so through lump sum payments. This occurs because tax cuts can increase economic output by increasing investment and employment, whereas lump sum payments do not.
- While large in absolute terms, the differences between the scenarios are small in the context of the overall economy.

Table 12 Projections of gross national income, economy-wide modelling, relative to cap and trade (lump sum), 2020–2050

Scenario	Unit	GNI in 2030	GNI in 2050	Cumulative discounted GNI, 2020–2030	Cumulative discounted GNI, 2020–2050
Emissions intensity scheme, absolute change	$bn	$3	$7	$20	$45
Emissions intensity scheme, percentage change	%	0.13%	0.18%	0.14%	0.15%
Cap and trade (tax cuts), absolute change	$bn	$5	$13	$51	$97
Cap and trade (tax cuts), percentage change	%	0.25%	0.36%	0.35%	0.33%

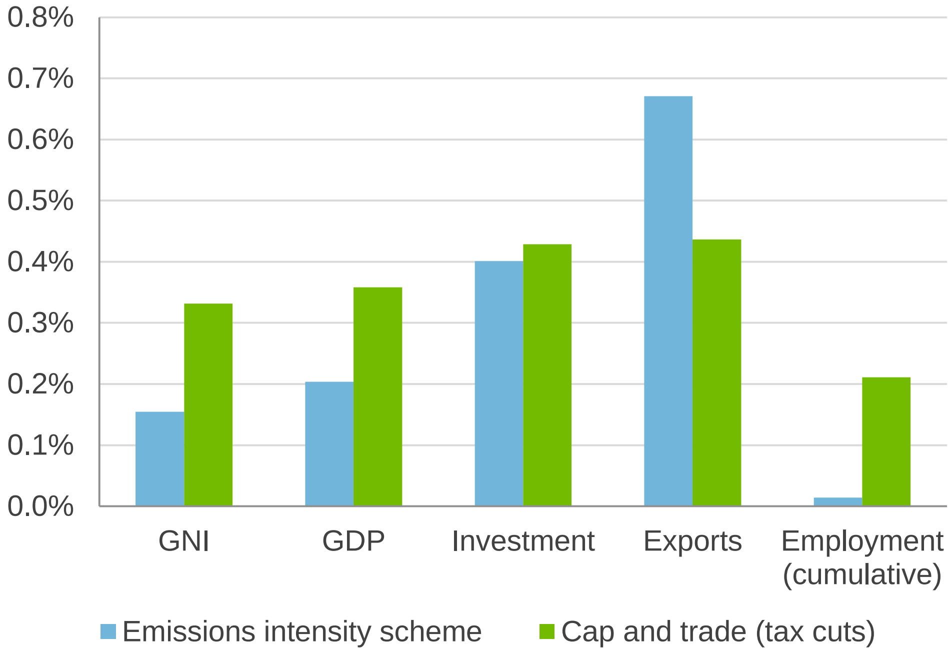
Note: Cumulative discounted gross national income is calculated using a seven per cent discount rate.
Source: Climate Change Authority based on Adams 2016 and Jacobs 2016d.

Figure 37 compares the three scenarios on a range of economic metrics. This figure shows that both an emissions intensity scheme and a cap and trade scheme that recycles revenue through tax cuts will increase economic output (as measured by GNI or GDP), investment, exports and employment relative to a cap and trade scheme with lump sum recycling. While using carbon revenue to cut taxes improves economic output and employment more than an emissions intensity scheme, investment outcomes are broadly similar and an emissions intensity scheme has a greater effect on exports.

GNI and GDP are higher under the cap and trade (tax cuts) scenario than the emissions intensity scenario. The difference in GNI results between these two scenarios is slightly larger than the difference in the GDP results. This is for two main reasons:

- Higher domestic emissions under the emissions intensity scenario mean more international permits or credits are required to meet the same net national emissions target. These purchases are netted out of GNI but not GDP. This effect reduces GNI under the emissions intensity scenario but has a negligible effect under the cap and trade (tax cuts) scenario.
- Australia's terms of trade (the ratio of export to import prices) is generally slightly lower under the emissions intensity scenario than the cap and trade (tax cuts) scenario. This is because Australia exports more under the emissions intensity scenario. Australia's increased export volume increases supply of electricity intensive goods in the international market, marginally reducing their price and therefore the terms of trade.

Figure 37 Percentage change in various economic metrics, economy-wide modelling, relative to cap and trade (lump sum) scenario, 2020–2050



Note: GNI, GDP, investment and exports are calculated as a present value over the period 2020 to 2050, using a seven per cent discount rate. Employment is a cumulative undiscounted figure over the period 2020 to 2050.
Source: Climate Change Authority based on Adams 2016 and Jacobs 2016d.

Sectoral effects

An emissions intensity scheme and recycling cap and trade revenue through tax cuts represent two different ways of increasing economic output relative to a cap and trade scheme with lump sum recycling. An emissions intensity scheme increases economic output by reducing electricity prices, which increases production of a range of goods and services, particularly electricity-intensive goods and services. Alternatively, using carbon revenue to cut taxes on labour and capital makes it cheaper to employ these factors of production, and so stimulates economic output.

These differing approaches have different effects on sectoral output. This can be seen by comparing the change in sectoral gross value added (GVA) in each economic sector modelled in VURM under these two scenarios relative to the cap and trade (lump sum) scenario (Table 13). This comparison illustrates that 22 out of the 70 sectors depicted contract relative to the cap and trade (lump sum) scenario in the emissions intensity scenario, compared to only four under the cap and trade (tax cuts) scenario.[7] This result reflects the fact that capital and labour are used in more similar proportions across economic sectors than electricity, and so cutting labour and company taxes gives a more evenly distributed stimulus than does reducing electricity prices.

[7] Seventy-two economic sectors are modelled in VURM. In this analysis the uranium processing and nuclear waste sectors are ignored because they are extremely small.

Table 13 Change in sectoral gross value added, economy-wide modelling, relative to cap and trade (lump sum) scenario, 2020–2050

VURM Sector	Share of total sectoral GVA (cap and trade (lump sum) scenario)	Change in GVA – emissions intensity scenario	Change in GVA – cap and trade (tax cuts) scenario
1 SheepCattle	0.4%	0.06%	0.21%
2 DairyCattle	0.1%	0.06%	0.21%
3 OtherAnimals	0.2%	0.05%	0.21%
4 Crops	0.3%	-0.07%	0.17%
5 OtherAg	0.8%	-0.01%	0.20%
6 FishHuntTrap	0.1%	0.00%	0.27%
7 ForestryLogs	0.2%	0.00%	0.08%
8 AgSrv	0.2%	0.04%	0.22%
9 Coal	0.5%	1.69%	0.27%
10 Oil	0.5%	-0.01%	0.04%
11 GasLNG	0.6%	0.19%	0.17%
12 IronOre	2.2%	0.39%	0.35%
13 NonFeOres	1.8%	1.35%	0.38%
14 NonMetMins	0.2%	0.49%	0.37%
15 MiningSrv	0.5%	0.92%	0.33%
16 MeatProds	0.4%	0.12%	0.23%
17 DairyProds	0.2%	0.08%	0.22%
18 OtherFood	0.9%	0.10%	0.25%
19 Beverages	0.6%	0.00%	0.31%
20 TCF	0.3%	0.02%	0.33%
21 WoodProds	0.3%	0.37%	0.36%
22 PulpPaper	0.3%	0.18%	0.30%
23 Printing	0.3%	0.03%	0.23%
24 RefineProd	0.3%	-0.02%	0.04%
25 Chemicals	0.9%	0.22%	0.32%
26 PlasticRub	0.5%	0.33%	0.33%
27 NonMetalMin	0.2%	0.20%	0.35%
28 CementLime	0.1%	0.23%	0.33%
29 IronSteel	0.3%	0.46%	0.19%
30 Aluminium	0.3%	0.75%	0.07%
31 OtherNonFeMt	0.6%	2.45%	0.33%
32 MetalProds	0.7%	0.35%	0.33%
33 MVPOtherTran	0.3%	0.77%	0.32%
34 OtherEquip	1.2%	0.99%	0.30%
35 OtherMan	0.3%	1.59%	0.33%
36 ElecCoal	0.0%	0.39%	0.33%
37 ElecGas	0.1%	2.30%	0.81%
38 ElecHydro	0.0%	-0.44%	0.18%
39 ElecOther	0.1%	-6.03%	-0.23%
40 ElecNuclear	0.0%	-17.60%	-1.27%
41 ElecSupply	0.4%	2.56%	0.17%
42 GasSupply	0.1%	0.06%	0.03%
43 WaterDrains	0.6%	0.01%	0.19%

VURM Sector	Share of total sectoral GVA (cap and trade (lump sum) scenario)	Change in GVA – emissions intensity scenario	Change in GVA – cap and trade (tax cuts) scenario
44 ResidCons	1.2%	-0.26%	0.53%
45 NonResidCons	2.6%	0.65%	0.19%
46 ConsSrv	3.1%	0.14%	0.31%
47 WholeTrade	5.5%	0.18%	0.28%
48 RetailTrade	3.6%	0.03%	0.25%
49 AccomFood	2.3%	-0.13%	0.40%
50 RoadFreight	1.4%	0.25%	0.25%
51 RoadPass	0.3%	0.12%	0.19%
52 RailFreight	0.3%	0.72%	0.30%
53 RailPass	0.2%	0.00%	0.17%
54 Pipeline	0.1%	0.15%	0.09%
55 WaterTrans	0.2%	0.52%	0.22%
56 AirTrans	3.0%	0.08%	0.24%
57 Commun	3.4%	0.01%	0.21%
58 Banking	5.4%	-0.12%	0.37%
59 Finance	4.1%	-0.09%	0.27%
60 Dwellings	8.6%	-0.19%	0.38%
61 BusinessSrv	14.6%	0.05%	0.27%
62 PubAdminReg	4.4%	-0.02%	-0.04%
63 Defence	0.8%	-0.01%	-0.09%
64 Education	5.0%	-0.22%	0.09%
65 HealthSrv	3.9%	-0.12%	0.07%
66 ResidCare	2.6%	-0.16%	0.09%
67 ArtsRecreate	1.4%	-0.17%	0.32%
68 Repairs	1.7%	0.09%	0.24%
69 OtherSrv	1.3%	-0.29%	0.41%
70 UranMining	0.0%	-0.11%	0.37%

Note: Sectoral gross value added (GVA) is calculated as a present value over the period 2020 to 2050, using a seven per cent discount rate. Seventy-two economic sectors are modelled in VURM. In this analysis the uranium processing and nuclear waste sectors are ignored because they are extremely small.
Source: Climate Change Authority based on Adams 2016.