Australian Government

AUSTRALIA'S LONG-TERM EMISSIONS REDUCTION PLAN:

Modelling and Analysis

CONTENTS

Executive Summary

This report summarises the methods, assumptions and results from the economic modelling conducted by the Department of Industry, Science, Energy and Resources (DISER) to inform the development of the Government's Long Term Emissions Reduction Plan (the Plan) and associated net zero emissions by 2050 target.

The main body of the report explains the context of the analysis, and then presents and explains the key findings. This is followed by a number of appendices that provide additional technical details and explanations.

The modelling and analysis is not a precise prediction of how trends in technology or the Australian economy will unfold over the next three decades. In particular, the quantity of emissions reduction or offsets generated in the model should not be interpreted as requiring a specific reduction or output from that sector. Australia's net zero emissions by 2050 target is a whole-of-economy target. Australia does not have any sectoral emissions reduction targets.

Modelling was undertaken by DISER, using the Global Trade and Environment Model (GTEM) model, with an experienced team of economists drawn from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Treasury, the Productivity Commission, CSIRO, as well as from within DISER. The modelling was complemented by analysis commissioned from McKinsey & Company (McKinsey) and DISER's Office of the Chief Economist. The project also drew upon other research and analytical work including the 2020 and 2021 Low Emissions Technology Statements (LETS) (Commonwealth of Australia, 2020, 2021c), Australia's Emissions Projections 2021 (Commonwealth of Australia, 2021a) and the Expert Panel Examining Additional Sources of Low Cost Abatement (the King Review) (Commonwealth of Australia, 2020b). The LETS and King Review included public and targeted consultation with peak bodies, industry groups, businesses and researchers.

The modelling and analysis assesses the economic and emissions impacts of changes in technology and action to reduce emissions by Australia and other countries. It does not assess the costs or impacts of climate change or the benefits of avoided warming associated with different global emissions trajectories.

Key Findings from the Analysis

1. Reducing the cost of low emissions technologies can provide net benefits to Australia and put us within reach of net zero emissions by 2050

Economic modelling for the Plan explored a range of scenarios to provide insights into the costs, risks and benefits of different options for achieving net zero emissions by 2050, with a focus on how these would change with successful efforts to drive down the costs of low emissions technologies, including hydrogen.

The core scenarios are explained in Box ES.B1. The Plan scenario reflects the approach laid out by the Government in the Plan (see https://www.industry.gov.au/data-and-publications/australias-long-term-emissions-reduction-plan). This approach involves Australia prioritising its investment towards technologies where it can make a difference in driving down cost. Together with global technology trends and and measures to encourage voluntary action to reduce emissions, this approach will enable Australia to achieve net zero emissions by 2050. This reflects the existing policies of the Australian Government, which includes more than $21 billion to be invested by 2030 in supporting low emissions technology development and deployment, and an expectation that the Government will play an ongoing role over the long term in supporting low emissions technologies and catalysing co-investment from business and other partners.

The Plan scenario is contrasted with a scenario where Australia does not take this action or adopt a 2050 target, and technology improvements are not accelerated beyond normal trends, as they would be under the Plan (the No Australian Action scenario).

A bottom-up technology analysis assessed the pathways to achieving the stretch goals identified in the Technology Investment Roadmap, and specifically the timeframes in which they might be achieved. Economic modelling assesses the impact that these cost reductions, coupled with global technology trends, could have on the Australian economy. As outlined in the Plan, this scenario relies on a voluntary incentive to support uptake of technologies as they approach commercial parity, with an important role for domestic offsets, as well as a targeted role for high-integrity offsets voluntarily purchased from our Indo-Pacific region. This scenario does not rely on a high carbon price, or conversion of productive farming land to provide carbon sequestration. The top-down modelling explored these questions and scenarios using alternative approaches, using GTEM, an established global computable general equilibrium (CGE) model that integrates economic activity, energy use, and greenhouse gas emissions.

In the analysis for the Plan, voluntary action is assumed to be supported by the Government either through an Emissions Reduction Fund-style incentive for abatement activities that are additional to business-as-usual, or by other enabling actions (such as providing information to consumers, investing in enabling infrastructure, or co-investing to de-risk and reduce the cost of deploying low emissions technologies). All action is taken voluntarily by the private sector, even where there are marginal costs up to $25/t CO_2-e. In this case, the action taken is still interpreted as being entirely voluntary as the cost is consistent with, or lower than, the marginal cost of voluntary action widely observed today (see Box B2 of voluntary action that are already widely observed (see Box B2 in the main report).

Box ES.B1: Core scenarios explored through the modelling

The modelling develops two primary scenarios, which underpin the key findings:

No Australian Action – All countries, except Australia, reduce their emissions to achieve a below 2°C global emissions trajectory. All developed countries reduce their emissions to net zero by 2050, except Australia. Technology improvements are not accelerated beyond normal trends (as it would be under the Plan). Australia does not adopt a 2050 target, which triggers an adverse market response in the form of a risk premium imposed on Australia's cost of capital.

The Plan – Australia continues to invest in technological breakthroughs including in partnership with other countries, working to reduce the cost of low emissions technologies. Government acts as an enabler to support consumer choice and voluntary adoption of other technologies driven by global trends. Along with all other developed countries, Australia adopts a target of net zero emissions by 2050, so that a capital risk premium is avoided. Abatement action is taken across all sectors on a voluntary basis, with this modelled as an abatement incentive which is taken up across the economy and rises to $24/t CO_2-e in 2050. This voluntary action is taken by emitters to either reduce their emissions or purchase offsets, consistent with investor expectations and consumer preferences. International offsets are available to the Australian economy at the global price ($40/t CO_2-e in 2050). The global context is a world on track to limit warming to below 2°C consistent with the objectives of the Paris Agreement. Advanced technology outcomes provide for stronger, low emissions economic growth and global and Australian hydrogen production is assumed to be in line with IEA projections. In this scenario net emissions in Australia fall by 85% compared to 2005 levels, with the remaining gap to be met through further technological improvements.

The modelling finds that success in making new technologies globally accessible and affordable would help achieve faster global emissions reductions, with lower costs and economic impacts, compared to a business as usual technology scenario. It is worth noting that global technology trends (for example, electrification of transport) reduce Australia's net emissions under both scenarios.

2. There are a range of pathways to delivering the reductions needed to achieve net zero emissions by 2050

Australia can achieve very significant reductions in net emissions while continuing to enjoy strong economic growth and rising national income.

This analysis illustrates there are a range of technology pathways that could put Australia on a trajectory to net zero emissions by 2050. Top-down economic modelling and bottom-up technology analysis come to similar high level findings, including the role of falling technology costs in enabling new consumer choices in Australia and globally, the importance of reducing technology costs to parity with incumbent alternatives in order to avoid a very high carbon price, and the importance of technologies like hydrogen, electrification and energy efficiency to enable net zero emissions by 2050.

A central role is played by low emissions electricity and electrification of road transport. Electricity and transport are projected to substantially decarbonise, even under current trends.

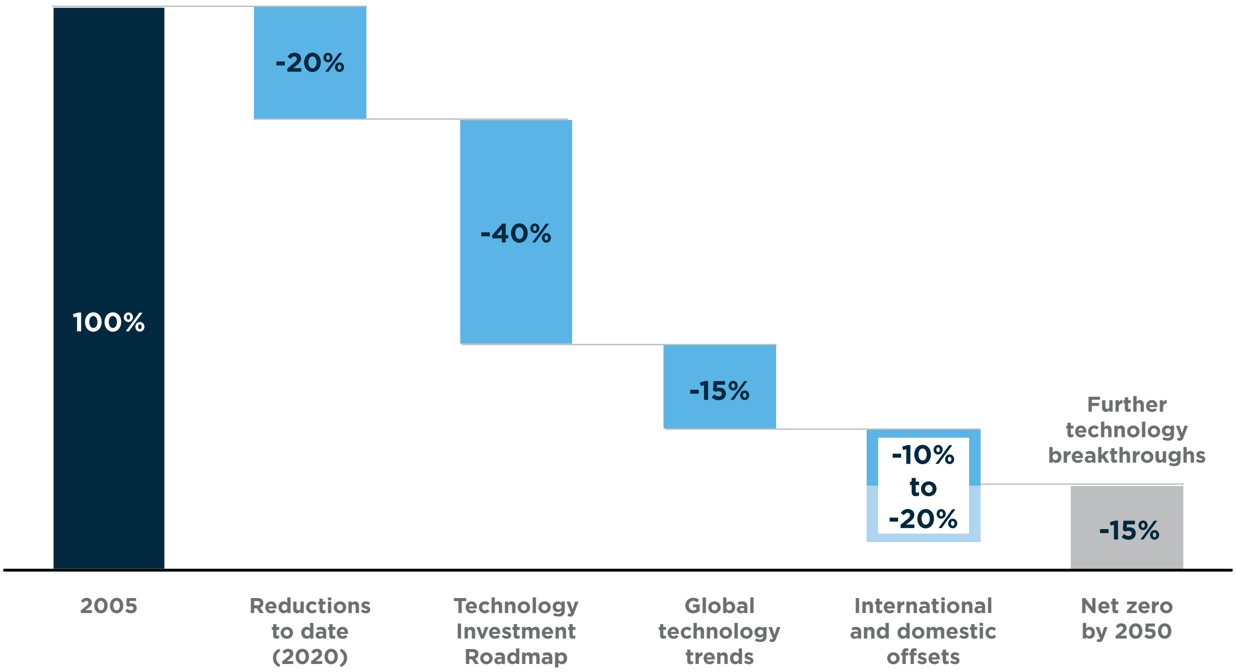
The economic modelling explores a range of scenarios, illustrating different combinations of emissions reductions and the use of domestic and international offsets. The analysis finds there are range of economically and technically feasible pathways for achieving net zero emissions by 2050, and that advanced technology provides additional flexibility in how Australia can achieve this target (as discussed below)

Taken together, these findings confirm that falling technology costs can underpin deep cuts in emissions across all sectors of the Australian economy, and that complementary measures, such as enabling investment in infrastructure to support the adoption of global technology trends (like electrification of transport) and a modest voluntary incentive to support opportunities along with land sector sequestration and international offsets will put Australia within range of net zero by 2050.

Figure ES.1 shows the Department's best estimate of the likely shares of abatement from different sources under the Government's Plan, drawing on multiple lines of evidence. Emissions are projected to fall across all sectors to 2050, with emissions falling even as sectors grow and increase their output, as technology enables emissions intensity to improve across all sectors.

The GTEM modelling shows that under the Government's Plan Australia's economy will continue to grow and each Australian will be almost $2,000 better off in 2050 compared with the 'No Australian Action' scenario, with advanced technology cost, associated deployment and the avoided capital risk premium driving these gains.

Figure ES.1 Australia's path to net zero emissions by 2050



Notes: *Chart shows DISER best estimates of abatement contributions, drawing on McKinsey analysis, DISER economic modelling for the Plan, and DISER analysis for the 2021 Low Emissions Technology Statement. Domestic and international offsets include accredited soil carbon, and could provide up to 20% of abatement, depending on the extent of further technology breakthroughs and voluntary demand for offsets. See notes for Table 2.*

Source: *DISER analysis, drawing on GTEM modelling, McKinsey analysis for the Plan, and other sources.*

3. Adopting a target of net zero emissions by 2050, with a credible plan to achieve it, provides economic benefits to Australia

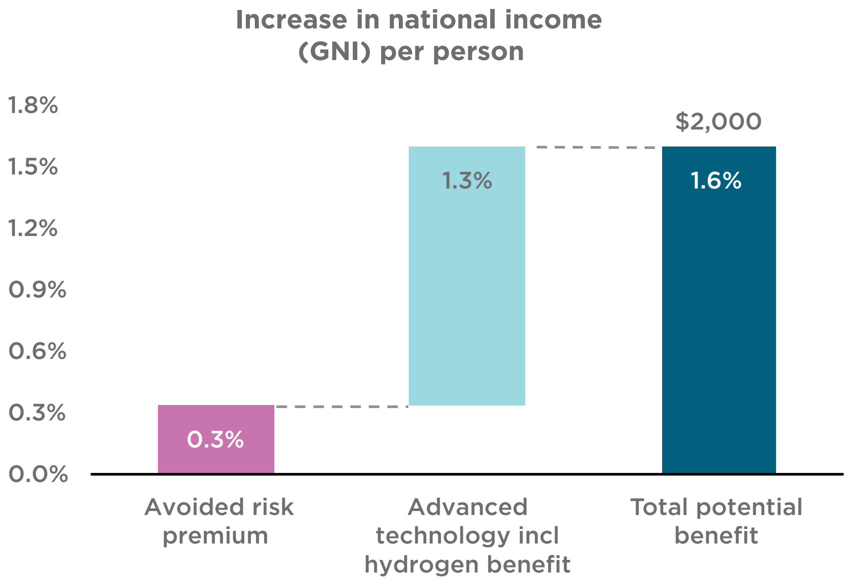
The benefits of the Plan scenario compared to the 'No Australian Action' scenario have three main drivers.

First, successful deployment of advanced technology provides benefits from higher global economic growth due to lower global abatement costs. Second, benefits are derived from the creation of a new cost-competitive global hydrogen sector. Australian hydrogen production could be worth more than $50 billion in 2050, in a world on track to limit warming to well below 2°C, lifting national income by about $1,000 per person in addition to the other benefits of advanced technology. Finally, the target, together with a plan to achieve it, avoids the imposition of a capital risk premium on Australian investors and firms assumed in the 'No Australian Action' scenario, and there are significant benefits as a result (Figure ES.2).

For the first time the modelling uses a new version of GTEM with an explicit hydrogen sector, which makes hydrogen available as a potential energy input for transport and industry. The modelling shows substantial benefits to Australia from a hydrogen sector. However, the findings that the 2050 target provides net economic benefits does not rely on the additional benefits associated with hydrogen. Australians are expected to be better off under the Plan, even if hydrogen impacts are not included (see Appendix A).

The Department took advice from the Treasury on analysing the effects of a capital risk premium (see Appendix E for details) using the GTEM model. The modelling found that a risk premium would reduce investment in Australia by an average of 5.5% over the period to 2050, reducing productivity growth. This reduces national income (GNI) and economic activity (GDP) by 0.9%, with the impact declining to 0.5% in 2050. Adopting the approach set out in the Plan avoids these impacts.

Figure ES.2 Economic impacts of the Government target and technology agenda vs no action in 2050



Notes: *Economic outcomes in the Plan assessed relative to the No Australian Action scenario, drawing on additional sensitivity analysis scenarios for the impacts of hydrogen, advanced technology generally, and the impacts of the 2050 target without a global risk premium. $ impacts larger than $100 are rounded to the nearest $25. Hydrogen represents approximately $1,000 of the total advanced technology benefits.*

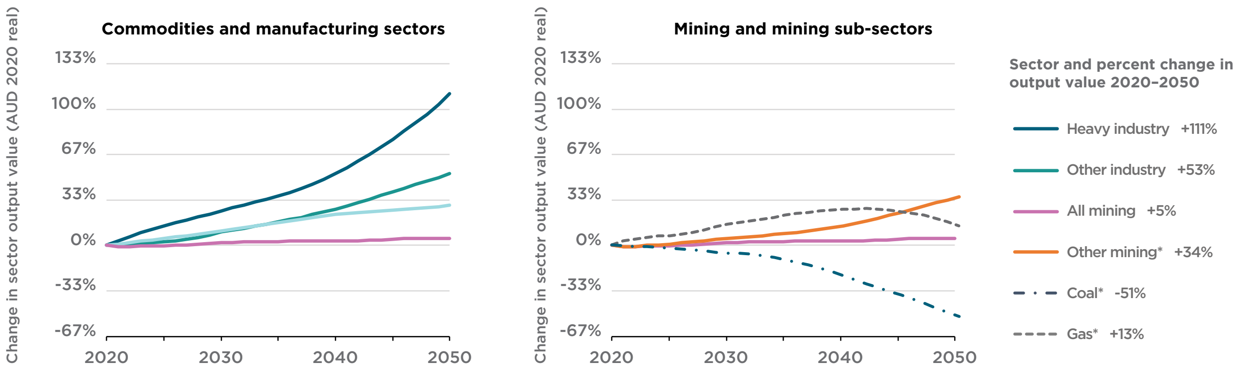
Source: *DISER economic modelling for the Plan.*

4. Jobs and output value grows across all major sectors to 2050 including mining

GTEM modelling finds that all major export sectors grow to 2050 across all scenarios, with the value of agriculture projected to grow around 30%, mining around 5%, and heavy industry around 110% in the Plan scenario. Scenarios with 'advanced technology' (including the Plan scenario) boost the overall growth of Australian emissions-intensive export sectors, benefitting Australia's regions.

The modelling projects a rebalancing in mining activity driven by shifts in international demand. Specifically, global demand shifts beyond Australian control are expected to reduce the value of coal production by around 50% to 2050, and slow the growth of gas, but mining overall grows by 5% in real terms to 2050, reflecting increased demand for critical minerals and other mining activities. This shift is projected to occur over several decades, with most impacts observed beyond 2030 as countries make progress towards their decarbonisation goals. Increases in other mining activity is projected to more than offset expected declines in coal and other traditional energy sources, as shown in Figure ES.3.

Figure ES.3 Outlook for the value of export oriented sectors, the Plan scenario, 2020-2050



Notes: *Declines in coal and slower growth of gas are driven by global changes in demand. The real value of other mining increases 34%, and outweighs declines in the value of fossil fuel extraction, resulting in net growth in the value of mining to 2050. The value of agriculture does not include payments for land sequestration. The GTEM industry structure used for this project does not separately identify services export sectors, such as education or inbound international tourism. Underlying growth rates are influenced by assumed productivity growth in the baseline scenario, see Table 16, Appendix D.*
** Coal, gas and other mining are sub-sectors of all mining.*

Source: *DISER economic modelling for the Plan.*

McKinsey undertook supplementary analysis of the impacts and opportunities associated with achieving net zero emissions and the broader global shift towards low emissions technologies. This included an assessment of energy sector jobs arising from electrification in transport and industry, as well as an assessment, drawing on sectoral production results from GTEM provided by DISER, of employment impacts in export-related heavy industries. This analysis concluded that Australia's comparative advantages, particularly in access to land and renewable energy resources, mean job gains can far outweigh job losses. The McKinsey analysis of GTEM volumes shows that almost all of the negative impacts on employment (at least 95%) are driven by changes in global demand consistent with global action to achieve a below 2 degree emissions pathway, with these impacts occurring over several decades. Changes in domestic demand drive the balance of any negative impact. These impacts are not within the control of Australian industries or the Australian Government.

The analysis finds positive impacts of Australia's choice to adopt a target of net zero emissions by 2050 with a plan to achieve it. The opportunities created by new clean energy industries outweigh the unavoidable negative impacts of global action, resulting in a net gain of up to 62,000 jobs in regional, export-facing mining, energy and heavy industry sectors, and up to 76,000 by 2050 when additional jobs in renewables for hydrogen production are included.

Under assumptions consistent with the Plan, McKinsey also projected net employment growth of between 35,000 to 40,000 new jobs related to domestic energy production, driven by growth in the electricity sector from electrification of the transport sector and the adoption of lower cost technologies. McKinsey estimates that to serve the increased electrical load, Australia's rate of deployment of renewable energy will double by 2050, with more than half of jobs in renewable energy to be operation and maintenance roles by the mid-2030s.

In total, McKinsey estimated that over 100,000 new direct jobs could be created in export and domestic sectors by 2050 under the advanced technology scenario, with many more potential indirect jobs.

5. Alternative approaches to achieving net zero involve additional costs and risks

The modelling explored a range of potential pathways for achieving net zero emissions in order to assess the costs, risks, and benefits of different options. This included the two core scenarios and additional scenarios with advanced and conservative technology that relied conceptually on more extensive use of mandatory cost increases, land sector offsets or international trading.

The modelling finds that the Plan provides the largest economic benefits of all the scenarios assessed, and that alternative approaches involve net costs relative to the Plan. These costs include higher marginal abatement costs that impact the competitiveness of Australian firms and reduce national income relative to the Plan (Table ES.1).

Table ES.1 Summary of economic impacts for different scenarios in 2050

		IMPACT OF CAPITAL RISK PREMIUM	BENEFITS OF THE PLAN	COSTS OF ALTERNATIVE PATHWAYS	
Scenario		**No Australian Action**	**The Plan**	**NZE 100% with advanced technology**	**NZE scenarios with conservative technology ***
Assessed against		2°C with no action and no risk premium	No Australian Action	The Plan	The Plan
Economic activity (GDP)	%	-0.55%	1.59%	-0.01%	-1.08% to -1.68%
$ per person (real 2020)	$	-650	1925	-10	-$1,325 to -$2,050
National income (GNI)	%	-0.51%	1.59%	-0.02%	-1.29% to -1.79%
$ per person (real 2020)	$	-625	2,000	-25	-$1,650 to -$2,275

Notes: *$ impacts larger than $100 rounded to the nearest $25. The impact of the capital risk premium is assessed against a background 2°C scenario that assumes no additional Australian action and no Australian 2050 target.*
** NZE scenarios included are NZE with offsets, NZE no trade are NZE no offsets.*

Source: *DISER economic modelling for the Plan.*

The scenarios explored for the Plan provide several insights into the costs and implications of different options and approaches to achieving net zero:

- Reducing gross emissions and the emissions intensity of production involves a range of economic costs.
- Larger emissions reductions can be achieved at lower costs with advanced technology. However, advanced technology does not make emissions reductions costless, or without consequences.
- Supply and use of land sequestration lowers the cost and economic impacts of achieving deep cuts in emissions. Larger volumes of sequestration are possible, and profitable, but involve conversion of farm land to carbon plantings.
- Access to international offsets reduces the economic impact of achieving the 2050 target by around two thirds, all else equal. However, excessive reliance on international offsets could expose Australia to additional risks around the price and availability of high quality international units.

Table ES.2 Summary of key scenario outcomes in 2050

		No Australian Action	The Plan	NZE 100% with advanced technology	NZE scenarios with conservative technology *
Marginal abatement incentive	$	$2	$24	$80	$100 to $400
Residual emissions before offsets	Mt	316	215	157	3 to 239 Mt
Agricultural land removed from traditional production**	%	0.0%	0.0%	0.0%	0.0% to 7.2%
Area of on farm plantings (cumulative to 2050)	Mha	0.14	0.31	1.50	0.15 to 10.03 Mha
International offsets	Mt	NA	-94	-94	-161 to zero Mt
Net emission vs 2005	%	-51%	-85%	-100%	-100%

Notes: *Marginal abatement incentives above $40 are rounded to the nearest $10.*
** NZE conservative scenarios are NZE with offsets, NZE no trade and NZE no offsets. ** Land withdrawn from agriculture does not include on-farm plantings with no negative impact on farm output, such as shelter belts. Area withdrawn is shown as percentage of the 78.8 million hectares (Mha) agricultural use zone, which does not include savanna or land in the arid zone. *** Negative international offsets indicate that Australia purchases abatement from overseas.*

Source: *DISER economic modelling for the Plan.*

A scenario was also undertaken to explore the economic impacts and outcomes of achieving 100% of the abatement required to get to net zero by 2050 on the basis of our current best estimate of advanced technology and abatement options, with the same volume of international offsets as the Plan (NZE 100% scenario). The modelling found that this scenario requires higher marginal abatement costs than the Plan, rising to $80/t CO_2-e in 2050.

The modelling finds these higher abatement costs have adverse impacts on some traditional energy sectors, with $4.9 billion lower output value from coal and gas in 2050 relative to the Plan and lower growth in heavy industry. These impacts are avoided with the lower abatement incentive assumed in the Plan. The NZE 100% scenario also involves higher volumes of land sequestration, which provides $4.3 billion in additional revenue to participating land holders, but requires more extensive on-farm plantings.

Conclusions

A central finding of this analysis is that driving down technology costs to allow Australia to adopt a net zero target by 2050 provides a net benefit to Australia. The modelling demonstrates that the Plan maximises the benefits relative to the no action scenario, avoids the need to impose mandatory high abatement costs and avoids significant conversion of agricultural land.

The modelling shows that Australia can reduce net-emissions by 85% based on achieving our technology stretch goals with a voluntary abatement incentive of up to $25/t CO_2-e in 2050. The work done by McKinsey (which shows an 82% reduction, without international offsets) and experience in the radical reduction in the costs of technology over time observed in industries, including solar, indicates that over the long term technology cost reductions typically exceed expectations. On this basis the Department considers it likely that further technology breakthroughs and cost reductions beyond those modelled could close the remaining gap to net zero emissions by or before 2050.

The analysis shows that policy choices are important in reaching net zero, and directly impact the future wellbeing and prosperity of Australians. The Plan provides a pathway to net zero emissions in 2050 that does not rely on mandating high abatement costs, conversion of productive farming land to carbon sequestration or excessive use of international units.

Additional information available in the full report

Further information on Australia's Plan to achieve net zero emissions by 2050 can be found in the document ***AUSTRALIA'S LONG-TERM EMISSIONS REDUCTION PLAN: A whole-of-economy Plan to achieve net zero emissions by 2050*** available at https://www.industry.gov.au/data-and-publications/australias-long-term-emissions-reduction-plan.

Further information on Australia's strategy to develop and deploy low emissions technology also be found in the document Technology Investment Roadmap: Low Emissions Technology Statement 2021 available at http://industry.gov.au/LETS2021.

Summary of key findings

1. **Reducing the cost of low emissions technologies can provide net benefits to Australia and put us within reach of net zero emissions by 2050**

    1.1. Advanced technology, including hydrogen, creates economic opportunities and accelerates emissions reductions, both domestically and globally

    See also findings 2.1, 2.2, 3.1, 3.2, 4.2, 4.4 and 5.2

2. **There are a range of pathways to delivering the reductions needed to achieve net zero emissions by 2050**

    2.1. Australia can achieve net zero emissions with strong economic growth

    2.2. Multiple lines of evidence find that net zero is achievable

    2.3. Electricity and transport are projected to substantially decarbonise, even under current trends

3. **Adopting a target of net zero emissions by 2050, with a credible plan to achieve it, provides economic benefits to Australia**

    3.1. Global responses would have significant economic impacts if Australia does not adopt a net zero target

    3.2. Adopting a net zero by 2050 target provides net economic benefits, with advanced technology providing additional benefits

4. **Jobs and output value grows across all major sectors to 2050 including mining**

    4.1. Global demand for food and fibre, minerals, and energy-intensive commodities sees all major sectors grow to 2050

    4.2. Low carbon technologies and supply chains create new opportunities for regional industries

    4.3. Global action will impact coal and gas production, regardless of the Australian Government's policies or targets

    4.4. Under the Plan, jobs gained from new economic opportunities exceed job losses associated with changes in demand, which are outside the control of the Australian Government

    4.5. There are additional benefits from coordinated global action to reduce emissions and avoid global warming

5. **Alternative approaches to achieving net zero involve additional costs and risks**

    5.1. The Plan minimises costs and risks, and maximises economic benefits to Australia

    5.2. Advanced technology provides additional flexibility in how Australia can achieve net zero

    5.3. Imposing higher abatement costs would amplify negative economic impacts on Australia

The scope and context of the analysis

Australia's Long Term Emissions Reduction Plan (the Plan) focuses on driving down the costs of technology to the point that it becomes the natural choice for rational economic actors. The quantitative analysis commissioned for this Plan explored the potential impacts, benefits and consequences of using a technology-based approach to reduce emissions.

The Plan recognises that once technology costs reach tipping points, uptake grows exponentially. Its focus is on driving down technology costs and through that, delivering emissions reductions and economic benefits.

This report outlines the modelling and analysis undertaken to to inform the development of the Plan and the Government's decision to adopt a net zero emissions by 2050 emissions reduction target. That analysis has focused on the question of how close to net zero Australia can get by 2050 in the context of the Government's technology-led approach.

The modelling and analysis is not a precise prediction of how trends in technology or the Australian economy will unfold over the next three decades. In particular, the quantity of emissions reduction or offsets generated in the model should not be interpreted as requiring a specific reduction or output from that sector.

The report explains the context of the analysis, and then presents and explains the key findings. As the primary scenarios assessed all occur in the context of ambitious global action, the modelling did not assess the impacts of climate change or the benefits of avoided climate damages associated with differences in global emissions trajectories.

Analytical approaches used to inform the Plan

Analysis for the Plan built on the work undertaken for the 2020 LETS (Commonwealth of Australia, 2020) to assess consumer and technology trends and identify priority technologies for Australia, as well as subsequent work for LETS 2021 to understand how far and how soon the costs of those technologies could fall. This work identified the timeframes in which the stretch goals could be achieved, and the components of the cost base that would need to be reduced to achieve them. This work is summarised below and was used as the basis for all of the subsequent modelling and analysis for the Plan.

Two complementary analytical approaches – top-down economic modelling and bottom-up analysis by McKinsey & Company (McKinsey) – were then used to understand the potential economic impacts that could follow. This approach enabled DISER to evaluate whether Australia can achieve net zero emissions by 2050 through an agenda that reduces technology costs and expands the choices available to consumers.

- **Top-down economic analysis:** Economic modelling provides a valuable way to assess the implications of different trends or policy options, exploring complex interactions and effects, and quantifying their potential impacts. The analysis for this project was conducted using GTEM, a global economic model with an established track record (see Box B1 below). The modelling was conducted by DISER with an experienced team of economists drawn from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Treasury, the Productivity Commission, CSIRO, and DISER.
- **Bottom-up analysis by McKinsey:** Drawing on its extensive database of low emission fuels, technologies and processes, this project examined the contribution that the technologies prioritised through the Technology Investment Roadmap, combined with global technology trends, could make towards Australia achieving net zero emissions by 2050 if we are successful in realising deep reductions in technology costs. This analysis converged with GTEM in key areas, such as the central role of low emissions electricity and electrification of road transport, notwithstanding differences in aspects of the detailed results.

McKinsey also undertook supplementary analysis of the employment impacts and opportunities associated with Australia's net zero target and the broader global shift towards low emissions technologies. This included an assessment of energy sector jobs arising from electrification in transport and industry, as well as an assessment, drawing on sectoral production results from GTEM provided by DISER, of employment impacts in export-related heavy industries.

The Plan also drew on analyses by DISER to inform Australia's National Greenhouse Gas Inventory and annual emissions projections, as well as analysis by the DISER's Office of the Chief Economist of the economic opportunities of rising global demand for battery minerals and base metals (as outlined in Australia's Long-Term Emissions Reduction Plan, Commonwealth of Australia, 2021b). This modelling and analysis has built on the work undertaken for the 2020 LETS to assess customer and technology trends and identify priority technologies for Australia, as well as subsequent work for the LETS 2021 to understand how far and how soon the costs of those technologies could fall.

Analysis for the Low Emissions Technology Statements

This modelling and analysis has built on the work undertaken for the 2020 Low Emissions Technology Statement (LETS) to assess customer and technology trends and identify priority technologies for Australia, as well as subsequent work for the LETS 2021 to understand how far and how soon the costs of those technologies could fall.

Through LETS 2020 and LETS 2021 the Government has undertaken detailed analysis to assess the potential of a wide range of new and emerging low emissions technologies. Based on extensive consultation and advice from the Technology Investment Advisory Council, the Government has identified six priority technologies that:

- will have the biggest impact in reducing emissions in Australia and globally
- have significant economic potential
- build on Australia's competitive advantages
- public investment can help develop and deploy.

Those priority low emissions technologies are:

- clean hydrogen
- ultra low-cost solar
- energy storage
- low emissions materials (steel and aluminium)
- carbon capture and storage
- soil carbon.

Each priority technology has a corresponding economic stretch goal. Stretch goals are ambitious, but realistic, goals that aim to bring priority low emissions technologies to cost parity with existing high emissions technologies.

The Australian Government will invest more than $21 billion to support the development and deployment of these priority low emissions technologies to 2030, and will continue to play a direct role in driving research and development, and catalysing co-investment from business and other partners, beyond that point. This will ensure these technologies are well on the pathway to achieving the stretch goals. The work for the Plan assumes that there are no changes to the rates of taxation or government expenditure overall in the economy to 2050 and that future decisions by government to continue investments in these technologies can be accommodated within that assumption.

The LETS 2021 examined potential deployment pathways for these technologies and when the economic stretch goals could be achieved under a 'high technology' (Figure 1). This assumes accelerated global uptake of low emissions technologies, driven by:

- public investments and policies that reduce risk for private investors
- a shift in consumer preferences towards low emissions supply chains
- private investments consistent with an average global temperature rise of no more than 2°C.

All charts in the following section present findings consistent with the high technology scenario used for LETS 2021 analysis.

A range is given for the estimated timeframe of achieving each economic stretch goal, starting with the earliest date it could be met.

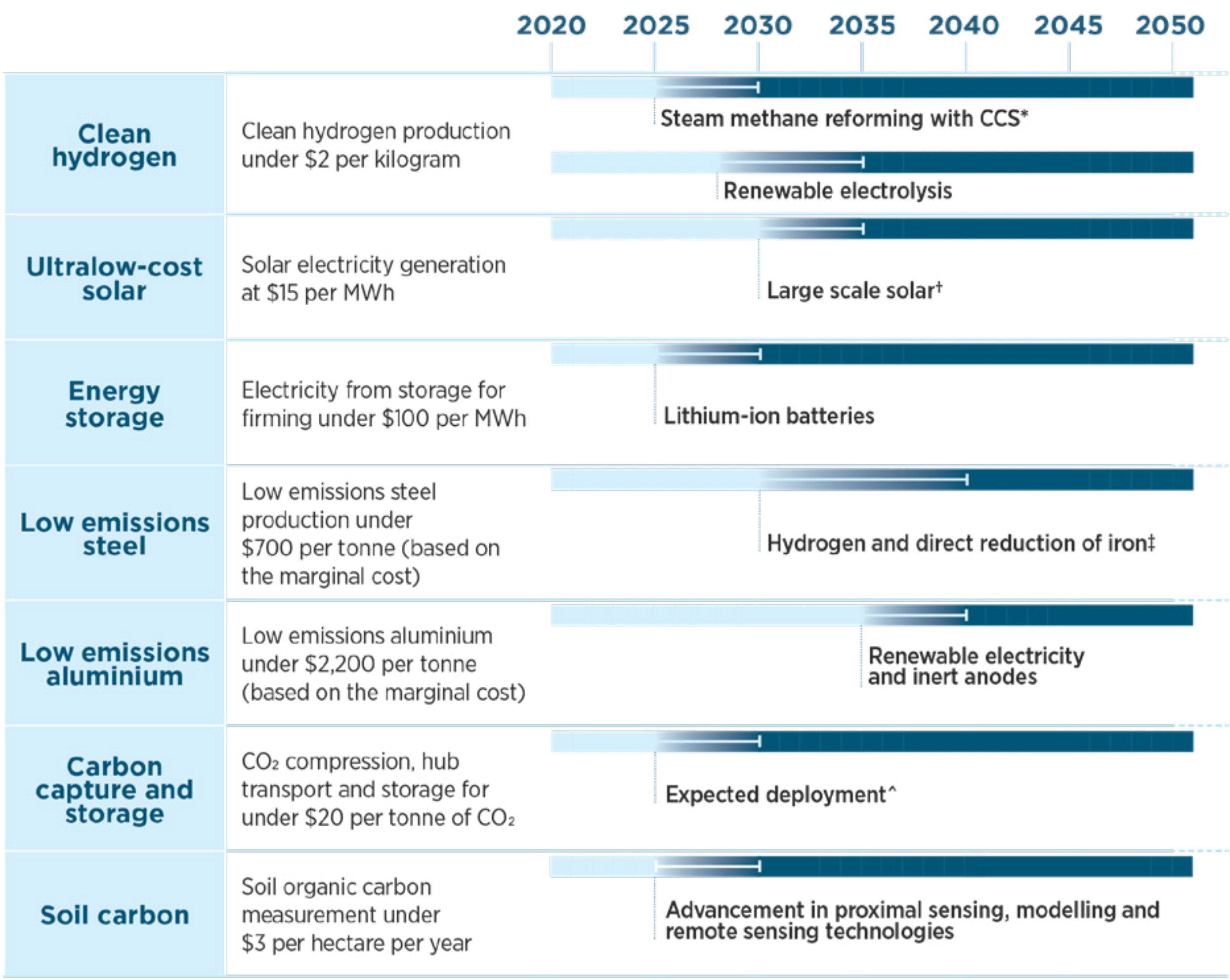
This recognises that the pace of reaching these goals will depend on a range of factors, including:

- technological advances
- capital and financing requirements
- approval and construction timeframes
- global uptake.

Confidence of reaching the stretch goal increases towards the end of the range.

The timeframes are informed by analysis from McKinsey, industry consultation and expert advice including the Technology Investment Advisory Council and other government agencies including ARENA and CER (Figure 1). These findings were then used to inform and calibrate the assumptions applied in the advanced technology scenarios in the economic modelling.

Figure 1. Priority technologies and economic stretch goals



* economically feasible now, but subject to offtake agreements, development approvals and the adoption of a hydrogen Guarantee of Origin scheme.

† the timeframe for achieving the ultralow-cost solar stretch goal does not yet underpin the electricity price assumptions used for achieving clean hydrogen, energy storage, and low emissions steel and aluminium stretch goals

‡ economically viable in the late 2020s, but subject to capital development cycles

^ subject to offtake agreements and development approvals

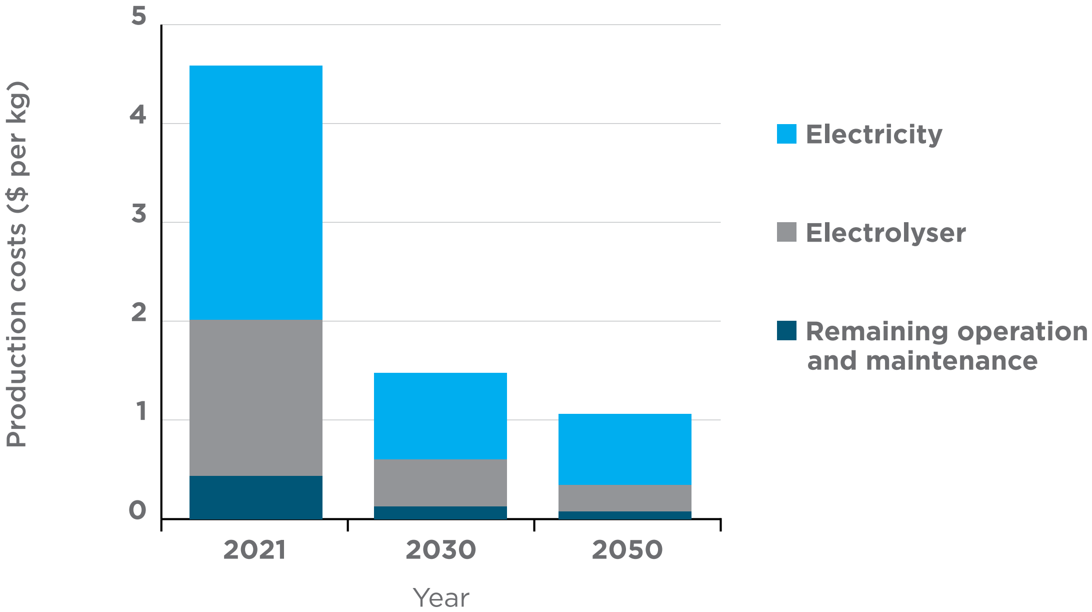
Clean hydrogen

Stretch goal: clean hydrogen production under $2 per kg

Renewable electrolysis

Clean hydrogen production from renewable electrolysis costs around $4.60 per kg now and is projected to achieve around $1.10 per kg by 2050 (Figure 2). Steep reductions in the costs of renewable electricity and electrolysers see hydrogen from renewable electrolysis meet the stretch goal for hydrogen production under $2 per kilogram as soon as 2028 (Figure 4).

Figure 2. Electrolytic hydrogen production cost breakdown

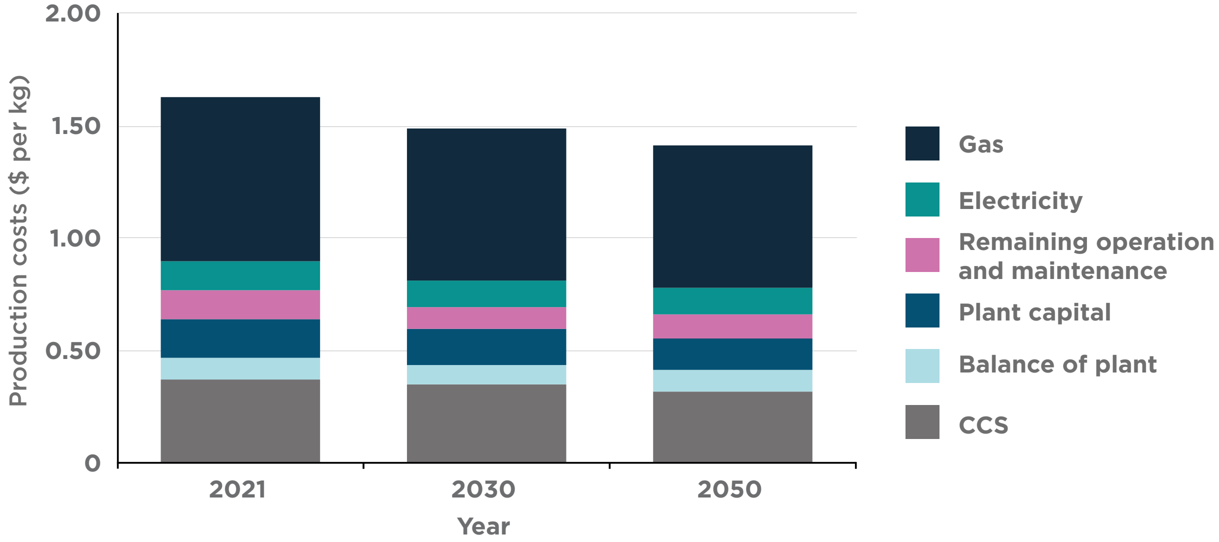


Steam methane reforming with CCS

Clean hydrogen production from gas with emissions captured and permanently stored underground could achieve the stretch goal now at around $1.60 per kg (Figure 3). Deployment of hydrogen production from steam methane reforming with CCS in Australia is subject to development of CCS basins, securing low-cost gas, offtake agreements, development approvals and the adoption of the Hydrogen Guarantee of Origin certification scheme. Should these be achieved, the clean hydrogen stretch goal could be met as early as 2025. By 2050, production cost could reach around $1.40 per kg.[1]

1 Natural gas cost of $5 per GJ used for analysis

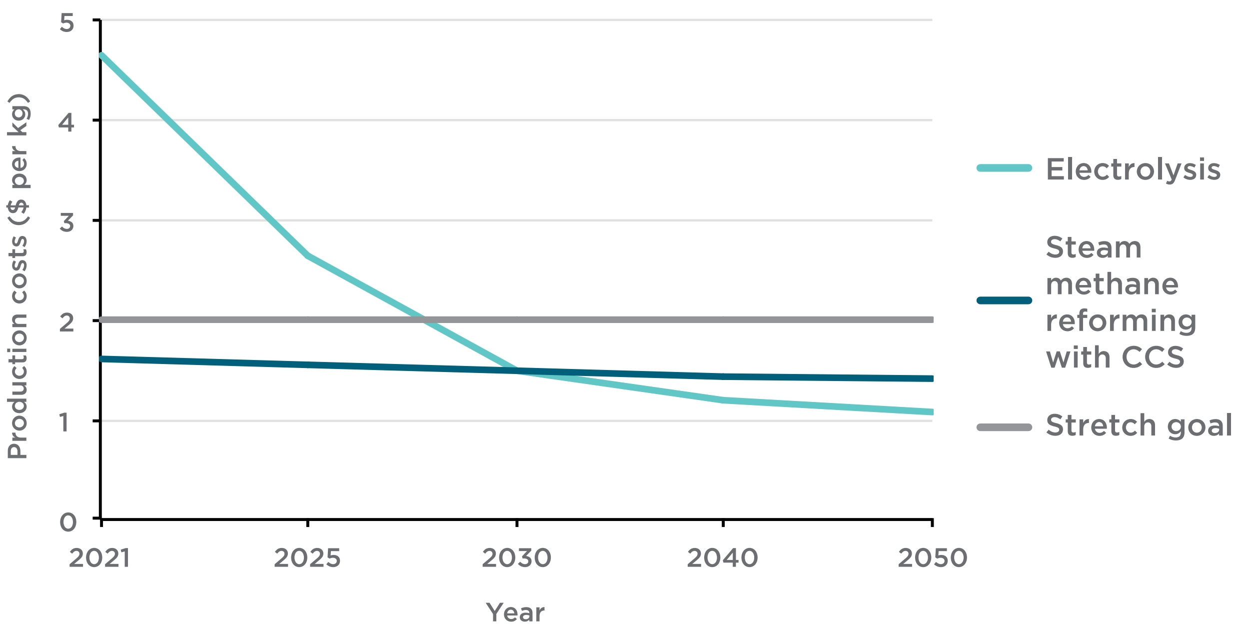
Figure 3: Cost breakdown of hydrogen production from steam methane reforming with CCS



Renewable electrolysis could reach parity with steam methane reforming and CCS around 2030

While clean hydrogen produced through electrolysis is significantly more expensive in 2021, its costs are expected to fall rapidly and could achieve parity with clean hydrogen from gas with CCS around 2030 (Figure 4).

Figure 4. Hydrogen production cost



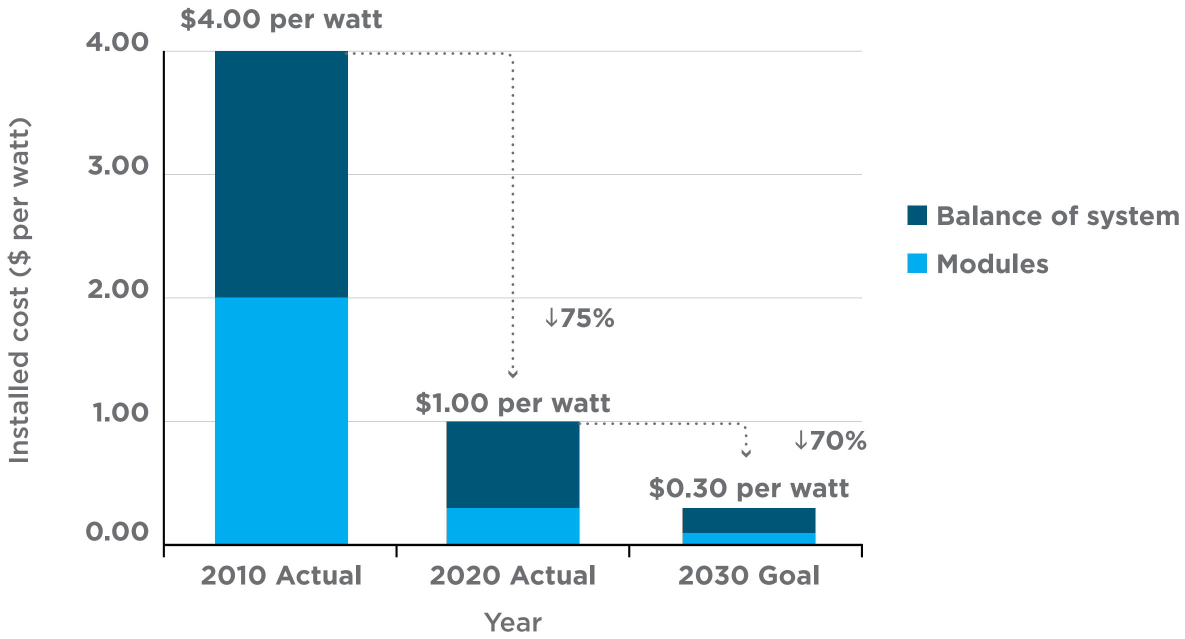
Ultra low-cost solar

Stretch goal: solar electricity generation at $15 per MWh

Ultra low-cost solar is likely to deliver significant cost reductions for clean electricity. Australia aims to generate solar electricity at $15 per MWh by 2030, approximately a third of today's cost.[2,3]

Reaching the stretch goal will require further innovation in the efficiency of solar modules and optimisation of large scale deployment. Supported by ARENA's 30 30 30 initiative, the government will work toward achieving 30% module efficiency at 30 cents per installed watt by 2030 (Figure 5).

Figure 5. Installed cost of solar electricity generation



Energy storage

Stretch goal: electricity from storage for firming (available on demand for 8 hours) at under $100 per MWh.

Lithium-ion batteries are the cheapest form of grid-scale battery storage currently available. Costs are expected to fall further thanks to manufacturing scale up driven by the rapidly growing electric vehicles market.

For 8 hour duration, the cost of electricity from storage for lithium-ion batteries is expected to decline from $170 per MWh in 2021 to below $100 per MWh over an 8 hour duration as early as 2025, and below $40 per MWh in 2050 (Figure 6).

Based on industry feedback that there is market demand for 4 hour storage over the medium term, energy storage costs were also analysed for 4 hour duration.

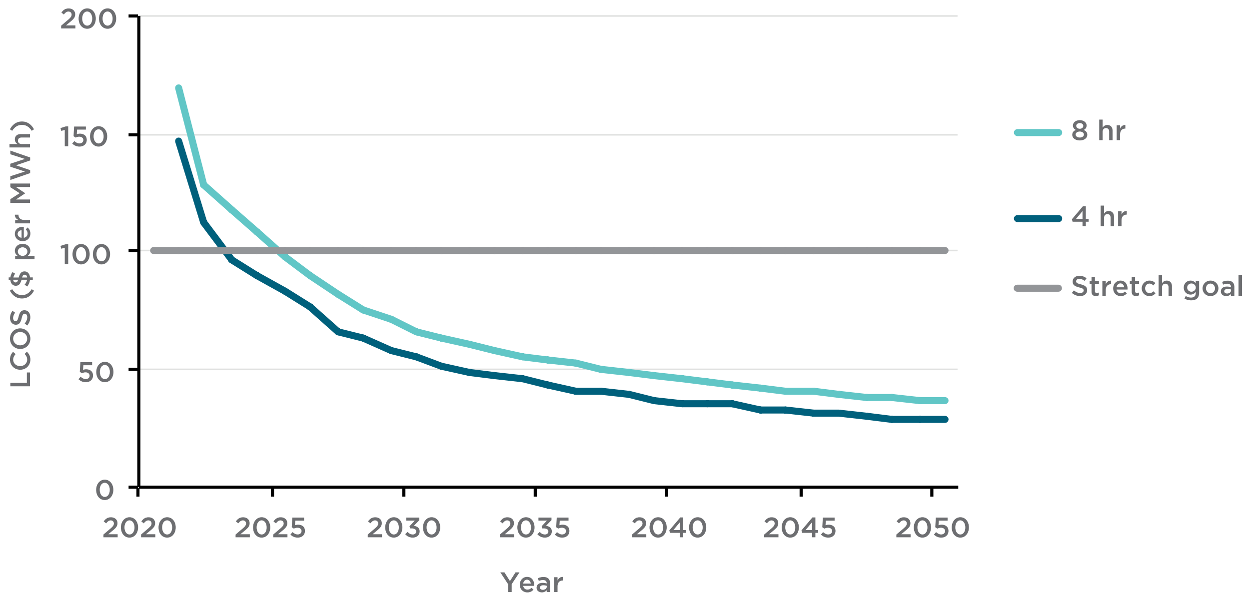
For 4 hour duration, the cost of electricity from storage for lithium-ion batteries could decline from $150 per MWh in 2021 to below $100 per MWh over a 4 hour duration before 2025, and below $30 per MWh in 2050.[4]

2 CSIRO 2020, GenCost report 2020-2021, accessed 3 November 2021

3 BloombergNEF, 1H 2021 LCOE Update. accessed at: 23 October 2021

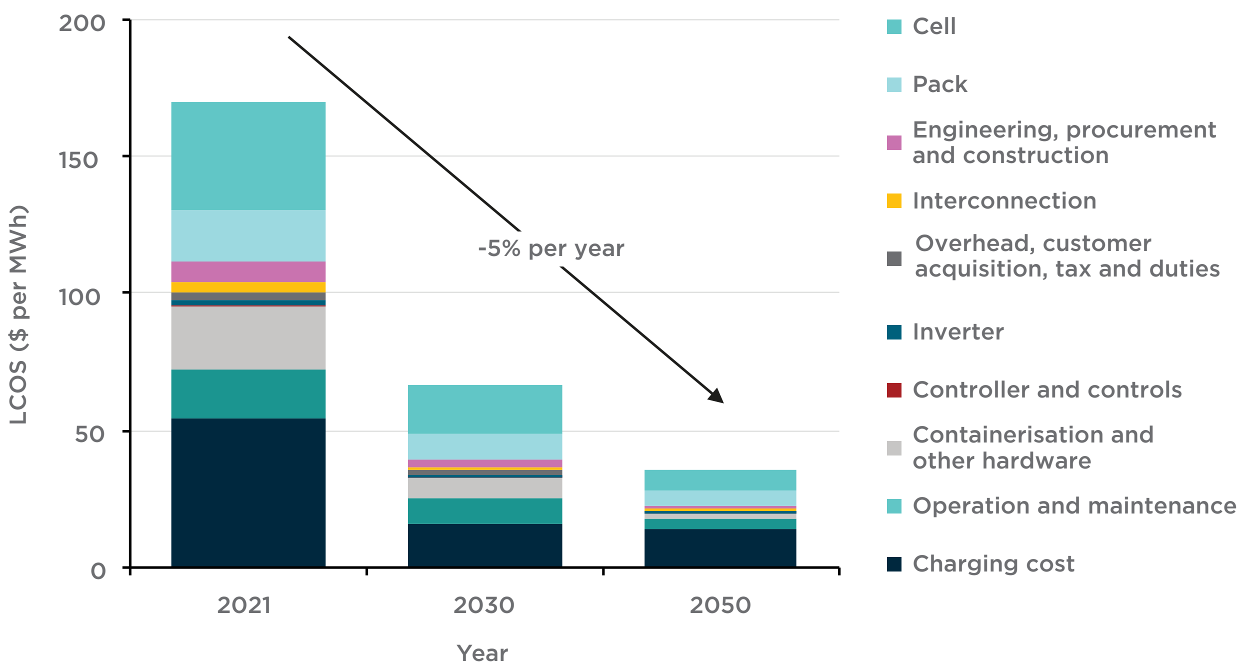
4 Assumes twice daily discharge cycle.

Figure 6. Levelised cost of storage for 100 MW lithium-ion batteries



This cost reduction is due to improved cell chemistries (Figure 7). The cost of battery cells is mainly driven by overseas developments. However, domestic engineering, procurement and construction costs depend on local demand. Australia can reduce these costs by supporting scale up of battery installations and supporting demonstration projects..

Figure 7. Cost breakdown of 100 MW, 8 hour duration lithium-ion batteries

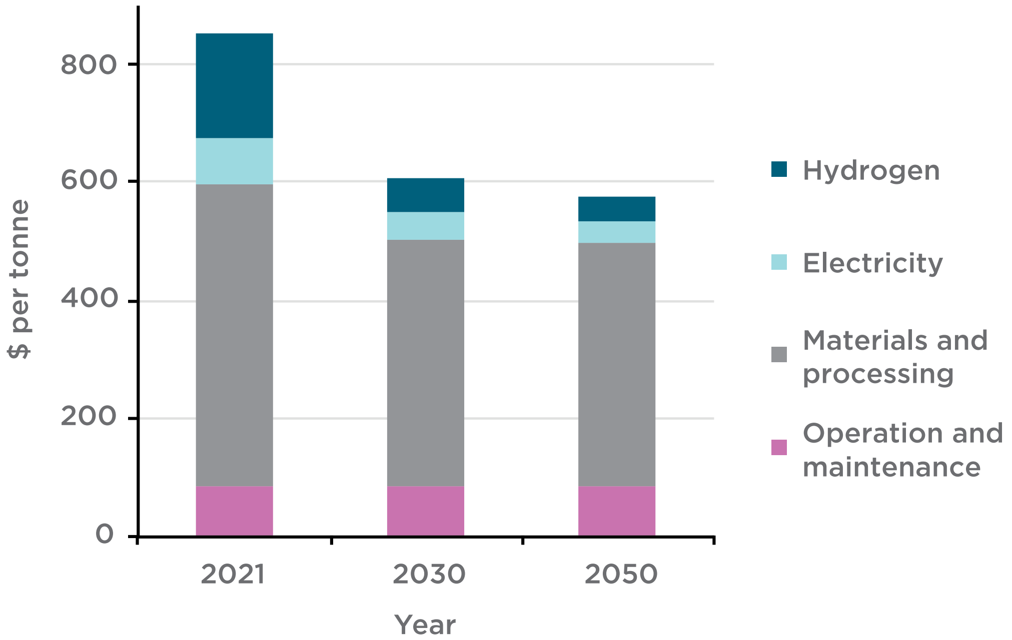


Low emissions steel

Stretch goal: low emissions steel production under $700 per tonne (based on marginal cost).

As clean hydrogen and renewable electricity become cheaper, the cost of producing low emissions steel from direct reduction of iron and an electric arc furnace could be reduced from almost $900 per tonne now to less than $600 per tonne by 2050 on a marginal cost basis.[5] This cost reduction trajectory would see low emissions steel production meet the stretch goal as early as 2030 (Figure 8).

Figure 8. Low emissions steel production cost breakdown



Low emissions aluminium

Stretch goal: low emissions aluminium production under $2,200 per tonne (based on marginal cost).

As renewable electricity becomes cheaper, the cost of producing low emissions aluminium with inert anodes could be reduced from over $2,700 per tonne now to less than $2,200 per tonne in 2050 on a marginal cost basis (Figure 9). This cost reduction trajectory would see low emissions aluminium production meet the stretch goal as early as 2035 (Figure 10).

5 The timeframe for achieving the stretch goal is dependent on raw material costs, including ore based metallics and the price of scrap.

Figure 9. Low emissions aluminium production cost breakdown

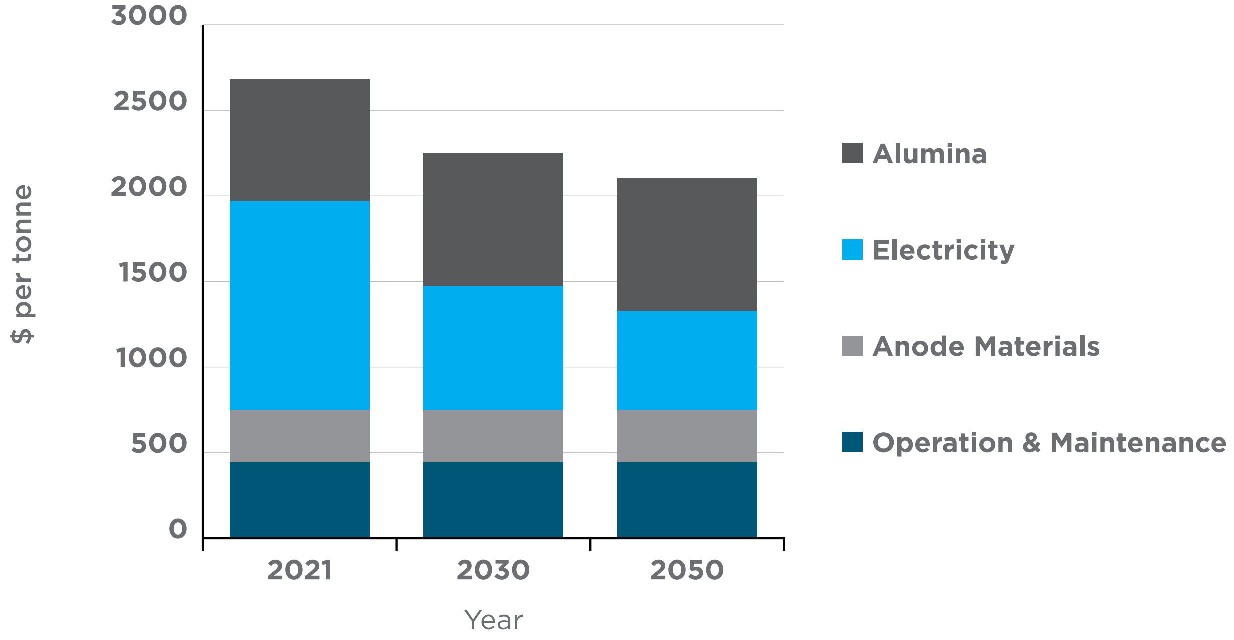
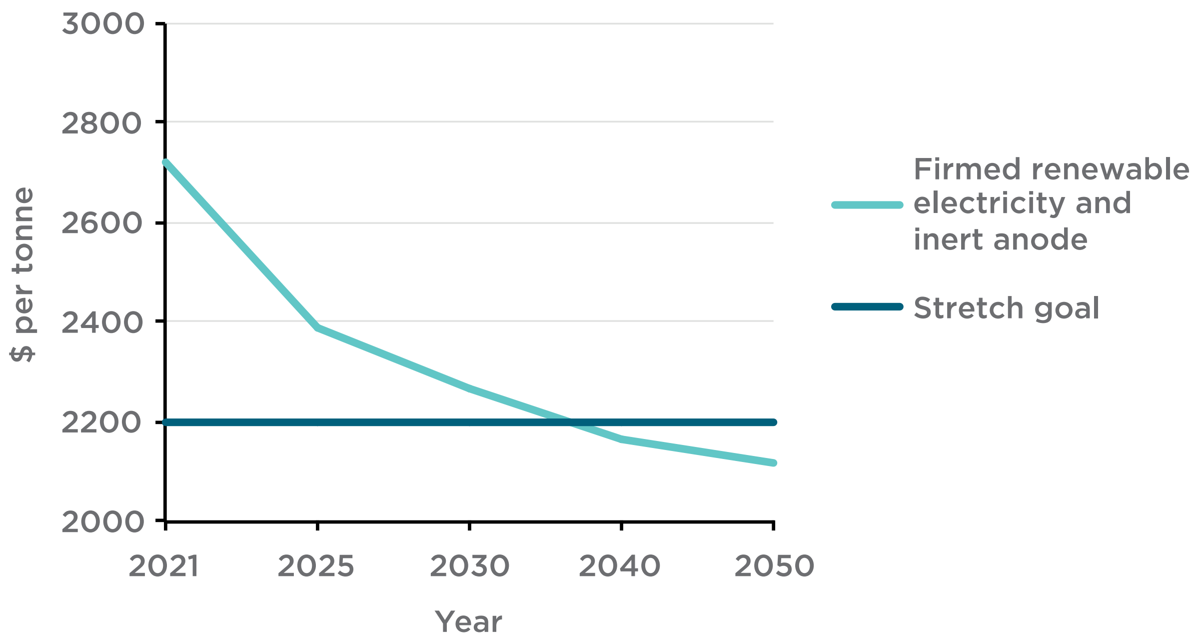


Figure 10. Low emissions aluminium production cost

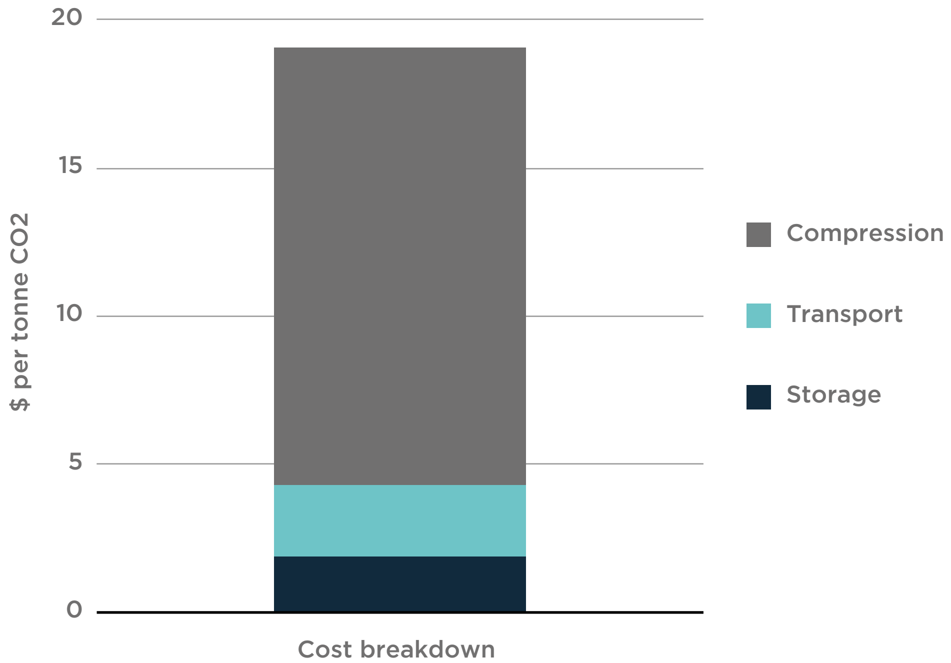


Carbon capture and storage

Stretch goal: CO_2 compression, hub transport and storage for under $20 per tonne of CO_2.

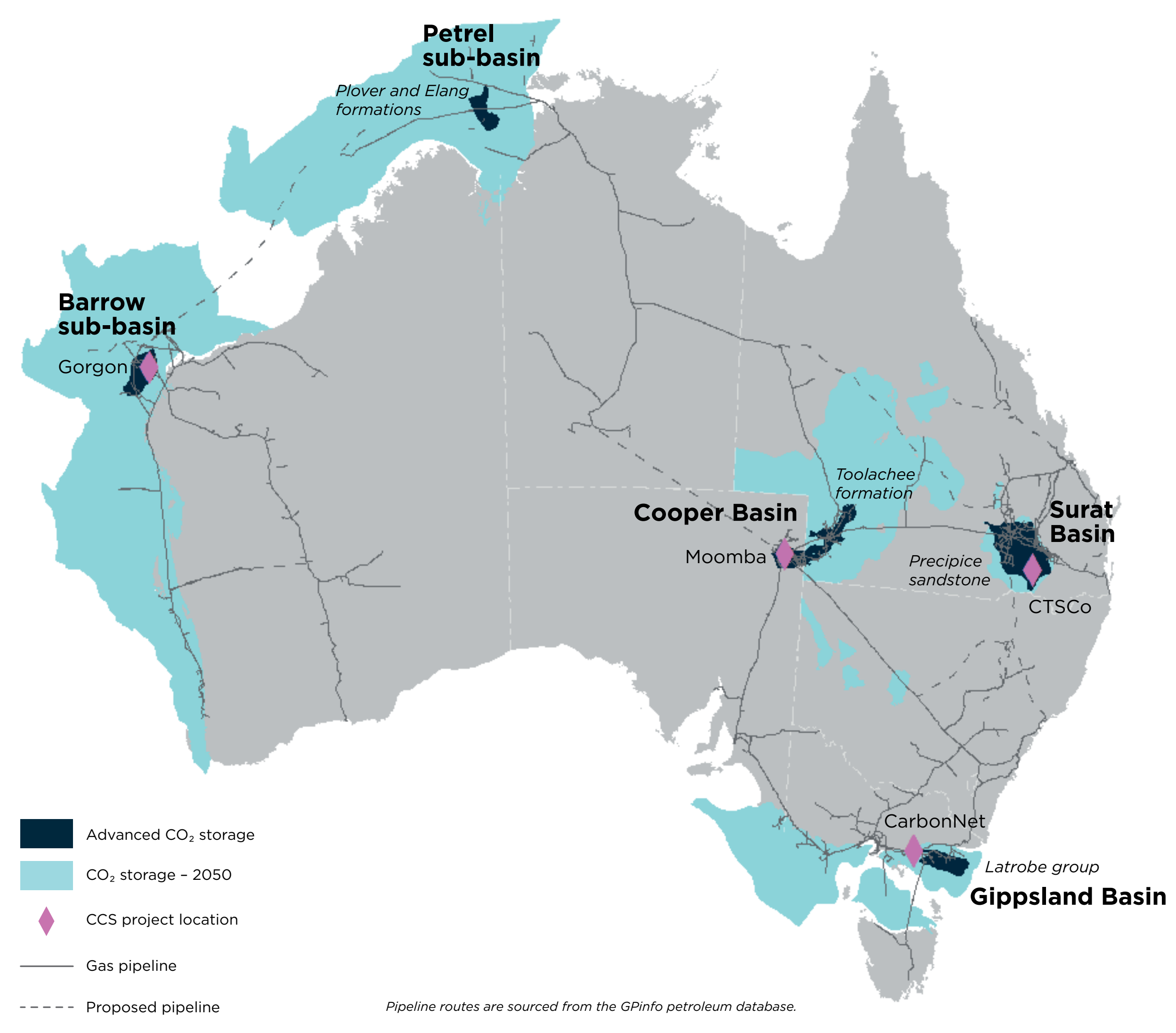
The cost of CO_2 compression, hub transport and storage could be close to $20 per tonne now, if high volumes of concentrated streams of CO_2 are clustered within 100 km of well-developed reservoirs (Figure 11). Material changes to CO_2 compression, hub transport and storage costs are not anticipated given the maturity of these technologies. Facilities that have started developing projects could implement CCS as early as 2025, subject to offtake agreements and development approvals.

Figure 11. CO_2 compression, hub transport and storage cost breakdown



The Gippsland, Surat, and Cooper Basins, together with the Petrel and Barrow sub-basins host carbon storage sites at an advanced stage of development, and each have genuine industry interest and support (Figure 12). The combined storage capacity at four of these key locations (Gippsland, Surat, and Cooper Basins, and the Petrel sub-basin) is over 20 billion tonnes.[6]

Figure 12. Prospective CO_2 storage sites in Australia



The Australian Government is undertaking further analysis to inform Australia's potential to store CO_2 in our basins as this varies widely depending on basin characteristics and injection rates.

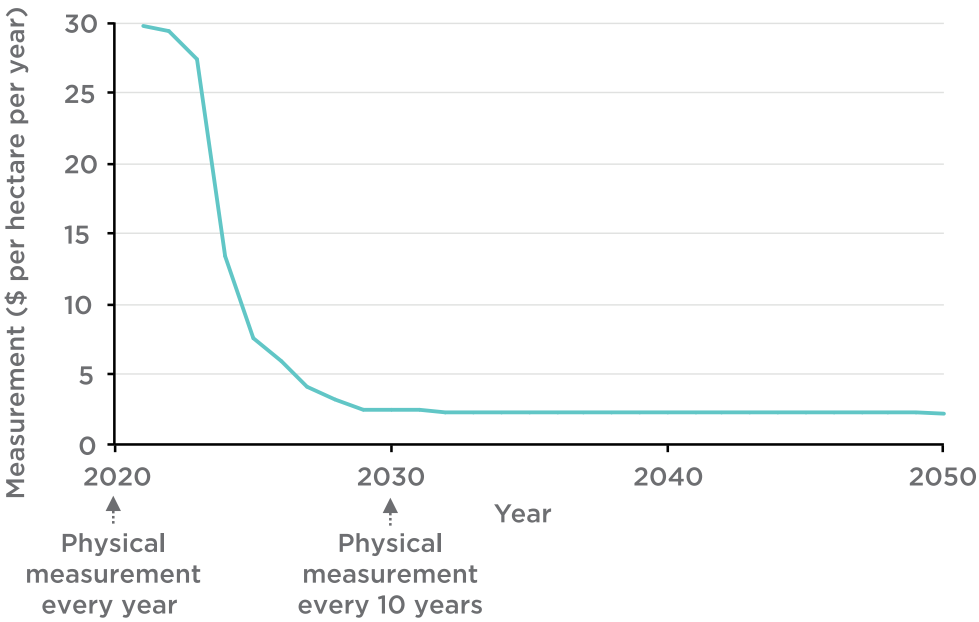
6 Estimates by Geoscience Australia.

Soil carbon

Stretch goal: soil carbon measurement under $3 per hectare per year.

The current cost of soil carbon measurement is around $30 per hectare per year (Figure 13).[7] Achieving the stretch goal will require advances in modelling and remote sensing to reduce the frequency of physical testing. Assuming early deployment of modelling and remote sensing technologies with physical testing occurring as infrequently as once every ten years, the cost of soil carbon measurement could be reduced to less than $3 per hectare per year before 2030. The stretch goal could be achieved as early as 2025 for land areas greater than 2000 hectares.

Figure 13. Soil carbon measurement costs breakdown[8]



7 CSIRO estimate based on a land area of 300 hectares. CSIRO estimates current measurement costs would be lower for larger areas.

8 High technology scenario, using DISER assumptions.

Questions and scenarios explored through the economic modelling

The economic modelling for Australia's Long Term Emissions Reduction Plan (the Plan) explored a range of scenarios to provide insights into the following questions:

- What are the costs, risks, and benefits of different options for achieving net zero? What are the likely consequences if Australia does not adopt a 2050 target?
- What is the outlook for Australian energy and emissions intensive sectors and regional industries in a low carbon world? What are the risks and opportunities for Australia of increased global effort to reduce emissions?
- How would these change with successful efforts to drive down the costs of low emissions technologies, including hydrogen?

Within this general set of questions, the modelling also sought to assess the extent to which an Australian pathway to net zero could be developed that would not rely on high carbon prices, large scale conversion of productive farming land to provide carbon sequestration, or excessive use of international offsets.

The scenarios were designed to provide insights into these questions, including the likely effects of a technology-led approach, and the implications of different options for achieving net zero by 2050.

The top-down economic modelling explores these questions and scenarios using GTEM, an established global computable general equilibrium (CGE) model that integrates economic activity, energy use, and greenhouse gas emissions. The model includes Australia as one of a large number of countries and regions, each of which has 28 industry sectors, all linked by trade and investment flows. The model includes multiple technologies for key energy-intensive sectors, as one of several abatement mechanisms. Box B1 and Appendix B and C provide more details.

The key results of the work were included in the Plan released by the Government on 26 October 2021.

Box B1: The Global Trade and Environment Model (GTEM)

The economic modelling uses GTEM, a multi-sector multi-region global computable general equilibrium (CGE) model.

In the version of GTEM used for this project Australia is represented as one of 24 regions (individual countries or groups of countries) that together make up the global economy. Each region has 28 industrial sectors and a representative household for that region (for each regional society). Trade and investment link the regions and a range of taxes and subsidies capture government policies. The model assumes multiple production technologies for three energy-intensive sectors: the electricity, land transport, and iron and steel sectors.

The model covers emissions of all greenhouse gases included under the Paris Agreement: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases (Fgases) including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). Projected emissions from each sector can be reported by UNFCCC emissions categories used in the National Greenhouse Gas Inventory. Emissions from waste are not represented explicitly in the model.

GTEM was originally developed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and is currently maintained and developed by CSIRO. GTEM has an established track record, and has been featured in several government reports, including Australia's Low Pollution Future (2008), Strong Growth Low Pollution (2011) and Climate Change Mitigation Scenarios (2013).

Core scenarios and issues explored through the modelling

The modelling develops two primary scenarios, which underpin the key findings for the questions above:

No Australian Action – All countries, except Australia, reduce their emissions to achieve a below 2°C global emissions trajectory. All developed countries reduce their emissions to net zero by 2050, except Australia. Australian emissions drift down to be 51% below 2005 levels in 2050 as a result of current trends, including changes in global demand for Australia exports. Technology improvements are not accelerated beyond normal trends (as it would be under the Plan). Australia does not adopt a 2050 target, which triggers an adverse investor response in the form of a capital risk premium.

The Plan – Australia continues to invest in technological breakthroughs and works through international partnerships to support a global acceleration of technology breakthroughs. Along with all other developed countries, Australia adopts a target of net zero emissions by 2050, so that the capital risk premium is avoided. Abatement action is taken across all sectors on a voluntary basis, with this modelled as an abatement incentive which is taken up across the economy and rises to $24/t CO_2-e in 2050. This voluntary action is taken by emitters to either reduce their emissions or purchase offsets, consistent with investor expectations and consumer preferences. International offsets are available to the Australian economy at the global price ($40/t CO_2-e in 2050). The global context is a world on track to well below 2°C. Advanced technology outcomes are available globally and global and Australian hydrogen production is assumed to be in line with IEA projections. In this scenario net emissions in Australia are reduced by 85% compared to 2005 levels, with the remaining gap to be met by further technological improvements.

These scenarios differ in several ways, including global and Australian development and deployment of advanced technology, successful deployment of cost-competitive hydrogen, and the adoption of a 2050 target by Australia (avoiding a capital risk premium). The key assumptions for these scenarios are summarised in Table 1. More details are provided on the assumptions and modelling implementation below and in Appendix A.

Table 1. Key assumptions for core scenarios

SCENARIO ASSUMPTION	No Australian Action	The Plan
Global emissions trajectory	World reduces emissions consistent with limiting warming to below 2°C	World reduces emissions consistent with limiting warming to well below 2°C
Global action	All countries achieve their 2030 targets. Developed countries achieve net zero emissions by 2050, China in 2060 and other countries consistent with the global emissions trajectory for each scenario.	
International trading	Limited international emissions trading	
Capital risk premium	Imposed on Australia	No risk premium
Technology	Conservative	Advanced, including hydrogen
Abatement incentive in Australia	$2/t in each year from 2031, including 2050, by assumption	Rises to $24/t in 2050, by assumption
Australian target in 2050	No target	15% gap remains, by assumption (to be met through further technological improvements)
Land sequestration	Below default supply	Default supply
International offsets	Australia does not participate in trading	Limited trade

Source: *DISER economic modelling for the Plan, see also Table 5 below for more details.*

The main modelling scenarios are based on an emissions trajectory that limits global warming to well below 2°C, consistent with the Paris Agreement. This reflects the focus of the modelling on assessing the implications of different choices and actions associated with Australian achieving net zero emissions in 2050, in the context of a technology-led approach. All countries achieve their 2030 targets (as set out in April 2021), with Australia's emissions calibrated to the 2021 projections. This analysis compares outcomes for Australia in 2050, assuming additional global and Australian efforts begin in 2031.

The global assumptions and results, including emissions pathways and abatement incentives, provide the context

Box B2: Interpreting abatement incentives in this report

In the real world, consumers and producers choose to voluntarily reduce their emissions across a wide range of marginal abatement costs. These costs can be negative or zero, representing a positive net present value or net economic gain to the actor, or negative, reflecting an economic cost. Observed voluntary action can occur at marginal abatement costs significantly higher than observed in voluntary markets like the Emissions Reduction Fund (ERF). Likewise, in other cases, some cost-effective abatement opportunities (opportunities with a positive net present value or negative marginal abatement cost) are not taken up.

The Government supports this voluntary action through a wide variety of enabling actions including providing information to consumers, investing in enabling infrastructure, investing in research, development and demonstration to bring the cost of new technologies and actions down, and providing voluntary incentives through the ERF (either purchasing offsets directly or underwriting investment in projects that reduce emissions through optional delivery contracts).

In Australia, the private voluntary market has shown growth of 76% between 2019 and 2020 and the Clean Energy Regulator expects it to exceed 1 million tonnes of offsets in 2021. Prices for these offsets have been above $30/t on the spot market. As a result of the private market (the voluntary purchase and surrender of Australian Carbon Credit Units generated through the ERF by private firms), abatement project proponents receive funding from the private sector for undertaking the activity and the private firm can count the ACCU towards their net emissions position.

There is corresponding evidence that the Government's role as a purchaser of ACCUs under the ERF will diminish over time, with an increasing proportion of ERF participants taking up optional delivery contracts. Under an optional delivery contract, the Government effectively underwrites projects that reduce emissions. Provided the project proponent elects to sell these offsets to voluntary participants in the private market, there is no cash transfer from the Government to the proponent.

The modelling represents this action by consumers and businesses to reduce emissions in a variety of ways, including changes in the fuel and technology mix in electricity, transport and industry; changes in production processes affecting non-combustion emissions; and changes in the relative demand for different goods and services.

The GTEM model is limited in the way it represents these processes, reflecting them as a 'marginal abatement cost'. This is a stylised mechanism that motivates the actions in the model that reduce emissions. The marginal abatement cost in the model represents the wide variety of ways that action can be motivated, including voluntary action (to meet investor expectations or consumer preferences), government regulation (such as efficiency standards or technology mandates), government financial support or incentives, or tax arrangements (such as fuel excise). The marginal cost of abatement does not represent a carbon tax, and no revenue is collected or paid to government within the model when it is implemented. For this reason the modelling does not assume that abatement incentives are imposed by government, and abatement incentives should not be interpreted as a government levy or financial impost upon any sector of the economy.

Where producers choose to switch to technologies or fuels with lower emissions but higher financial costs, the model assumes that this management of emissions is considered as part of production costs, and passed through to final consumers, including overseas consumers of exported products. All scenarios also assume abatement incentives are universal (motivating action in all sectors), and uniform (applying at the same level) across all sectors in any given country or region.

This approach and the use of marginal abatement costs to motivate emission reductions in the model is widely used across all computable general equilibrium modelling, and other types of economic models, to assess different options for reducing greenhouse gas emissions.

To represent this context in the model, the assumptions for the Plan scenario include capping the marginal abatement incentive in Australia, so that it rises to no more than $25/t CO_2-e in 2050, which is less than the cost of voluntary action observed today. In this scenario, the modelled marginal abatement incentive rises to $24/t CO_2-e in 2050, with all actions that reduce emissions and cost less than $25/t CO_2-e assumed to be implemented in the analysis. These actions are entirely voluntary.

The level of abatement incentive in all other scenarios with a 2050 target are determined by the model (rather than being capped by assumption), and range from $80/t to $400/t in 2050. This level of incentive is interpreted as being higher than could be achieved through voluntary action alone, and thus would require some form of government impost (such as a tax) or regulation.

Establishing the context: A world on track to below 2°C, with no additional action by Australia

To understand the implications of different options, the GTEM modelling begins by establishing the context: a world on track to limit warming to below 2°C, in which Australia has not set a target to achieve net zero by 2050. This scenario is used as the key reference point for assessing national and sectoral economic outcomes, and assessing different potential pathways to achieving net zero.

Shifting to a low carbon world

The modelling undertook a two-step process to establish a world on track to limit warming to below 2°C.

The first step establishes a counterfactual scenario based on pre-Glasgow policies and technology trajectories, including energy technology deployment consistent with IEA 'current polices' projections, and global population and economic growth consistent with the Intergenerational Report 2021 (as detailed in Appendix D).

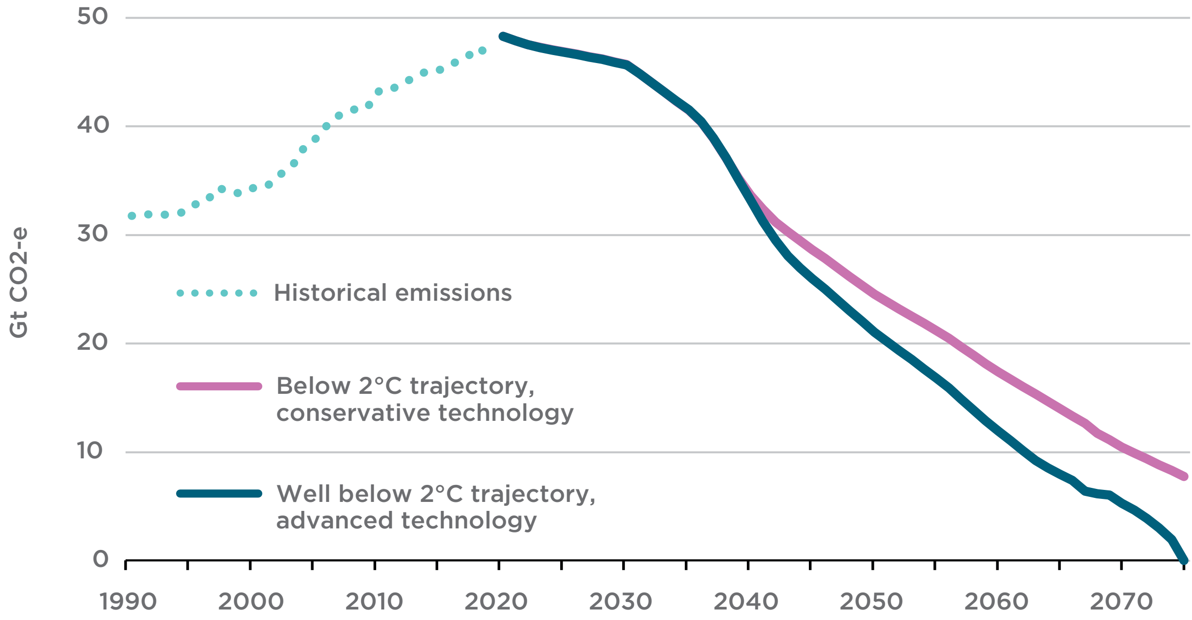
The second step models staged international action to limit global warming to below 2°C. This assumes all high income countries take on emissions budgets that track from their 2030 Nationally Determined Contribution (NDC) level to net zero in 2050, and that China tracks from 2030 baseline emissions levels to net zero in 2060, in line with its NDC. Middle income countries (other than China) take on abatement obligations from 2035, while low income countries take on abatement obligations from 2040 (see Appendix D). For consistency, the modelling assumes all countries, including Australia, implement additional abatement action to shift to this below 2°C trajectory beginning from 2031.

The modelling assumes international emissions trading, which reduces the cost of high income countries achieving their targets, while driving greater abatement in low and medium income countries, and providing them economic benefits. Access to international offsets is limited, with high income countries and regions required to reduce their domestic emissions by at least 70% by 2050, allowing them to use international offsets equivalent to up to 30% of their 2020 gross emissions in any year.

This attention to the role of emissions trading is consistent with Australia's investment of $104 million through the Indo-Pacific Carbon Offsets Scheme to develop a market for trading high-integrity offsets within our region. Expected benefits of the scheme include boosting public and private investment in climate action, providing environmental, climate adaptation and livelihood benefits for communities, and strengthening partner countries' role in setting global standards.

Figure 14 shows the global net emissions trajectories to 2075 for the core scenarios (both of which are consistent with below 2°C). The global emissions trajectory with conservative technology assumes a rapid transition from baseline emission levels in 2030 to the benchmark IPCC trajectory emissions trajectory for below 2°C (RCP2.6), which falls to net zero globally around 2090. This trajectory provides the context for the 'No Australian Action' scenario. The modelling assumes that the benefits of advanced technology are shared two thirds as lower abatement costs and one third as more rapid emissions reductions. This results in a well below 2°C trajectory, with global emissions in 2050 15% below the benchmark trajectory used for conservative technology, and falling to net zero globally around 2075. This trajectory provides the global context for 'the Plan' scenario. More details on the trajectories are provided in Appendix D.

Figure 14. Global net emissions trajectories, 2020–2075



Source: *DISER economic modelling for the Plan, see also Table 5 below for more details.*

Modelling likely costs if Australia does not set a 2050 target

In a world taking more ambitious climate action it is almost certain that Australia would face some form of global response if it did not take on a credible 2050 emissions target. This could take a variety of forms: increased capital costs for Australian governments, firms and households reflecting increased perceived financial risks; trade action against Australian exports intended to offset any competitive advantage derived from perceived weaker abatement policies; or lower demand for specific Australian products reflecting potential consumer concerns about a perceived lack of action on climate. These responses would be in addition to the impact of global technology trends and shifts in consumer preferences (in a world taking action to limit warming to below 2°C) reducing demand for Australia's traditional energy exports.

The modelling assesses the impacts of a capital risk premium, reflecting a market-driven response to higher perceived risks of investing in Australia in a scenario where Australia does not take on a credible 2050 target. Global financial institutions and policymakers have already begun taking steps to align public and private investment with Paris targets, and investor expectations and emerging technological pathways are rebalancing investment towards net zero aligned activities.

The modelling uses the impacts of this capital risk premium as a minimum estimate of likely global responses, of all forms, if Australia does not adopt a credible 2050 target. The impacts of the risk premium are included in the 'No Australian action' scenario (where Australia does not take on a 2050 target).

Treasury advised that assuming a capital risk premium between 100 and 150 basis points would appropriately reflect the kind of capital market response Australia could experience if it did not adopt a net zero by 2050 target. They noted that a risk premium of 300 basis points could be possible in a circumstance where Australia is the only developed country not to adopt a net zero target. Consistent with Treasury advice (included at Appendix E), the modelling assumes capital markets impose a 100 basis point (1%) premium on top of current financing costs. The risk premium is imposed from 2031, at the same time the world shifts to its new below 2°C global emissions trajectory. Treasury reviewed the implementation and approach taken and confirmed they consider the macroeconomic results from DISER's implementation of a capital risk premium to be credible and reasonable. More details are provided in Appendix E, and under Key Findings 3.1 and 3.2 below.

Key findings

1. Reducing the cost of low emissions technologies can provide net benefits to Australia and put us within reach of net zero emissions by 2050

The first key finding is that successful global deployment of advanced technology would provide net economic benefits for Australia, and create a practical path to achieving net zero emissions.

Methods and inputs for the analysis of accelerated technology deployment

The economic modelling assessed the impacts and benefits of a technology-led approach by implementing contrasting conservative and advanced technology scenarios. This assessment was underpinned by three elements of the modelling, each of which are applied globally across all sectors.

First, the modelling uses a new version of GTEM with an explicit hydrogen sector, which makes hydrogen available as a potential energy input for transport and industry. This version of GTEM is used to model all the scenarios. The default hydrogen sector is not cost competitive, and remains dormant in the conservative technology scenarios. The advanced technology scenarios assume lower hydrogen production costs make hydrogen cost competitive, with the reduction in costs calibrated to result in Australian and world production volumes that match the IEA 2°C sustainable development scenario (see Appendix D). This approach acknowledges significant uncertainties around the range of future technology costs, and allows the modelling results to be benchmarked and interpreted in light of the IEA scenarios and other studies with similar production volumes. The approach treats Australian hydrogen production volumes as an assumption, with the modelling providing results and findings in relation to economic impacts and differences in emissions, given this assumed volume.

Second, in the advanced technology scenarios GTEM's sector-level marginal abatement functions (also referred to as MAC curves) for non-energy emissions are adjusted to reflect the additional abatement from a successful technology-led approach. These adjustments were informed by McKinsey's analysis for the LETS 2021, and other sources. Consistent with the focus of the technology priorities on delivering low cost solutions, the adjustments double Australian economy-wide abatement at low levels of incentive (from 7% to 15% at \$25/t CO_2-e), and have a relatively smaller impact at higher levels of incentive (see Table 14 Appendix C). No other changes were implemented to abatement functions and processes. The conservative technology scenarios use pre-existing GTEM abatement functions and processes. Both advanced and conservative technology settings include learning by doing for new technologies, which reflects how technology costs decline with the scale of technology deployment.

Last, the modelling assumes the benefits of advanced technology are shared two thirds as lower abatement costs and one third as faster emissions reductions (see Figure 14 above), reflecting how falling technology costs drive more rapid deployment.

1.1 Advanced technology, including hydrogen, creates economic opportunities and accelerates emissions reductions, both domestically and globally

Given this approach, the modelling finds that success in making new technologies globally accessible and affordable would help achieve faster global emissions reductions, with lower costs and economic impacts, compared to a business as usual technology scenario.

The modelling finds that advanced technology reduces the economic impact of Australia achieving the 2050 target by more than two thirds, and reduces the cost of international offsets purchased through emissions trading by more than 40% in 2050, all else equal. Along with these lower costs, more rapid emissions reductions would see Australian and global emissions around 10% lower in 2050. These additional emissions reductions put the world on track to achieve net zero emissions globally more than a decade earlier than would occur otherwise.

The benefits of advanced technology for Australian economic growth and export industries are discussed in more detail in key finding sections 3.1, 3.2 and 3.4 below.

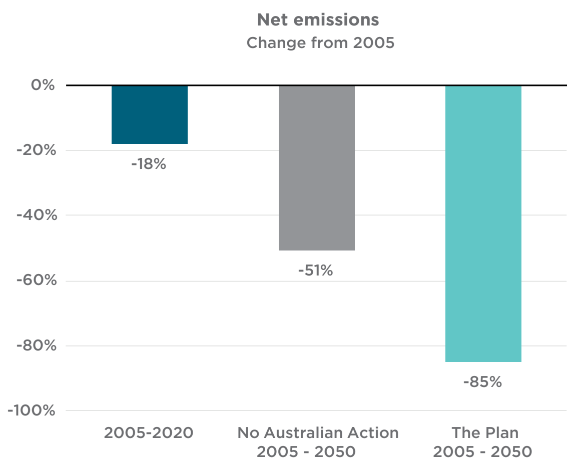
2. There are a range of pathways to delivering the reductions needed to achieve net zero emissions

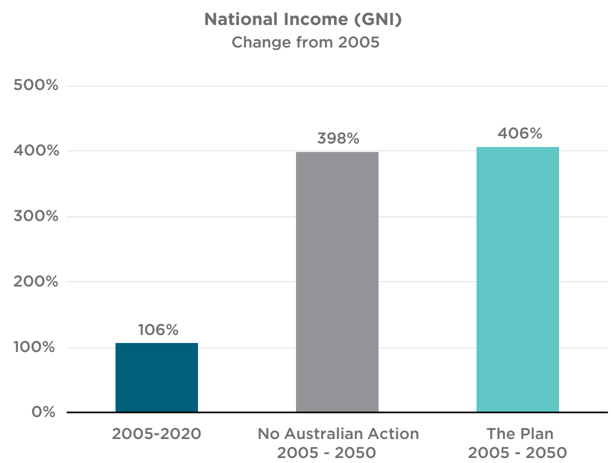
The second key finding is moving to net zero emissions by 2050 is practical, and can be achieved in a variety of ways. This finding draws on multiple lines of evidence, as set out in Key Finding 2.1 below. The consequences and impacts of achieving net zero are set out under Key Findings 3 and 4, while the implications of different options and pathways are set out under Key Finding 5.

2.1 Australia can achieve net zero emissions by 2050 with strong economic growth

The economic modelling finds Australia can achieve significant reductions in net emissions while continuing to achieve strong trend economic growth and rising national income. As shown in Figure 15, net emissions in the No Australian Action scenario are projected to trend down to 316 Mt CO_2-e in 2050, which is about 50% below 2005 levels. This contrasts with reductions that leave only a 15% gap to net zero by 2050 in the Plan, achieved through a combination of emissions reductions, land sector sequestration, and international offsets. Notwithstanding these falls in emissions, national income rises, to be around 400% higher than 2005 levels in 2050 across both scenarios. Avoiding the capital risk premium and implementing advanced technology (including hydrogen) boosts national income by 1.6% in 2050, relative to the No Australian Action scenario, equivalent to around $2,000 per person in today's dollars.

Figure 15. National emissions and national income with and without a net zero target, core scenarios, 2020-2050





Notes: *Net emissions account for the use of international offsets. Reductions in gross emissions occur in response to multiple factors, and do not follow the same trajectory as net emissions.*

Source: *DISER economic modelling for the Plan, DISER Emissions Projections 2021 and ABS (Australian System of National Accounts).*

In the scenario for the Plan, Australian gross emissions fall to 253 Mt CO_2-e in 2050. This is 371 Mt CO_2-e lower than 2005, and 105 Mt CO_2-e lower than 2050 emissions in the No Australian Action scenario. Along with negative emissions from Bioenergy with Carbon Capture and Storage (BECCS), this scenario offsets 17 Mt CO_2-e through accredited soil carbon, 10 Mt CO_2-e through other domestic land sequestration, and 94 Mt CO_2-e from international offsets in 2050. Net emissions in 2050 are 94 Mt CO_2-e, leaving a 15% gap to be closed through further technology breakthroughs or by overachieving abatement through existing technology priorities, relative to the assumptions in our modelling. For example, the Plan (Commonwealth of Australia, 2021b, p. 56) explains the potential abatement that could be available from soil carbon ranging from 35 Mt CO_2-e to 103 Mt CO_2-e per year, where the formal modelling and analysis used a more conservative contribution from soil carbon (around 17 Mt CO_2-e in the Plan scenario).

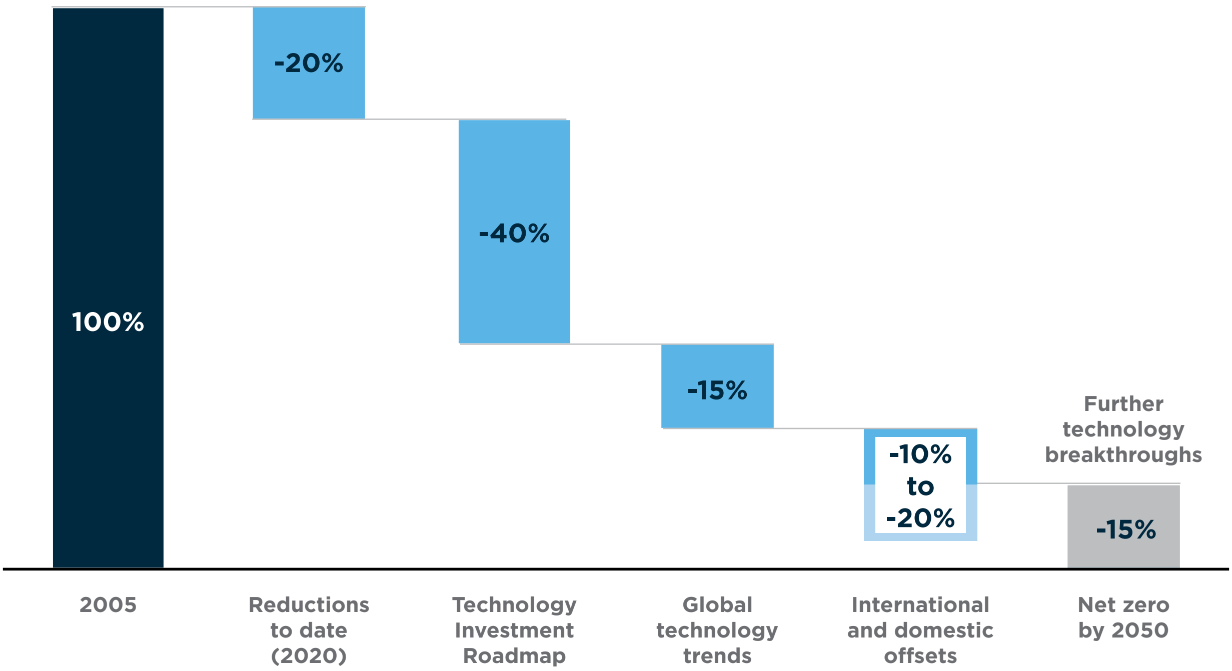
These GTEM findings are broadly consistent with the outcomes, at an economy-wide level, of the scenario modelled by McKinsey. In McKinsey's scenario, technology improvements and a marginal abatement incentive of $25/t CO_2-e could enable Australia's gross emissions to fall to 164 Mt CO_2-e in 2050, and net emissions to fall to 111 Mt CO_2-e in 2050, 82% below 2005 levels. Net emissions include 53 Mt CO_2-e of domestic offsets assumed to be available at the $25/t CO_2-e marginal abatement incentive. McKinsey results do not include the use of any international emissions trading.

2.2 Multiple lines of evidence find that net zero by 2050 is achievable

Analysis undertaken for Australia's Plan illustrates there are a range of technology pathways that could put Australia on a trajectory to net zero emissions by 2050. Top-down economic modelling and bottom-up technology analysis by McKinsey come to similar high level findings, such as the central role of low emissions electricity and electrification of road transport, notwithstanding differences in aspects of the detailed results. Taken together these different methods of analysis provide robust support for the conclusions that technology can underpin deep cuts in emissions across all sectors of the economy, and that complementary measures, such as modest levels of land sector sequestration and regional offset trading, put us within range of net zero.

Figure 16 shows the Department's best estimate of the likely shares of abatement from different sources under the Government's net zero plan, drawing on multiple lines of evidence. Table 2 below summarises the results from the McKinsey analysis and DISER economic modelling of the Plan that informed these estimates. In some cases the Department felt confident in the higher ends of the ranges, in others the Department took the more conservative end. As shown in the table, emissions are projected to fall across all sectors by 2050. Further, technology enables emissions intensity to improve across all sectors, meaning that emissions fall even as sectors grow and increase their output. An important difference is that the McKinsey analysis did not include the potential use of international offsets, which GTEM finds to be a cost effective source of abatement in a world on track to well below 2°C.

Figure 16. The path to net zero emissions



Notes: *Chart shows DISER best estimates of abatement contributions, drawing on McKinsey analysis, DISER economic modelling for the Plan, and DISER analysis for the 2021 Low Emissions Technology Statement. Domestic and international offsets include accredited soil carbon, and could provide up to 20% of abatement, depending on the extent of further technology breakthroughs and voluntary demand for offsets. See notes for Table 2.*

Source: *DISER analysis, drawing on GTEM modelling, McKinsey analysis for the Plan, and other sources.*

Table 2 also reports projected changes in emissions intensity from the GTEM modelling, reflecting the change in emissions per dollar of output value from 2020 to 2050. For example, the emissions intensity of agriculture falls by 40%, reflecting the combined effect of a 24% reduction in emissions from 2020 (see Table 6) and a 29% increase in the value of agricultural output over the same period (see Figure 20).

Table 2. DISER estimates and McKinsey and GTEM findings on abatement to 2050

	Abatement contribution			Change in sector emissions level		Change in intensity
	Share of total reduction from 2005 levels			*Sector reduction from 2005 to 2050*		*From 2020 to 2050*
	Best estimate	McKinsey	GTEM	McKinsey	GTEM	GTEM
Reductions to date	**20%***	**15%**	**18%**			
Technology investment roadmap	**40%**	**37%**	**17-42%**			
Electricity		28%	8-25%	97%	91%	96%
Industry, mining and manufacturing		3%	8-10%	54%	18%	54%
Transport (e.g. hydrogen)		5%	2%	N/A	N/A	N/A
Negative emissions from BECCS		N/A	0-6%	N/A	N/A	N/A
Global technology trends	**15%**	**26%**	**10-32%**			
Transport (e.g. electric vehicles)		12%	3-7%	71%	53%	79%
Agriculture		2%	3-4%	29%	36%	40%
Other abatement		11%	Up to 24%	N/A	43%	N/A
Domestic and international offsets	**10% or more**	**4%**	**15-20%**			
Soils and land use		4%	0-5%	N/A	N/A	N/A
International offsets		N/A	15%	N/A	N/A	N/A
Further technology breakthroughs	**15%**	**18%**	**13-15%**			
Total reduction	**100%**	**100%**	**100%**	**82%**	**85%**	

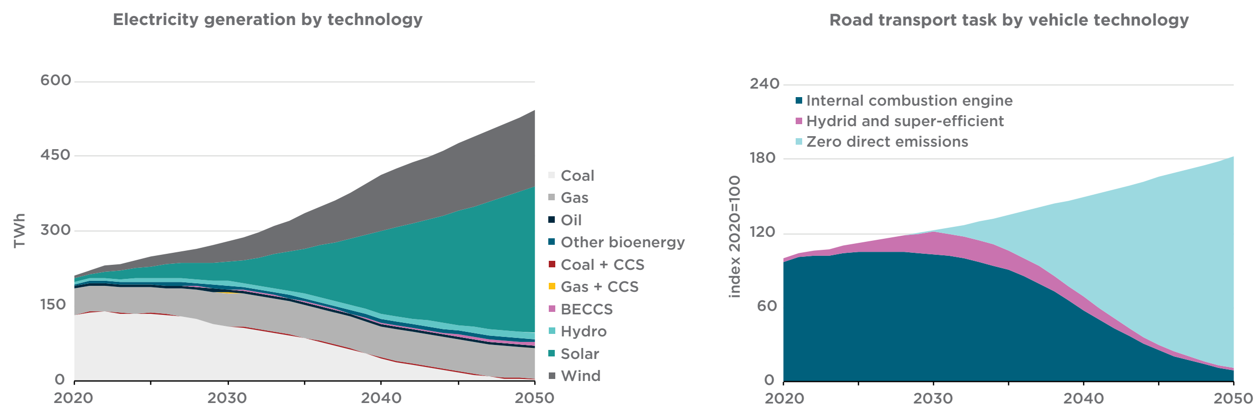
Notes: **The best estimate of emissions reductions to date reflects actual emissions reductions from the latest National Greenhouse Gas Inventory. Estimates for reductions to date by McKinsey and GTEM were completed before this data was available. McKinsey calculations reflect a 2019 base year and global warming potential (GWP) values from the IPCC's 4th Assessment Report. Best estimate based on DISER analysis of multiple lines of evidence, accounting for the strengths and weaknesses of each method, rounded to the nearest 5%. This includes economic modelling, analysis by McKinsey and analysis undertaken by DISER for the 2021 Low Emissions Technology Statement. Industry, mining and manufacturing includes stationary energy (including gas use in buildings), industrial emissions and fugitives. BECCS is bioenergy with carbon capture and storage. While soil carbon has been prioritised under the Technology Investment Roadmap, it is included here under domestic and international offsets because it is a negative emissions technology and so contributes to the 'net' outcome rather than gross emissions reductions. Other abatement results for McKinsey include various abatement activities across buildings, industry, mining and oil and gas sectors. The range of GTEM abatement contributions reflects two methods to assess contributions: (i) attributing abatement by each sector to the most closely aligned high level abatement category; (ii) attributing all emissions reductions achieved in the No Australian Action scenario to 'other abatement' under global technology trends, and all additional abatement for each sector to the most closely aligned high level abatement category. The upper end of the GTEM range for soils and land use assumes landholders receive voluntary payment at the global market price, providing an additional 2% of abatement relative to projected outcomes for the Plan. Detailed GTEM projections of emissions by sector are provided in Table 6 Appendix A. The column on the right reports the change in emissions intensity, defined as gross emissions per dollar of sector output value, from 2020 to 2050. Gross emissions in the Plan scenario fall by 60% from 2005 to 2050, and emissions intensity falls 91%. Columns may not sum due to rounding.*

Source: *DISER and McKinsey analysis for the Plan.*

2.3 Electricity and transport are projected to substantially decarbonise, even under current trends.

The modelling finds that all sectors can contribute to Australia achieving its net zero target. In particular, the modelling projects that electricity and road transport will substantially decarbonise by 2050 under the Plan. As shown in Figure 17, electricity generation in 2050 is projected to be around 2.6 times 2020 levels, with variable renewables accounting for about 80% of generation. The share of vehicles with zero direct emissions is projected to grow strongly, from less than 1% to around 90%, resulting in road transport emissions falling by more than 70% by 2050 as the number of vehicles and total passenger kilometres grows. Average whole-of-system electricity costs are stable, per unit of output, from 2020 to 2050. In combination with improved energy efficiency, this is projected to result in lower energy bills for households and businesses.

Figure 17. Electricity generation and road transport by technology under the Plan, 2020-2050



Notes: *The right hand panel shows the index of the aggregate transport task, including freight and passenger transport.*

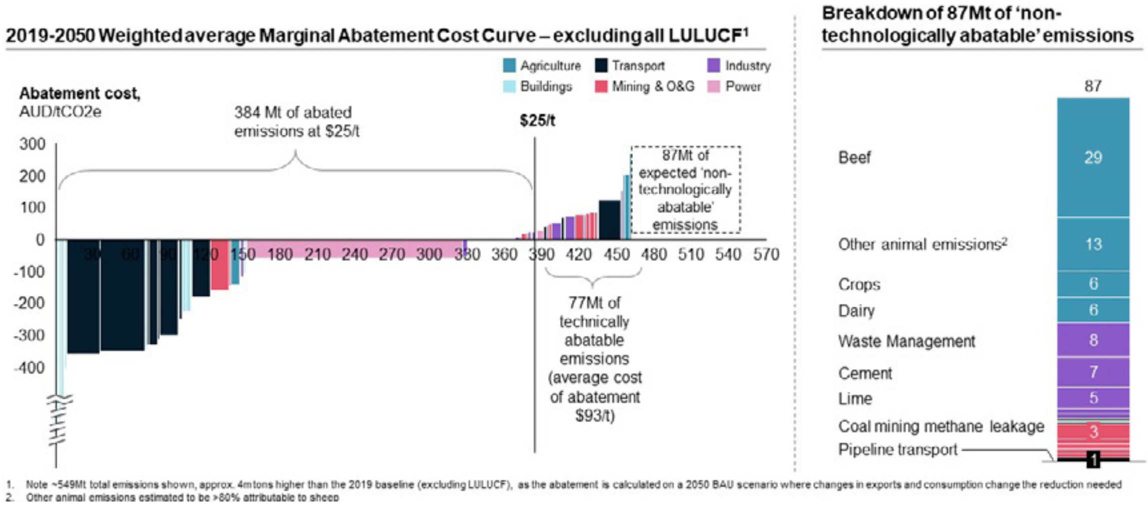
Source: *DISER economic modelling for the Plan.*

The scenario modelled by McKinsey reinforces that there are different technology pathways Australia could follow to achieve its net zero emissions by 2050, as shown in Figure 18 (see Box B3 for an explanation of methodology). In this analysis, technology improvements and a marginal abatement incentive of \$25 per tonne CO_2-e could enable Australia's gross emissions to fall to 164 Mt CO_2-e in 2050. Similar to GTEM, McKinsey projects that electricity emissions will decline by around 95% on 2005 levels by 2050, however the McKinsey analysis finds deeper emissions reductions could be achieved by industry (54% reduction by 2050, compared with 18% under GTEM) and transport (71% reduction by 2050, compared with 53% under GTEM). In part, this is the result of a high degree of electrification in the road transport and industrial sectors. In McKinsey's analysis, all road transport is expected to have either electrified or shifted to hydrogen by 2050. Electrification is also expected to occur across a range of applications in industry, mining and manufacturing, as well as gas use in buildings. A higher degree of electrification, combined with clean hydrogen production using renewable electricity, means that electricity generation by the power sector increases six-fold between 2020 and 2050.

These differences in detailed findings demonstrate the value of using complementary analytical approaches. The more granular McKinsey technology analysis finds larger abatement potential from technology investment roadmap priorities than the more stylised abatement mechanisms in GTEM, which instead find larger abatement from wider global technology trends and from harnessing emissions trading to unlock abatement potential in low and medium income counties. The differences also reflect, in part, that GTEM projections are likely to overstate the uptake of renewable electricity in Australia under conservative technology (without additional innovation to deal with storage and reliability issues), which results in some electricity abatement being allocated to 'global trends' rather than to advanced technology in Table 2 above.

McKinsey's bottom-up analysis highlights the challenges some sectors will face in reducing emissions, given existing and known prospective low emissions technologies. McKinsey has identified 87 Mt CO_2-e of 'non-technologically abatable' emissions, primarily in the agriculture and industrial sectors. These relate to both the absence of suitable technologies and practical issues with known technologies, such as challenges in delivering livestock feed supplements to geographically dispersed grazing cattle. Offsets could play an important role in addressing these emissions. In the scenario analysed by McKinsey, domestic offsets available at up to $25/t CO_2-e mean net emissions could fall to 111 Mt CO_2-e in 2050, 82% below 2005 levels. McKinsey did not include voluntary purchases of offsets from regional partners in this analysis.

Figure 18. Weighted average Marginal Abatement Cost Curve (excluding LULUCF)



Source: *McKinsey*

The marginal abatement cost curve (Figure 18) illustrates that a significant portion of the abatement up to $25/t CO_2-e up to 2050 is delivered for a net benefit (negative cost). Under the Emissions Reduction Fund (ERF), this type of activity would not be eligible without proof that it was 'additional'. This is because the Government does not want to spend taxpayer's money on action that would be likely to occur on its own. In the analysis for the Plan, all of the abatement action below $25/t CO_2-e is assumed to occur voluntarily. Voluntary action is assumed to be supported by government, either through an ERF-style incentive to overcome upfront costs or through other enabling roles to unlock negative cost actions, such as by providing information to consumers about energy efficiency, supporting transparency in markets (for example, the Hydrogen Guarantee of Origin scheme), or by investing in infrastructure. No abatement actions that cost more than $25/t CO_2-e are assumed to be taken up in the modelling and analysis.

It has already been demonstrated under the systems established for the ERF, that private buyers in Australia are voluntarily offsetting their emissions for prices significantly higher than the assumed voluntary incentive, with prices above $30/t on the spot market. This shows that the private sector is willing to reduce emissions (up to this level of cost and voluntarily incur a cost in doing so), either by taking action to reduce their emissions themselves (not in any market) or by approaching the market for emissions offsets up to this cost.

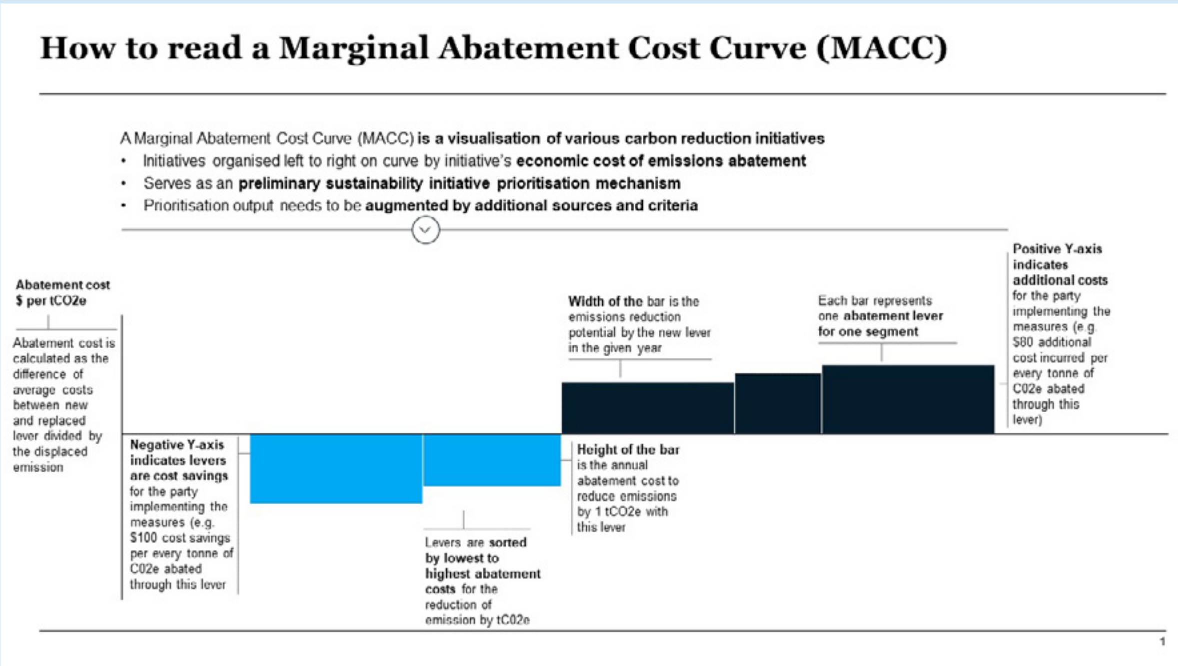
Box B3: Decarbonisation pathway analysis by McKinsey

McKinsey based their analysis on their extensive research on decarbonisation pathways globally and locally, across different geographies, sectors and technologies. The analysis includes proprietary perspectives on technology cost developments and input cost trends across a library of 450+ decarbonisation levers, a selection of which were used for the analyses for the Plan.

The McKinsey decarbonisation pathway for Australia was first published in 2008 – which included the first marginal abatement cost curve (MACC) for Australia. Since then, the analysis has been refreshed several times, including in 2019 and the latest version in 2021, which incorporate the latest global technology developments in all relevant sectors and recent analysis performed for the Australian Government to inform the LETS 2021, particularly on the costs of hydrogen, energy storage and low emissions steel production.

Sectors that are particularly impacted by global trends are hydrogen, electric vehicles and heat-pumps for HVAC – where recent global trends supported by investment in China, the EU and the US have rapidly reduced costs of new, low-emissions equipment. A final critical global trend is reduced demand for fossil fuel commodities, which is reflected in this analysis.

The analysis incorporates McKinsey's proprietary electricity sector modelling, which includes all relevant capacity plans and targets for the National Electricity Market, including various state-based targets with concrete delivery mechanisms and transmission constraints, and scales it on a proportional basis to the rest of the electricity sector nationally. Technology costs in the power sector reflect costs in the AEMO ISP 2022. Further McKinsey's modelling includes legally required reductions (i.e., HFC reductions under the Montreal Convention), LULUCF potential that can be achieved with a $25/t CO_2-e incentive payment to landowners as provided by DISER, and an assumption (provided by DISER, to allow triangulation with the GTEM modelling) of a universally adopted marginal abatement incentive of $25/t CO_2-e. The analysis also assumes that all "NPV positive" levers (e.g., building upgrades, electric vehicle adoption and substitution of hydrogen for certain industrial uses) are adopted fully, regardless of any non-economic barriers.



3. Adopting a target of net zero emissions by 2050, with a credible plan to achieve it, provides economic benefits to Australia

The third key finding is that adopting and achieving a 2050 target provides net economic benefits to Australia, with accelerated global and Australian deployment of advanced technology providing additional benefits.

3.1 Global responses would have significant economic impacts if Australia does not adopt a net zero target

The modelling finds that global responses (modelled as a capital risk premium) could have significant economic impacts if Australia does not adopt a credible 2050 target.

The Treasury analysis undertaken as an input to the modelling finds that some form of global response is almost certain if Australia does not commit to a 2050 target in a world taking more ambitious action.

While this could occur in a variety of ways, the modelling uses the impacts of a capital risk premium as a minimum estimate of likely global responses or retaliation, across all forms. The risk premium can be interpreted as a market-driven response to higher perceived risks of investing in Australia in a scenario where Australia does not take on a 2050 target. This is represented by the imposition of a capital risk premium of 100 basis points across all sectors, and mimics the way in which financial markets typically bring forward the impacts of changes in future returns. More details and results are provided in Appendix E, and Figure 19 below.

The modelling finds that the risk premium reduces investment in Australia by an average of 5.5% over the period to 2050, reducing productivity growth. Lower wages and returns to capital flow through to lower economic growth and national income, with an early peak impact of around 0.9% of GDP and GNI, which declines to 0.5% in 2050. (These impacts are assessed relative to a background conservative technology scenario with 2°C global action and no 2050 target, but no capital risk premium on Australia.)

The analysis does not consider potential additional types of global responses or retaliation that might occur if Australia does not take on a target before 2050, such as Carbon Border Adjustment Mechanisms (CBAMs) or other trade-related actions, or potential non-price related shifts in demand for Australian goods and services.

3.2 Adopting a net zero emissions target for 2050 provides net economic benefits, with advanced technology and hydrogen providing additional benefits

The economic modelling finds that adopting a net zero by 2050 target, supported by Australian and global action consistent with the Government's technology-led approach, provides net economic benefits totalling about $2000 per person in 2050 relative to the No Australian Action scenario.

Benefits of the Plan scenario compared to the 'No Australian Action' scenario have three main drivers:

First, successful deployment of advanced technology provides benefits from higher global economic growth due to lower global abatement costs. Second, benefits are derived from the creation of a new cost-competitive global hydrogen sector. Finally, the target, together with a plan to achieve it, avoids the capital risk premium on Australian investors and firms experienced in the 'No Australian Action' scenario, and there are significant benefits as a result. (The impacts of the capital risk premium and the target are shown separately in Table 8 and Table 9 in Appendix A.)

The modelling finds the avoided capital risk premium increases national income (GNI) by over $400 per person in 2050, and the value of national economic activity by over $600 per person, relative to the No Australian Action scenario, as shown Figure 19.

In addition, the modelling finds, the creation of a new cost-competitive global hydrogen sector would provide substantial economic benefits to Australia. Assuming global efforts are successful in reducing production costs, Australian hydrogen production could be worth more than $50 billion in 2050, in a world on track to limit climate change to well below 2°C, lifting national income by about $1,000 per person in addition to the other benefits of advanced technology and avoided capital risk premium.

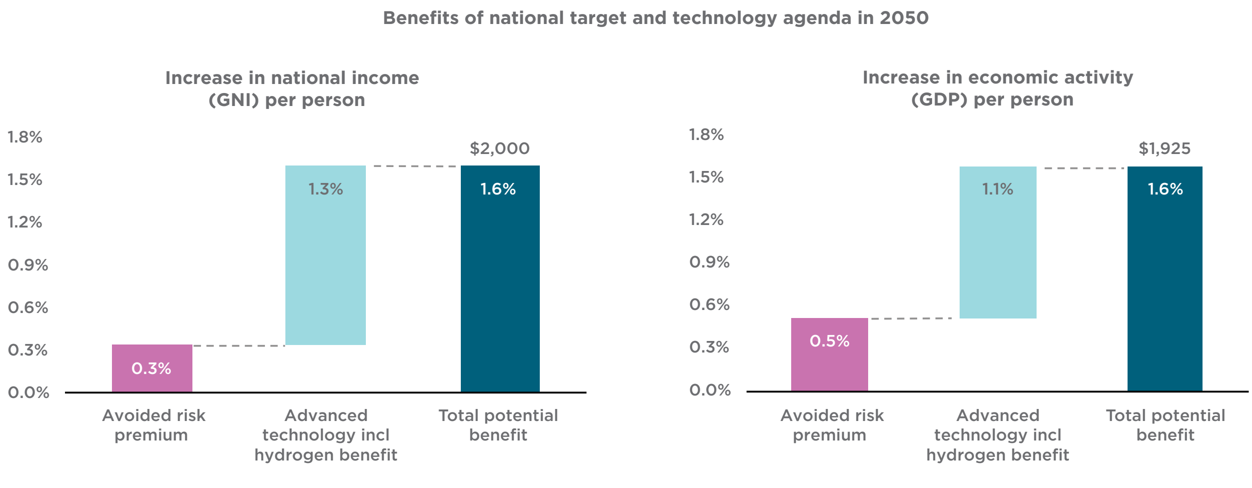
Global deployment of lower cost low emissions technology boosts global economic growth, relative to a conservative technology world. This higher growth boosts demand for Australian exports, feeding through to higher Australian national income and economic growth (see Box B4 below). Lower abatement costs in Australia also lift national income and economic growth, over and above the global growth effect, as shown in Table 8 in Appendix A.

Together advanced technology increases national income (GNI) by almost $1,600 per person in 2050, and the value of national economic activity by around $1,300 per person, relative to the No Australian Action scenario.

While total impacts – and benefits – are similar, effects on GDP and GNI occur through different channels, and have different drivers. The avoided capital risk premium has a larger impact on economic activity (than national income) because avoiding the risk premium boosts investment, and thus boosts productivity. Advanced technology reduces the economic impacts of global action (effecting both GDP and GNI), but provides additional benefits to national income (GNI) by reducing the global price of international offsets. (Appendix A provides more information, including a decomposition of the effects of different scenarios on real GDP and GNI in Table 10.)

Hydrogen benefits are reported separately as the results are contingent on achieving substantial reductions in production costs, and the CGE modelling of hydrogen-based energy relationships is relatively novel. It is important to note, however, that the finding that adopting and achieving a target of net-zero emissions by target (supported by focusing on advancing technology) provides net economic benefits does not rely on the additional benefits associated with hydrogen. Australians are expected to be better off under the Plan, even if hydrogen impacts are not included.

Figure 19. Economic benefits of the Plan vs No Australian Action scenario in 2050



Notes: *Economic outcomes in the Plan assessed relative to the No Australian Action scenario, drawing on additional sensitivity analysis scenarios for the impacts of hydrogen, advanced technology generally, and the impacts of the 2050 target without a global risk premium. $ impacts larger than $100 are rounded to the nearest $25. Hydrogen represents approximately $1,000 of the total advanced technology benefits for both GNI and GDP.*

Source: *DISER economic modelling for the Plan.*

Economic co-benefits of technology adoption

McKinsey's analysis also highlights many of the economic co-benefits that could arise as Australia adopts and integrates new technologies, in line with its net zero target.

McKinsey analysis suggests that technology could enable economy-wide energy productivity improvements over the next 30 years, with energy consumption per dollar of GDP falling by half in per capita terms by 2050 (from 54 PJ/$GDP per capita to 27 PJ/$GDP per capita). This is substantially driven by the projected substitution of largely imported oil for domestically produced electricity in the transport sector. This would increase Australia's energy self-sufficiency from 53% to 88% and help reduce the cost of Australia's energy as a share of GDP from 8% to 2%.

Box B4: Improved global technology boosts economic growth

The modelling finds advanced technology improves productivity and lowers global production costs in industries covered by the Technology Investment Roadmap, including hydrogen, relative to a below 2°C scenario with conservative technology. These lower global production costs increase output of these industries in Australia and elsewhere, increasing the demand for capital and labour in Australia and, with it, Australian factor incomes and investment. This increase in investment is reinforced by avoiding the capital risk premium that is applied to Australia in the No Australian Action scenario.

Increased factor incomes and higher productivity from increased investment together lift the value of economic activity (real GDP), to be 1.6% higher in 2050, relative to the No Australian Action scenario. Real national income (GNI) is 1.6% higher in 2050 as higher factor incomes flow through into higher consumption, driven largely by the impacts on real GDP, with minor impacts from exchange rate effects (from lower net exports) and divergence in the GDP and GNI price deflators.

More detail is provided in Table 8 below, and in Appendix A.

4. Jobs and output value grow across all major sectors to 2050, including mining

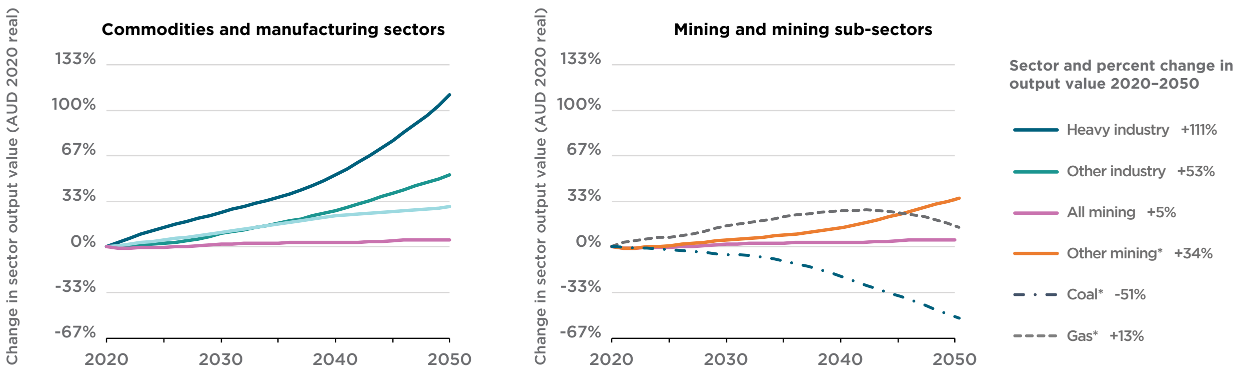
The fourth key finding is that jobs and output value grow across all major export-oriented sectors, including mining, notwithstanding reduced demand for traditional energy sources as a result of stronger global action. This is true in all of the scenarios modelled, not just the core scenarios.

4.1 Global demand for food and fibre, minerals, and energy-intensive commodities sees all major sectors grow to 2050

The modelling finds that Australian export-oriented activity continues to grow in a world on track to well below 2°C, but that the shift to a low carbon global economy affects the composition of growth across Australian sectors.

The modelling finds that all major export sectors grow to 2050, in aggregate, with the value of agriculture projected to grow around 30%, mining up around 5%, and heavy industry up around 110%, as shown in Figure 20. Within the mining sector, however, the value of coal mining is projected to decline. This shift is projected to occur over several decades, not as a sudden shock. Over time, this results in a rebalancing of the mix of mining activity as the value of gas, minerals and metal ores rise while the value of coal falls, with a net increase in the value of all mining. Other analysis, including by McKinsey, suggests slower growth or declines in the value of gas production, but also suggests the new energy economy will result in stronger growth than GTEM projects for non-ferrous metal ores and critical minerals within other mining (including for batteries and electrification).

Figure 20. Outlook for the value of export oriented sectors, the Plan scenario, 2020-2050



Notes: *Declines in coal and slower growth of gas are driven by global action. The real value of other mining increases 34%, and outweighs declines in the value of fossil fuel extraction, resulting in net growth in the value of mining to 2050. The value of agriculture does not include payments for land sequestration. The GTEM industry structure used for this project does not separately identify services export sectors, such as education or inbound international tourism. Underlying growth rates are influenced by assumed productivity growth in the baseline scenario, see Table 16, Appendix D. * represents subsectors of all mining; coal, gas and other mining are subsets of all mining.*

Source: *DISER economic modelling for the Plan.*

4.2 Low carbon technologies and supply chains create new opportunities for regional industries

The modelling finds that successful deployment of advanced technology boosts Australian economic activity and national income, relative to the No Australian Action scenario, with different impacts across key sectors.

Stronger global action on emissions reductions accelerates shifts that are already in train in energy systems, away from energy-dense traditional energy sources towards renewable energy, characterised by relatively higher capital costs and lower operating costs. Achievement of the Technology Investment Roadmap stretch goals lowers the cost of deployment, putting downward pressure on electricity prices and encouraging more rapid deployment.

At the sector level, reducing the cost of deployment of low emissions technologies creates new growth opportunities for industries and firms, particularly for electricity and heavy industry. Lower production costs (for example, the provision of very low cost bulk electricity supply through the achievement of the ultra low cost solar stretch goal) could broaden Australia's comparative advantage to include greater production and export of energy-intensive commodities, in addition to exporting energy or energy carriers (such as gas and hydrogen). This boosts projected growth in heavy industry sectors, including iron and steel, aluminium and other non-ferrous metals, pulp and paper, chemicals and hydrogen.

Australian and global efforts to create a cost-competitive hydrogen sector delivers significant benefits to Australia. The advanced technology scenarios assume reductions in production costs that result in hydrogen production increasing to 290 Mt globally, and 27 Mt in Australia, matching the projections from the IEA 2°C sustainable development scenario. Given this, the modelling finds a new Australian hydrogen sector could be worth more than $50 billion in 2050, with hydrogen increasing the value of Australian economic activity (GDP) by 0.8% in 2050 (assessed relative to a scenario with advanced technology but no global hydrogen production). This gain accounts for most of the increase in the value of heavy industry in advanced technology scenarios, relative to the No Australian Action scenario (see Figure 23 below).

4.3 Global action will impact Australian coal and gas production, regardless of the Australian Government's policies or targets

The modelling finds that global action to limit climate change reduces demand for Australian coal and gas exports, particularly coal mining, and has impacts on the Australian economy more generally.

The modelling projects the output value of coal will fall by around 50% over the long run in all scenarios. Differences in technology and the Australian policy settings explored through the modelling have little impact on coal production, which shifts to be almost entirely export oriented as the electricity sector decarbonises (see Figure 17 above). These projected impacts occur across all global action scenarios, regardless of whether Australia adopts a 2050 target.

If countries take action to achieve their 2030 and 2050 targets, there will be a corresponding reduction in the global demand for traditional energy sources. This reduced demand will impact Australian production, as Australia is a major exporter of traditional energy sources such as coal and gas. The outlook for gas is more positive, with demand projected to grow until 2040, before turning lower. This is consistent with other analyses. For example, analysis for the LETS finds that clean hydrogen (produced from gas with emissions captured and permanently stored) could support the development of early demand opportunities and position Australia to be an early global leader in hydrogen production. To inform customer choice, the government is developing a Guarantee of Origin scheme for hydrogen. The scheme will provide hydrogen customers with data on how and where the hydrogen they purchase is produced, including the quantity of carbon dioxide emissions associated with the production of each tonne of hydrogen.

The modelling finds that the impacts of more ambitious global action flow largely from slower global economic growth, which drops by around 0.1% per year, so that the global economy is 1.5% smaller in 2050 than it would be otherwise. This general growth impact is exacerbated by a global decline in the demand for traditional energy sources, particularly the use of coal, which is 23% lower globally in 2050 than it would be under pre-Glasgow trends. Together these effects result in real GDP in the No Australian Action scenario being 0.86% lower than it would be otherwise in 2050.

4.4 Under the Plan, jobs gained from new economic opportunities exceed job losses associated with changes in demand, which are outside the control of the Australian Government

McKinsey undertook supplementary analysis of the impacts and opportunities associated with Australia's net zero target and the broader global shift towards low emissions technologies. This included an assessment of energy sector jobs arising from electrification in transport and industry, as well as an assessment, drawing on sectoral production results from GTEM provided for this purpose by DISER, of employment impacts in export-related heavy industries (Box B5).

This analysis by McKinsey, drawing on GTEM production volumes, concluded that Australia's comparative advantages mean job gains can far outweigh job losses. The McKinsey analysis of GTEM volumes shows that employment impacts would be driven by changes in demand, and that at least 95% of these impacts would be the result of shifts in international demand. This impact is not within the control of the Australian Government. The positive impacts of Australia's choice to adopt a target of net zero by 2050 and the opportunities created by new clean energy industries outweigh these unavoidable negative impacts, resulting in a net gain.

Box B5: Analysis of employment impacts and opportunities in the Plan

Economic modelling for the Plan was completed using GTEM, a global CGE model that represents Australia as one of 24 countries and groups of countries. GTEM provides valuable insights into how global action to reduce emissions impacts on patterns of economic activity and energy use, and implications for trade flows. However, GTEM does not provide detailed information on sub-national impacts within Australia (associated with specific facilities or locations), and does not account for changes in labour participation. Together these limitations mean that GTEM is not well suited to provide detailed insights into employment impacts and opportunities in regionally-based mining and heavy industry in Australia.

Supplementary analysis was commissioned from McKinsey to understand employment impacts and opportunities in Australia that could arise from global and domestic climate action, with a focus on export industries. McKinsey drew on the national production output values to 2050 from GTEM for the mining and heavy industrial sectors under advanced technology scenarios and translated these production changes using standard employment-tonnage ratios. McKinsey allocated job losses and gains to regions using McKinsey's proprietary database of Australian supply curves (i.e., which show the volume of supply and the cost of supply of every productive asset in Australia for each commodity), announced projects, the cost competitiveness of regions, and announced government policy. This analysis (to 2050) using GTEM outputs was benchmarked against complementary analysis of employment impacts (to 2030) under three scenarios developed by McKinsey which varied in the pace of technology development and international action. McKinsey was ideally placed to support this work given its proprietary global supply cost curves and detailed understanding of competitiveness within key regionally based export industries, both at a sub-national level within Australia and internationally.

McKinsey's analysis of employment opportunities in the domestic energy sector was derived from the outcomes of its bottom-up decarbonisation pathway analysis with a \$25/tCO_2-e marginal abatement incentive, as discussed in Box B3.

Outlook for export-focused heavy industries

Drawing on sectoral production results from GTEM, McKinsey projected that jobs related to the production of traditional energy sources for export consumption could decline over the period to 2050, regardless of Australia's policy choices. McKinsey concluded that almost all of the negative impacts on employment (at least 95%) are driven by changes in global demand consistent with global action to achieve a below 2 degree emissions pathway, with these impacts occurring over several decades. Changes in domestic demand drive the balance of any negative impact. These impacts are not within the control of Australian industries or the Australian Government. The modelling and analysis projects these impacts would occur over several decades, not as a sudden shock, with any of these job losses more than outweighed by new job opportunities opened up through low emissions technologies.

Australia's comparative advantages – including high capacity factor renewables, abundant land, gas reserves and storage basins, mineral deposits, established infrastructure, skilled labour, strong trade relationships, and a stable regulatory environment – can create many more jobs than will be lost if Australia seizes the opportunities. These include:

- Producing and exporting the minerals needed for clean energy technologies like cobalt, copper, lithium, nickel, uranium and rare earth elements could support up to 52,000 new jobs nationally in regions including (but not limited to) southern Western Australia, the Pilbara and South Australia by 2050.
- Hydrogen production could support up to 16,000 new jobs nationally by 2050 in regions including (but not limited to) central Queensland, southern Western Australia and the Pilbara.
- The construction boom associated with new renewable energy generation to support hydrogen production could support up to 13,000 new, permanent jobs by 2050 across Australia. This is in addition to potential jobs growth in the domestic energy sector.
- Low emissions iron and alumina could support up to 18,000 new jobs nationally.

Domestic energy sector jobs

Under the decarbonisation pathway it modelled for the Plan, McKinsey projected a net employment growth of between 35,000 to 40,000 jobs related to domestic energy production. That is, 5,000 to 6,000 jobs related to the production of traditional energy for domestic consumption will have shifted into new clean energy sectors, with 40,000 to 45,000 total new jobs created overall. Under this scenario, total employment relating to domestic energy use would grow from around 89,000 in 2019 to 124,000 in 2050. Net job gains for domestic energy supply are projected to be driven by the growth in the electricity sector resulting from electrification of the transport sector and the adoption of lower cost technology. The job growth is sustained beyond the capital construction phase because an ongoing operation and maintenance cycle is expected to sustain regional jobs in domestic energy supply.

In the scenario modelled by McKinsey, job gains will be driven by Australia's domestic energy mix shifting from a heavy reliance on imported liquid fuels (around 50% of final energy consumption in 2019-20), and towards domestic renewable power (around 60% of final energy consumption in 2050). The primary driver of this substitution is the electrification of road transport.

To serve the increased electrical load, Australia will need to double the rate of renewable development to 2050. The doubling of renewable development, and the increased operations and maintenance required, will grow net domestic energy sector employment. The expenditure and employment profile for renewables is heavily dominated by the capital intensive construction phase but will shift to permanent operations and maintenance jobs over time. By 2035, when a substantial share of new renewable capacity will have been installed McKinsey estimate that more than half of renewables jobs will be ongoing operation and maintenance jobs.

Direct and indirect jobs

In total, over 100,000 new direct jobs could be created in export and domestic sectors by 2050 under the advanced technology scenario. Net regional employment in mining and heavy industry alone could grow by 62,000 – or around 76,000 when renewables for hydrogen production is included.

McKinsey has also identified further indirect job opportunities, both upstream and downstream, including:

- expanded manufacturing powered by low-cost renewable energy in regions like Geelong, the Hunter Valley and the Pilbara
- new upstream energy generation manufacturing like wind turbines and hydrogen electrolysers, which could support jobs in existing industrial areas like Geelong, the Hunter Valley and the Illawarra
- new downstream value-adding manufacturing like the production and export of green ammonia and hot briquette iron, which could support jobs in Central Queensland, Gladstone, the Hunter Valley and the Pilbara.

4.5 There are additional benefits from coordinated global action to reduce emissions and avoid global warming

GTEM does not account for the effects of avoided climate change as a result of more ambitious global action to reduce emissions, implying that it will overstate the costs and understate the long term benefits of moving to a lower global emissions trajectory. This reflects GTEM's current structure and dynamics, which do not account for the impacts of climate change or variability.

5. Alternative approaches to achieving net zero involve additional costs and risks

The modelling explored a range of potential pathways for achieving net zero emissions by 2050 to assess the costs, risks, and benefits of different options. This included the two core scenarios (No Australian Action and the Plan) and additional scenarios with advanced and conservative technology.

The modelling uses additional scenarios explore multiple pathways to net zero

In addition to the core scenarios discussed above (see page 27), the analysis of options for achieving net zero draws on insights from four further scenarios:

Net zero emissions assuming conservative technology, with domestic and international offsets (NZE with offsets) – Australia takes emissions all the way to net zero in 2050, with business as usual technology trends, and the use of domestic and international offsets. The modelling assumes limited emissions trading, with high income countries required to reduce their domestic emissions by at least 70% from 2020 levels. Countries are able to offset only up to 30% of 2020 emissions in 2050 using international offsets. This limit binds in Australia a few years before 2050 (including 2050) in this scenario, bidding up the price paid for land sequestration (to secure additional units) which drives additional reductions in gross emissions, resulting in an economy-wide marginal cost of $100 in 2050. The global context is a world on track to below 2°C, with a global marginal cost of abatement rising to $80/t CO_2-e in 2050. The domestic price is higher than the international price because of the limit on emissions trading. Hydrogen does not emerge at scale in the conservative technology scenarios.

Net zero emissions with no international offsets (NZE no trade) – Australia takes emissions all the way to net zero in 2050, with business as usual technology trends (conservative technology) and the use of domestic offsets, but no use of international emissions trading. The larger volume of domestic offsets required bids up the economy-wide marginal cost of abatement to $170/t CO_2-e in 2050, and results in 7% of Australian agricultural expansion being withdrawn from traditional agricultural production. The global context matches the NZE with offsets scenario.

Net zero emissions with no offsets (NZE no offsets) – Australia takes emissions all the way to net zero in 2050, with business as usual technology trends (conservative technology), but no use of additional land sequestration or any international offsets from emissions trading. This results in the economy-wide marginal cost of abatement rising to $400/t CO_2-e, the assumed cost of Direct Air Capture, a negative emissions technology which serves as a backstop technology in GTEM. This occurs shortly after 2040. The global context matches the NZE with offsets scenario.

Forcing emissions all the way to net zero under advanced technology (NZE 100%) – Australia forces its emissions to net zero in 2050, under the advanced technology scenario without increasing the volume of international offsets used under the Plan. International offsets are limited, by assumption, to the same level as the Plan to facilitate comparisons, and to demonstrate the impact of increased abatement. Achieving net zero emissions in this scenario requires a larger volume of domestic offsets, bidding up the price paid for land sequestration, resulting in an economy-wide marginal cost of $80/t CO_2-e in 2050 and additional negative impacts on coal and gas production, and an expansion in the area of land required for on-farm plantings. The global context is a world on track to well below 2°C, with hydrogen production in line with IEA projections. The global marginal cost of abatement is $40/t CO_2-e in 2050.

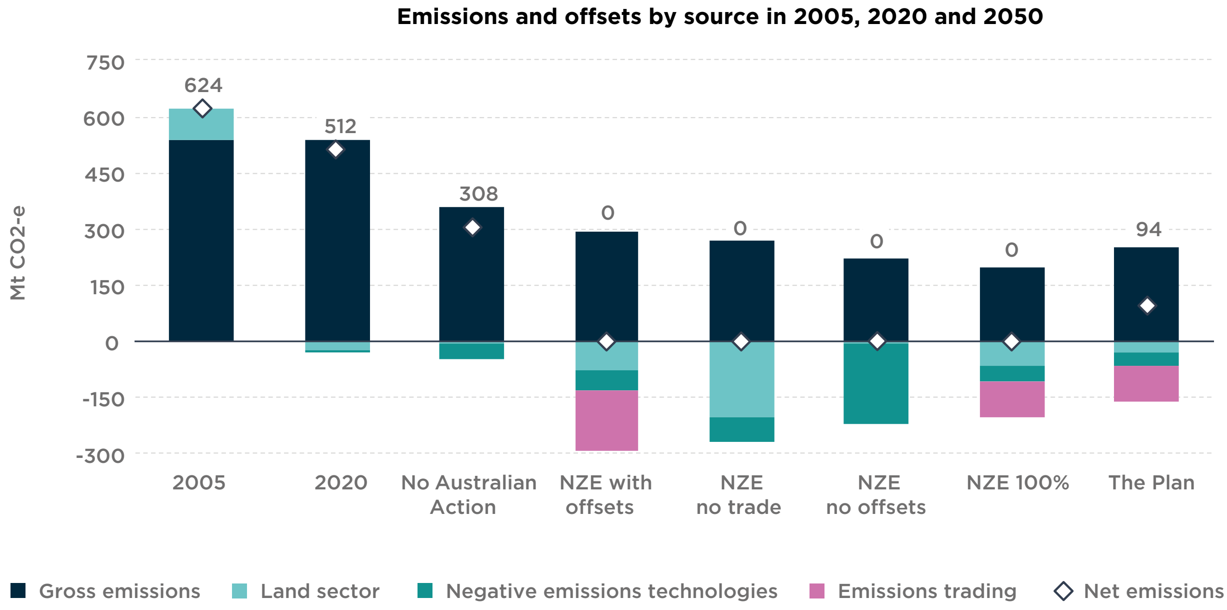
These additional scenarios provide insights into a range of potential pathways to achieve net zero emissions by 2050, and the consequences associated with these.

Australia's gross emissions in the No Australian Action scenario are projected to fall to 43% below 2005 levels by 2050. Across the scenarios where Australia takes action, gross emissions are 18-44% (up to 158Mt CO_2-e) lower than in the No Australian Action scenario. (Emissions by source are also reported in Table 6 in Appendix A).

The McKinsey cost curve analysis assessed a different NZE scenario to the DISER modelling, using different assumptions. McKinsey's cost curve analysis found 460Mt of gross emissions abatement (relative to Government's 2005 baseline) could be achieved with using levers expected to cost less than $25/t CO2-e. The analysis found that net zero emissions could be achieved with 77Mt of additional abatement (using levers expected to cost more than $25/t) at a weighted average abatement cost of $93/t CO2-e. This also requires 87Mt of land sector offsets (at a cost of up to $80/t CO2-e) to offset emissions which currently are not technically abatable. It did not include international offsets.

The different combinations of options used to achieve these emissions outcomes have different consequences for abatement costs, land use, and reliance on international offsets, as summarised in Table 3 below.

Figure 21. Emissions and offsets by source, 2005, 2020 and 2050



Notes: *The modelling assumes a minimum deployment of negative emissions technologies (bioenergy with carbon capture and storage - BECCS) in all below 2°C scenarios, including No Australian Action. Data for this figure is provided in Table 6 below. Scenario assumptions are set out in Table 5 and in text in Appendix A.*

Source: *DISER economic modelling for the Plan.*

Table 3 Summary of key scenario outcomes in 2050

		No Australian Action	The Plan	NZE 100%	NZE with offsets	NZE no trade	NZE no offsets
Marginal abatement incentive	$	$2	$24	$80	$100	$170	$400
Residual emissions before offsets vs 2005	Mt	316	215	157	239	205	3
Agricultural land removed from traditional production**		0.0%	0.0%	0.0%	0.1%	7.2%	0.0%
Area of on farm plantings (cumulative to 2050)	Mha	0.14	0.31	1.50	3.52	10.03	0.15
International offsets***	Mt	NA	-94	-94	-161	0	0
Net emission vs 2005		-51%	-85%	-100%	-100%	-100%	-100%

Notes: *Marginal abatement incentives above $40 are rounded to the nearest $10.*
*** Land withdrawn from agriculture shown as percentage of the 78.8 million hectares (Mha) agricultural use zone, which does not include savanna or land in the arid zone.*** Negative international offsets indicate that Autralian businesses voluntarily purchase abatement from overseas.*

Source: *DISER economic modelling for the Plan.*

5.1 The Plan minimises costs and risks, and maximises economic benefits to Australia

The modelling finds that the Plan provides the largest economic benefits of all the scenarios assessed, and that alternative approaches involve net costs relative to the Plan, as shown in Table 4 below. Consistent with the principles outlined by the Government, the approach set out in the Plan recognises there is a role for offsets that leverages Australia's abundant biological and geological storage potential but does not rely on high mandatory carbon prices, conversion of productive farming land to carbon sequestration, or excessive use of international offsets.

Table 4. Summary of economic impacts for different scenario in 2050

		Impact of capital risk premium	Benefits of the plan	Costs of alternative pathways			
Scenario		No Australian Action	The Plan	NZE 100%	NZE with offsets	NZE no trade	NZE no offsets
Assessed against		2°C with no action and no risk premium	No Australian Action	The Plan			
Economic activity (GDP)		-0.55%	1.59%	-0.01%	-1.08%	-1.17%	-1.68%
$ per person (real 2020)	$	-650	1925	-10	-1,325	-1,450	-2,050
National income (GNI)		-0.51%	1.59%	-0.02%	-1.46%	-1.29%	-1.79%
$ per person (real 2020)	$	-625	2,000	-25	-1,850	-1,650	-2,275

Notes: *$ impacts larger than $100 rounded to the nearest $25. The impact of the capital risk premium is assessed against a background 2°C scenario that assumes no additional Australian action and no Australian 2050 target.*

Source: *DISER economic modelling for the Plan.*

5.2 Advanced technology provides additional flexibility in how Australia can achieve net zero

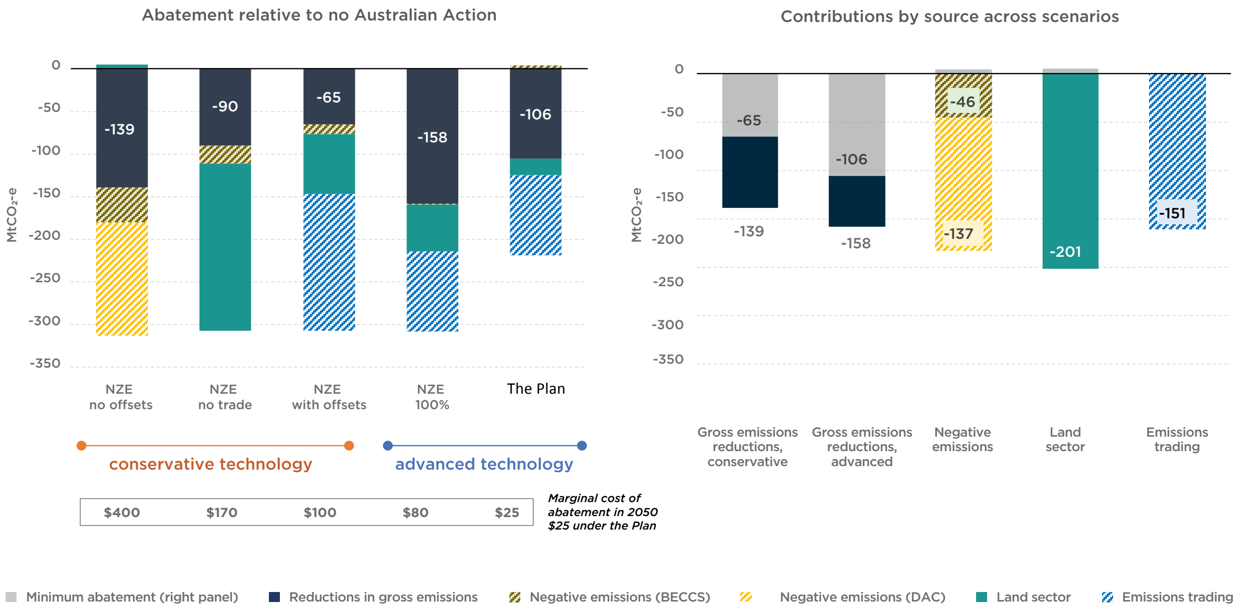
The modelling assesses four main options for achieving net zero emissions:

- Reducing gross emissions and the emissions intensity of economic production and consumption;
- Land sector sequestration (or domestic offsets), including enhanced soil carbon, on-farm plantings that do not reduce farm output (such as windbreaks), on-farm plantings that reduce the area of land available for traditional agriculture, and off-farm activities such as improved savanna management and improved forestry management;
- International offsets from emissions trading within our region; and
- Deployment of negative emissions technologies, such as bioenergy with carbon capture and storage (BECCS) and direct air capture (DAC).

The first three options are well understood and already available at scale. As shown in Figure 22, the modelling finds that each of the first three options could deliver 140-200 Mt CO_2-e of additional abatement in 2050, equivalent to each providing up to 45-65% of projected net emissions in the No Australian Action scenario. In addition, the modelling finds that negative emissions technologies could provide up to an additional 22 MtCO_2-e, relative to the No Australian Action scenario, with a marginal abatement incentive of up to $170/t CO_2-e.

In combination, the modelling finds these sources could provide 375 Mt CO_2-e of abatement (equivalent to 1.2 times the net emissions projected with No Australian Action) in 2050 with a marginal abatement incentive of up to $80/t CO_2-e, with advanced technology. Adding in the best estimate of the contribution of un-modelled future technology contributions would increase this to around 470 Mt CO_2-e of abatement, equivalent to 1.5 times the total net emissions projected with No Australian Action.

Figure 22. Contributions of different abatement options in different scenarios, 2050



Notes: *The left panel shows the abatement by source given the assumptions for each scenario, assessed relative to the No Australian Action scenario. The right panel shows the maximum additional contribution of each option across the five scenarios, and the minimum additional contribution of gross emissions reductions with conservative and advanced technology, all relative to the No Australian Action scenario. Appendix C provides more detail on GTEM abatement mechanisms and outcomes. Marginal abatement incentives above $40 are rounded to the nearest $10.*

Source: *DISER economic modelling for the Plan.*

The scenarios explored for the Plan provide several insights into the costs and implications of different options and approaches to achieving net zero:

- Reducing gross emissions and the emissions intensity of production involves a range of economic costs, with GDP being as much as 0.7% lower in conservative technology scenarios as a result of achieving 18-39% reductions in gross emissions relative to No Australian Action in 2050.
- The modelling finds larger emissions reductions can be achieved at lower costs with advanced technology. For example, the reduction in gross emissions in the NZE 100% scenario is 2.4 times the reduction in the NZE with offsets scenario in 2050, despite having a 20% lower marginal abatement incentive. However, advanced technology does not make emissions reductions costless, or without consequences. This is illustrated by the additional impacts of the NZE 100% scenario on production of traditional energy sources like coal and gas, relative to the Plan (see Figure 23 on page 48 below).
- Supply and use of land sequestration lowers the cost and economic impacts of achieving deep cuts in emissions. Domestic offsets provide 27-63 Mt CO_2-e of sequestration and up to $5.0 billion in additional income to landholders in advanced technology scenarios, without displacing productive farmland. The modelling and analysis finds larger volumes of sequestration are possible, and profitable, but involve conversion of farm land to carbon plantings. For example, while not the Government's policy, the modelling finds no trade scenario uses over 200 Mt CO_2-e of abatement in 2050, involving 10 Mha of on-farm plantings, and withdrawing 7.2% of land from traditional agricultural production.
- Access to international offsets reduces the economic impact of achieving the 2050 target by around two thirds, all else equal. International offsets support additional abatement in other countries, that would not occur otherwise, as well as providing economic benefits to Australia and the supplying country. However, excessive reliance on international offsets could expose Australia to additional risks around the price and availability of high quality international units.

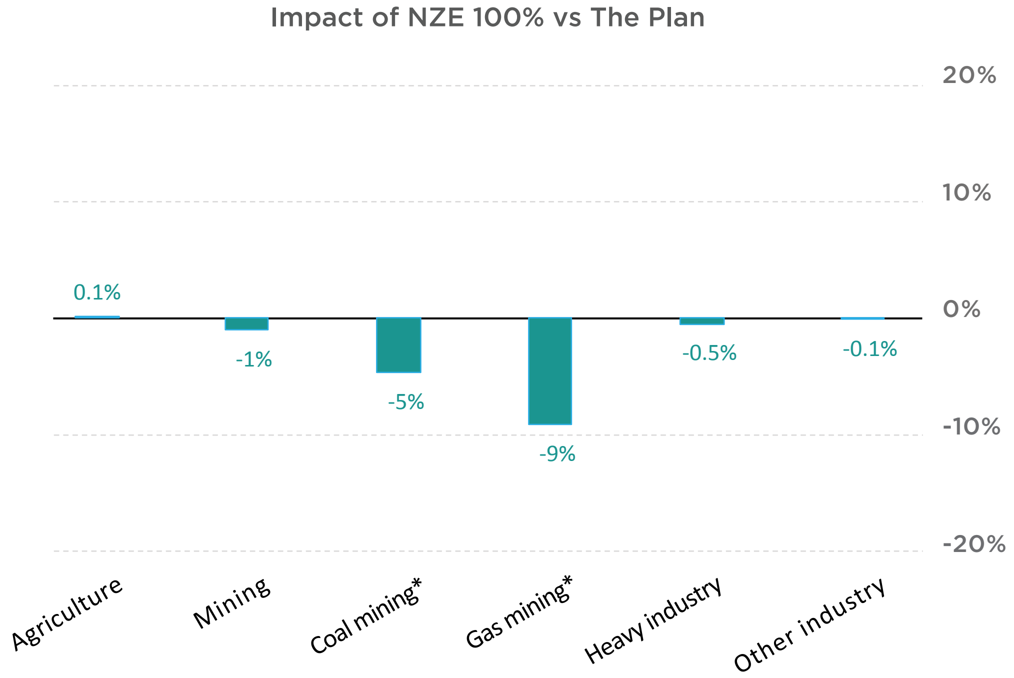
5.3 Imposing higher abatement costs would amplify negative economic impacts on Australia

As part of exploring alternative pathways to net zero, the NZE 100% scenario provides insights into economic impacts and outcomes of forcing the economy all the way to net zero by 2050 using our current best-estimate of advanced technology and abatement options. This is in contrast to accepting the 15% gap that remains under the Plan based on the expectation that actors in the economy will voluntarily reduce emissions to that point, using options available under advanced technology. Under the Plan, the gap is expected to be closed by future additional technology breakthroughs or by overachievement of abatement from technologies that are already included in the analysis.

Achieving net zero emissions with the same volume of international offsets requires higher marginal abatement incentives than the Plan, rising to \$80/t CO_2-e in 2050, which exacerbates the impacts of global action on some sectors while creating additional opportunities for others.

The modelling finds the higher abatement costs in the NZE 100% scenario have adverse impacts on fossil fuel based sectors, with \$4.9 billion lower output value from coal and gas in 2050 relative to the Plan (see Figure 23 below), and lower growth in heavy industry. The NZE 100% scenario also involves higher volumes of land sequestration, which provides \$4.3 billion in additional revenue to participating land holders, but requires more extensive on-farm plantings. Overall, the NZE 100% scenario is projected to have only modest impacts on the total value of economic activity, relative to the Plan, with real GDP only 0.01% (\$0.4 billion) lower in 2050.

Figure 23. Sectoral impacts of higher marginal abatement incentives, 2050



Note: *Shows the effects of higher marginal abatement incentive of \$80/t CO_2-e rather than \$24/t CO_2-e in Australia, under advanced technology, assessed using outcomes for NZE 100% against the Plan. Impacts are shown to one significant figure. The value of agriculture does not include payments for land sequestration. Coal mining* and Gas mining* and are a subset of all Mining. Scenario assumptions are detailed in Table 5 in Appendix A.*

Source: *DISER economic modelling for the Plan.*

Contributions and limitations of the modelling and analysis

Economic models allow the rigorous examination of complex issues across long timeframes, however, they are only an approximation of the real world and have limitations. Therefore, the results of modelling require careful interpretation.

Important limitations of the economic modelling include:

- This modelling does not assess the benefits of avoiding climate change, such as reduced climate risks and decreased impacts of global warming. The modelling partially takes into account the economic and environmental benefits achieved when reducing emissions through advanced technology scenarios, however the model does not seek to quantify outcomes from avoiding climate change and the findings should not be considered in isolation.
- Analysis over long time horizons is inevitably uncertain and technology and broader economic trends can shift quickly and in unexpected ways. For example, history shows that the potential of technology is often underestimated in the long-term; technology costs may fall faster than anticipated for some technologies, and new and disruptive technologies may emerge which would affect the accuracy of the modelling projections.
- Economic models are generally not well suited to modelling innovation as an exogenous process (other than narrowly defined reductions in production cost), and so instead technology changes need to be imposed explicitly by assumption.
- The model structure and calibration is relatively cautious in estimating the potential for substitution between energy inputs, such as electrification of industry (displacing gas use) or the uptake of low or zero emissions transport technologies (displacing petroleum). Many technology based models and analytical approaches project more rapid uptake of EV and other zero emissions land transport options.
- The model also does not capture the effects of uncertainty, or non-market factors which can significantly affect economic behaviour. Economic agents are not forward looking.
- Labour market participation and unemployment rates are not endogenous within the model, and so do not vary with economic conditions. This will typically tend to understate economic benefits (as participation does not rise with stronger economic growth) and overstate economic costs.

In addition, this modelling incorporates a new hydrogen sector into GTEM. Growth of a new sector cannot be calibrated to historical performance, which is the traditional way of calibrating in CGE modelling, and future technology costs are uncertain. The analysis thus necessarily breaks new ground, and while useful for providing new insights the results should be treated with some caution. The modelling thus provides additional results for economic impacts assessed with advanced technology but with the hydrogen sector left dormant, to ensure robust conclusions can be drawn from the GTEM modelling, even if the benefits of global and Australian deployment of hydrogen do not accrue to Australia.

With regard to the analysis of employment impacts by McKinsey, DISER requested McKinsey create a view of employment changes informed by the GTEM production results. McKinsey did not quality assure the GTEM model or its outputs, however the GTEM results were broadly in line with McKinsey's own scenarios. McKinsey provided DISER with fact-based, independent analysis to inform the Commonwealth Government's own work and recommendations. McKinsey were not engaged to provide policy advice or specific policy recommendations.

APPENDICES

Appendix A provides an overview of the key scenario assumptions and more detailed results for the core scenarios explored and assessed through the DISER modelling.

- This includes a description of how and why the modelling finds a 2050 target would provide net benefits given the focus, scope, and context of the analysis, in contrast to most previous GTEM modelling which found emissions reductions result in net economic costs (not accounting for the benefits of avoided climate damages).

Appendix B provides an overview of the GTEM model, including model dynamics, structure, database, and the addition of a new hydrogen sector.

Appendix C describes GTEM abatement mechanisms and the abatement assumptions for the analysis, including:

- How GTEM represents and models abatement;
- Assumptions used to represent advanced technology, and economy-wide abatement outcomes for conservative and advanced technology
- The role of international offsets from emissions trading
- Analysis of the supply of land sector sequestration and offsets for Australia and other regions.

Appendix D describes the assumptions and methods used in the modelling, including:

- Assumptions that underpin Pre-Glasgow baseline scenario that underlies the modelling.
- Assumptions for global action to achieve the below 2°C and well below 2°C trajectories.
- How the modelling was implemented and interpreted, including details of the additional modelling runs used allow decomposition of impacts.

Appendix E describes the assumptions, methods and results for the analysis of a capital risk premium, including the advice provided by Treasury.

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Acknowledgements

The GTEM modelling was undertaken by the Department of Industry, Science, Energy and Resources. The Minister for Industry, Energy and Emissions Reduction appointed an expert Peer Review Panel comprising of Dr Brian Fisher, Ms Anna Matysek and Ms Lisa Gropp to provide independent technical advice to the Department on modelling assumptions and methods, and to review modelling results. The Panel was not asked to endorse the modelling methods, assumptions or results, and the Department takes full responsibility for all aspects of the modelling. The Department would like to express its gratitude and appreciation for the advice it received from the Panel.

Acknowledgement also goes to Dr Steve Hatfield-Dodds for his leadership of the modelling team and the outstanding team of dedicated public servants who worked with him. Particular thanks go to Dr Kee Hiaujoo from the Office of the Chief Economist, Melissa Hinson from the Treasury, Owen Gabbitas from the Productivity Commission, Dr Yingying Lu from the CSIRO, and Kath Rowley from DISER. The technical contribution of Dr LY Cao from ABARES was essential to the task. There were other members of the modelling team over the course of the project, to whom thanks and appreciation is also extended.

Treasury seconded two staff to DISER to assist with the modelling and provided advice on input assumptions for economic growth for the Pre-Glasgow baseline scenario. Treasury also provided advice on assessing the potential economic 'cost of inaction' to Australia in a scenario where Australia does not adopt a 2050 target in the context of concerted global action to address climate change, including all other developed countries committing to a net zero target. The Department also appreciates Treasury's support in reviewing the presentation of results in this report and thanks all the departments and agencies who provided advice and support throughout this process.

APPENDIX A: Scenario overview and results

This Appendix provides an overview of the key scenario assumptions and more detailed results for the core scenarios explored and assessed through the DISER modelling. This includes:

- An overview and explanation of the key scenario assumptions in relation to Australian action.
- Detailed results of emissions by source and economic impacts for all scenarios.
- The full decomposition of impacts on economic activity (GDP) for the Plan, assessed against the No Australian Action and Pre-Glasgow scenarios.

More information on assumptions and methods are provided in the other appendices, as summarised above.

Key scenario assumptions

Scenarios are stylised representations of what Australia and the world could look like if a particular course of action was taken to reduce emissions in Australia and in the rest of the world. They are built by making evidence-based assumptions about future emission reduction actions. Scenarios do not represent an official economic forecast, but are instead model projections of emissions, energy use, and economic performance predicated on a specific set of assumptions.

The primary purpose of the scenarios in the economic modelling is to underpin exploration and assessment of the implications of different potential events or pathways, by contrasting outcomes across scenarios with different assumptions. For example, the modelling may compare a scenario where Australia has access to international offsets with a scenario where Australia chooses not to use international offsets, but is otherwise exactly the same. The difference in economic performance across this pair of scenarios can thus be used to assess the impacts of allowing emissions trading (or of not using it).

Each of the Australian scenarios is constructed as a combination of key assumptions, summarised in Table 5 below.

Key global assumptions include:

Technology trends – whether cost reductions unlock deployment, in Australia and globally, of advanced technologies associated with the Government's technology priorities, including establishing cost-competitive hydrogen.

Global emissions trajectory, and associated global action – including emissions trading between countries. The modelling assumes that advanced technology results in both lower abatement costs and more rapid global emissions reductions, and so this global trajectory is a modelling result (given other assumptions). Technology assumptions, trajectory (relative to the Pre-Glasgow underlying baseline), and international emissions trading assumptions together determine the level of the global marginal abatement incentive in each scenario.

Potential global responses – whether Australia is subject to a capital risk premium in scenarios where Australia does not adopt a 2050 target.

The key Australian scenario assumptions are:

Abatement incentive in Australia – whether the level of incentive is set by assumption, or arises as a modelling result given other attributes of the scenario.

2050 target – whether Australia adopts a net emissions target for 2050, and the assumed level of emissions reduction.

Land sequestration – whether and to what extent Australia allows voluntary market-based supply of sequestration.

International offsets – whether and to what extent Australia chooses to use international emissions trading.

Together these assumptions drive the modelled outcomes for emissions, energy use, and national and sectoral economic performance in the context of global action on climate. These outcomes are summarised in the following section, complementing the discussion and results presented under relevant key findings in the main report.

Table 5. Key assumptions that define the set of scenarios

Interpretive key	Specific assumption for Pre-Glasgow or No Australian Action scenarios	Alternative assumption applied to multiple scenarios	Model determined result	Assumption applied to multiple scenarios, including the Plan	Specific assumption applied to only one scenario

SCENARIO ASSUMPTION	Pre-Glasgow	No Australian Action	NZE no offsets	NZE no trade	NZE with offsets	NZE 100%	The Plan
Global action	No additional action	Staged global action reduces emissions to achieve trajectory, with limited emissions trading					
Global trajectory	*Assumptions result in 4°C*	Assumes below 2°C trajectory (RCP2.6)				*Assumptions result in well below 2°C trajectory*	
Capital risk premium	Not applicable	Imposed on Australia	No premium				
Technology	Conservative	Conservative *(action to achieve global trajectory accelerates learning by doing)*				Advanced	
Abatement incentive in Australia in 2050	No incentive	$2/t by assumption (below world price)	*Model determined result*				$24/t by assumption (below world price)
Australian target in 2050	No 2050 target		Net zero in 2050				15% gap remains, by assumption
Australian land sequestration	Conservative supply	Equals baseline	Less than baseline	Conservative supply		Advanced supply	
International offsets	Australia does not participate in international emissions trading				Limited trade, purchased at global price (binds)	Trade capped to match the Plan outcome (binds)	Limited trade, purchased at global price (does not bind)

Notes: *All scenarios with global action assume limited emissions trading. Australian net emissions in 2050 are a model-determined results in the Pre-Glasgow and No Australian Action scenarios (42% and 51% below 2005 levels, respectively). Supply of land sequestration is defined as a function of the marginal abatement incentive, and so modelled results for the volume of land sequestration vary across scenarios (see Table 6 below). All Australian scenarios with trade assume international offsets are purchased at the global price, including NZE 100%.*

Source: *DISER economic modelling for the Plan.*

Projected emissions and economic impacts across scenarios

Key findings and results from the modelling are presented throughout the main body of the report, with additional details in Appendix C, D and E.

This section complements this other information by providing two additional key sets of results for all six scenarios:

- Table 6 provides detailed emissions in 2050 by UNFCCC categories, along with historical data for 2005 and 2020 to allow sector and aggregate comparisons across sectors and over time.
- Table 7 provides information on impacts on economic activity (GDP) and national income (GNI) in 2050 across all six scenarios. These impacts are assessed against five reference points or scenarios: the Pre-Glasgow baseline; two counterfactual scenarios with no Australian target but no global retaliation; the No Australian Action scenario and the Plan scenario.

Table 6. Emissions and offsets by source, 2005, 2020 and all scenarios 2050

Units: $MtCO_2$-e A$ (2020 real)	2005	2020	Pre-Glasgow	No Australian Action	The Plan	NZE 100%	NZE with offsets	NZE no trade	NZE no offsets
Marginal abatement incentive Australia	N/A	N/A	zero	$2	$24	$80	$100	$170	$400
Emissions by source									
Electricity	197	172	39	20	18	17	17	15	13
Stationary energy	82	103	89	95	69	65	88	85	78
Industrial emissions	47	44	65	65	47	27	54	49	41
Fugitives (from mining)	41	53	39	28	25	21	23	21	15
Transport	82	94	70	70	39	31	57	52	41
Agriculture	86	72	82	80	55	39	54	47	32
Land Sector (net source)	89	0	0	0	0	0	0	0	0
Gross Emissions	**624**	**536**	**383**	**358**	**253**	**200**	**293**	**268**	**219**
Negative emissions (BECCS)	0	0	-11	-42	-38	-43	-54	-64	-84
Negative emissions (DAC)	0	0	0	0	0	0	0	0	-132
Emissions before offsets	**624**	**536**	**372**	**316**	**215**	**157**	**239**	**205**	**3**
Domestic offsets: Land sector	N/A	-25	-8	-8	-27	-63	-78	-204	-3
International offsets: Emissions trading	0	0	0	0	-94	-94	-161	0	0
Net emissions	**624**	**512**	**364**	**308**	**94**	**0**	**0**	**0**	**0**

Note: *Marginal abatement incentives shown are rounded to two significant figures. The marginal abatement incentive assumed for No Australian Action is $2.0/t. Industrial emissions include emissions from waste and industrial processes and product use. Marginal abatement incentives above $40 are rounded to the nearest $10.*

Source: *DISER economic modelling for the Plan.*

Table 7. Economic impacts relative to multiple points of comparison, all scenarios, 2050

Scenario	No Australian action	The Plan 100% no trade	NZE 100%	NZE with offsets	NZE 100%	NZE no offsets
Marginal abatement incentive Australia	$2	$24	$80	$100	$170	$400
Relative to Pre-Glasgow underlying baseline						
Economic Activity (GDP)	-1.39%	0.17%	0.16%	-0.91%	-1.00%	-1.51%
National Income (GNI)	-2.05%	-0.48%	-0.50%	-1.94%	-1.77%	-2.27%
Relative to no Australian 2050 target, with no capital risk premium, conservative technology (background scenario)						
Economic Activity (GDP)	-0.54%	0.19%	0.19%	-0.05%	-0.14%	-0.66%
National Income (GNI)	-0.51%	0.27%	0.25%	-0.40%	-0.23%	-0.73%
Relative to no Australian 2050 target, with no capital risk premium, advanced technology with hydrogen (background scenario)						
Economic Activity (GDP)	N/A	-0.01%	-0.02%	N/A	N/A	N/A
National Income (GNI)	N/A	-0.13%	-0.15%	N/A	N/A	N/A
Relative to No Australian Action (including impacts of capital risk premium)						
Economic Activity (GDP)	0.00%	1.59%	1.58%	0.49%	0.40%	-0.12%
National Income (GNI)	0.00%	1.59%	1.57%	0.11%	0.28%	-0.23%
Relative to the Plan						
Economic Activity (GDP)	-1.56%	0.00%	-0.01%	-1.08%	-1.17%	-1.68%
National Income (GNI)	-1.57%	0.00%	-0.02%	-1.46%	-1.29%	-1.79%

Note: *Marginal abatement incentives above $40 are rounded to the nearest $10. The marginal abatement incentive assumed for No Australian Action is $2.0/t. See Table 23 and Table 24 in Appendix D for more details on background scenarios.*

Source: *DISER economic modelling for the Plan.*

Table 8 provides more detailed findings on the impacts of global action, the capital risk premium, and the 2050 target and technology agenda that together make up the Plan. This unpacks the impacts on the real value of economic activity (GDP). The modelling assesses each of these impacts by comparing scenarios which only differ in one way.

In addition to the findings on the impact of the 2050 target, set out above, the modelling finds that global efforts to accelerate the development and deployment of technology could offset the negative impacts of global emissions reductions.

Table 8. Detailed impacts of global action and the Plan on economic activity (GDP) in 2050

Impacts on Australian GDP $ (2020 real) per person in 2050	Impacts of global response	Impacts of adopting a net zero by 2050 target supported by advanced technology
Scenario	**No Australian Action**	**The Plan**
Assessed against	**2°C no action scenario with no capital risk premium**	**vs No Australian Action**
Global actions		
Slower global growth and shifts in demand	N/A	N/A
Capital risk premium, if applicable	-657	N/A
Total impact of global action	-657	N/A
Impacts of Australian 2050 target		
Avoided risk premium, if applicable	N/A	657
Target impact (conservative technology)	0	-49
Effect of limited trade (globally)	0	-16
Other effects	0	34
Total net impact of the 2050 target	0	626
Technology agenda (deployed globally)		
Advanced technology effects on Australia	0	
– stronger global economic growth	0	235
– lower cost abatement in Australia	0	31
Hydrogen impact on Australia	0	1028
Total technology agenda impact	0	1294
NET IMPACT (COST OR BENEFIT)	**-657**	**1920**
% impact	-0.55%	1.59%

Notes: *Target effect assumes conservative technology. Other effects include the net impacts of all other assumptions, including the level of the voluntary abatement incentive and the net emissions target modelled for the Plan. Technology agenda effects are separated into the effects of stronger global economic growth, lower abatement costs in Australia, and hydrogen effects as explained in Table 24. Numbers may not add to sub-total or totals due to rounding.*

Source: *DISER economic modelling for the Plan.*

Economic impacts of the core scenarios versus Pre-Glasgow underlying baseline

To establish the No Australian Action scenario, the modelling develops an underlying baseline scenario in which the world is not on track to limiting warming below 2°C. This scenario also provides the basis for assessing the economic costs and opportunities of increased global climate ambition.

Pre-Glasgow underlying baseline – A world which maintains current global policies and commitments (as at early April 2021), and associated technology trends, without adjustment through to 2100. Australian and world economic assumptions align with the Treasury Intergenerational Report 2021. Global emissions and the projected long term temperature are not pre-defined, and are determined by the other characteristics of this scenario. The GTEM analysis does not account for the impacts of climate change, or the benefits of avoided climate impacts.

More details on implementation are provided in Appendix D.

To allow comparisons to other economic analysis, Table 9 reports the economic impacts associated with the No Australian Action scenario (including the impact of the capital risk premium) and the Plan scenario relative to the Pre-Glasgow underlying baseline scenario. Impacts are reported as deviations in real dollars rather than percentages as the table also reports deviations for the Plan against the No Australian Action scenario. Table 8 in the main body of the report provides similar information.

Table 9. Economic impacts of No Australian Action and The Plan vs Pre-Glasgow underlying baseline scenario

Impacts on Australian GDP $ (2020 real) per person in 2050	Impacts of global response	Impacts of adopting a net zero by 2050 target supported by advanced technology
Scenario	**No Australian Action**	**The Plan**
Assessed against	**Pre-Glasgow**	**No Australian Action**
Global actions		
Slower global growth and shifts in demand	-1052	N/A
Capital risk premium, if applicable	-657	N/A
Total impact of global action	-1709	N/A
Impacts of Australian 2050 target		
Avoided risk premium, if applicable	N/A	657
Target impact (conservative technology)	0	-49
Effect of limited trade (globally)	0	-16
Other effects	0	34
Total net impact of the 2050 target	0	626
Technology agenda (deployed globally)		
Advanced technology effects on Australia	0	
– stronger global economic growth	0	235
– lower cost abatement in Australia	0	31
Hydrogen impact on Australia	0	1028
Total technology agenda impact	0	1294
NET IMPACT (COST OR BENEFIT)	-1709	1920
Percent impact	-1.39%	1.59%

Source: *DISER economic modelling for the Plan.*

Detailed decomposition of economic impacts

To allow comparisons to other economic analysis, Table 10 reports the decomposition of impacts on real GDP and GNI.

Table 10. Decomposition of the effect on real GDP and GNI in 2050

Contribution to percent (%) deviation of GNI in 2050	Global action	Avoided capital risk premium	Global action and avoided capital risk premium	2050 target and technology agenda
Scenario	2°C no action scenario with no capital risk premium	No Australian Action (with risk premium)	No Australian Action	The Plan
Assessed against	Pre-Glasgow scenario	2°C no action scenario with no capital risk premium	Pre-Glasgow scenario	No Australian Action
Factor income	-0.63	-0.40	-1.03	1.16
Allocative efficiency	-0.23	-0.15	-0.38	0.48
Technical change	-0.01	0.00	-0.01	-0.02
Real GDP (subtotal)	**-0.87**	**-0.55**	**-1.42**	**1.62**
Terms of trade	-0.53	0.04	-0.49	0.14
Permit trade	0.00	0.00	0.00	-0.09
Other Foreign income	-0.14	0.00	-0.14	-0.08
Real GNI (total)	**-1.55**	**-0.51**	**-2.05**	**1.59**

Note: *Deviations for real GDP, terms of trade, permit trade and other foreign income may not sum to the real GNP due to rounding. The impact of the capital risk premium is assessed against a background 2°C scenario with conservative technology that assumes no additional Australian action and no Australian 2050 target. The impact on foreign income of the capital risk premium rounds to less than 0.00% as the combined effect of the capital risk premium shifting the apparent supply of investment up (increasing the cost per unit of investment), resulting in a move along the Australian investment demand curve (reducing the quantity of investment), with almost exactly offsetting effects in 2050.*

Source: *DISER economic modelling for the Plan.*

Comparison of findings relative to previous GTEM analysis

A central finding of this analysis is that adopting and achieving a net zero target in 2050 provides a net benefit to Australia. This contrasts with previous GTEM analysis of Australian emissions reductions, which have generally found that deep cuts in emissions result in net economic costs (not accounting for the benefits of avoided climate damages).

This finding reflects the distinctive focus, scope, and context of the current analysis, particularly the assessment of the impacts of shifts in global demand as other countries' act to achieve their decarbonisation goals, and the assessment of the benefits of global deployment of advanced technology.

Box B6: Factors that contribute to the finding that the Plan results in net economic benefits

While it is not possible to undertake precise 'like for like' comparisons of economic impacts with previous studies (due to multiple differences in context and assumptions across the studies), a number of important factors can be identified that explain why the current modelling finds a net benefit, in contrast to previous Australian studies.

- The modelling focuses on assessing the economic impacts of potential Australian actions, assuming a world on track to limit climate change to below 2°C. While the impacts of global action are reported, these are not included in the headline impact of taking on a 2050 target of the current report. By contrast, the headline results of previous studies often combined the impacts of global and national action.
- For the first time, the modelling also accounts for the impacts of likely global responses if Australia does not take further action to reduce emissions, by analysing the impacts of a capital risk premium. The modelling finds that avoiding this global response provides a net benefit.
- The modelling assesses the impacts of advanced technology, including a new hydrogen sector, as important elements of the Plan. It finds successful global deployment of advanced technologies would provide further benefits, in addition to the benefits of adopting and achieving the 2050 target. This detailed technology assessment has not been included in the scope of previous modelling of the impacts of reducing Australian emissions.
- The 'underlying baseline' projections for global and Australian emissions (with no additional action) are significantly lower than in previous studies. Given the circumstances of their time, previous studies typically projected Australian emissions would increase by more than 50%, and up to 100% in some cases. Faster than expected reductions in technology costs has changed the outlook. Consistent with the DISER emissions projections, the modelling for this study projects Australian emissions will fall by 40-50% by 2050 with no additional Australian action. This reduces the abatement task required to achieve the 2050 target by more than 65% in the current analysis, relative to previous studies. While not assessed in the modelling, this is likely to result in the cost and impact of achieving the target being lower than they would be if assessed relative to previous baseline emissions projections.

Comparisons across studies indicate that abatement outcomes as a function of marginal abatement incentives in the conservative technology scenarios are very similar compared with previous studies (see Apendix C and Figure 26). This demonstrates that lower economic impacts projected by the analysis are not the result of changes to the model. As expected, advanced technology consistent with the stretch goals achieves more abatement than previous studies (particularly for marginal abatement incentives up to $80/t), which did not assess advanced technology potential in the same way.

Assessing the impact of Australian action in a world on track to below 2°C

The headline economic impacts from the modelling largely focus on the impacts of different potential Australian actions, assuming a world on track to limit climate change to 2°C or lower.

Previous studies (such as Australian Government 2008, CSIRO 2015) often reported the combined impacts of global action and Australia emissions reductions. As shown in Figure 19 and Table 8 above, the current modelling finds that the net impact of national action is much smaller than the impacts on Australia of global action to reduce emissions. Focusing on the impacts of national action may thus result in headline impacts that appear smaller than those in previous studies.

Assessing the impact of not adopting a 2050 target

The modelling assesses the economic impacts of adopting a 2050 target against a scenario where Australia does not adopt a target, and global capital markets respond by pricing in the risks associated with this via a capital risk premium. Both scenarios include the impact of global efforts to reduce emissions resulting in shifts in demand for Australian emissions-intensive products. Including the effects of this market-driven global response in the scope of the modelling reflects both the focus and context of the analysis, recognising that it is almost certain that Australia would face some form of retaliation if it does not take on to a credible 2050 emissions target. The modelling uses the impacts of a capital risk premium as a minimum estimate of likely impacts of global retaliation, of all forms, if Australia does not adopt a 2050 target.

The modelling finds that the impact of this risk premium is significantly larger than the impacts of taking on a target, and so adopting and achieving a 2050 target provides net benefits (as shown the main report).

Assessing the effects of lower technology costs and accelerated deployment, including hydrogen

The scope of the modelling gives particular attention to the potential contribution of accelerating the uptake of low emissions technologies consistent with the stretch goals, such as improved energy storage to enable greater use of variable renewables, clean hydrogen, and reduced industrial emissions (such as from producing steel and aluminium). While other studies have explored the benefits of accelerating technology deployment, these issues have generally not been included in the scope of previous model-based assessments of the macroeconomic impacts of reducing Australian emissions.

Differences in context also affect the size of economic impacts

The findings on the economic impacts of the 2050 target are also influenced by the current global context, particularly the outlook for global and Australian emissions without additional action.

This is because impacts are assessed by comparing differences between scenarios, particularly their economic performance relative to the No Australian Action scenario, which is built on the Pre-Glasgow underlying baseline. The impact of moving from these 'no additional action' scenarios to net zero is thus strongly influenced by the emissions trajectory in the underlying scenarios.

As shown in Figure 24, previous studies projected Australian emissions rising by more than 50% by 2050 with no additional policy action, whereas the economic modelling for this report projects emissions to fall by 40% in the Pre-Glasgow underlying baseline scenario, or by around 50% in the No Australian Action scenario with the world on track to below 2°C.

This difference in underlying baselines results in the abatement task being more than 65% lower in the current analysis, avoiding the need to abate as much as 525-700 Mt CO_2-e in 2050 – a task similar to total national emissions in 2005 or 2020.[9]

Overall, it is likely that lower projected emissions in the Pre-Glasgow underlying baseline scenario makes a significant contribution to the lower economic impacts found by this study, relative to previous studies. While it is not possible to precisely estimate the effects of the differences in projected baseline emissions without modelling them, the analysis of abatement outcomes indicates that doubling the abatement task (back towards the levels expected a decade ago) would more than double the abatement incentive required. Against this, doubling the abatement incentive would be expected to increase GDP impacts by a smaller amount.

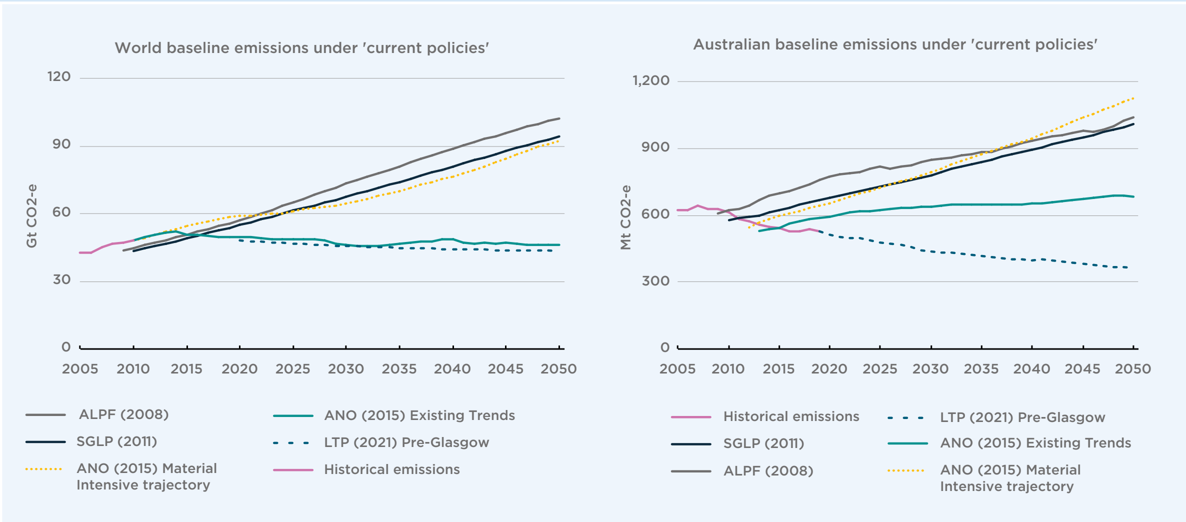
9 The most ambitious target in the Treasury (2008) analysis involved a 90% reduction target in 2020 (from 2000 levels). This required emissions to be reduced by 832 Mt in 2050, from projected baseline emissions of 958 Mt, with a $275 carbon price (in 2020 dollars). The abatement task for the most ambitious 2050 target in the CSIRO (2015) analysis is similar, reducing emissions by 976 Mt from a projected 1011 Mt emission intensive baseline.

Box B7. Outlook for baseline emissions in this analysis and previous studies

The emission trajectory for the Pre-Glasgow underlying baseline – assuming current policies and technology trends – is significantly lower than the underlying 'current policies' emissions projections used in previous studies.

This illustrates how dramatically the world has changed in recent years. As shown in Figure 24, studies from a decade ago judged the world to be on track to temperature increases of at least 6°C, with global emissions projected to increase by more than 90% from 2005 to 2050, and Australian emissions increasing more than 50% by 2050 (and by 100% in some cases). These studies reflected the circumstances of their times, but times have changed. The cost of renewable electricity has fallen dramatically, and faster than expected, accelerating uptake of low carbon options, and laying the groundwork to decarbonise road transport – the two largest sources of global emissions. As a result of these and other changes, the analysis for this project finds that emissions under 'current policies' are projected to decrease globally and in Australia – rather than increase – over coming decades. The task required to shift from the Pre-Glasgow 'current policies' trajectory to a new trajectory consistent with below 2°C is less costly than it was before – largely because of investments already made that have made low carbon technologies cheaper and more attractive.

Figure 24. Projected emissions under 'current policies', selected studies from 2008 to today



Notes: *Referenced previous studies are Australia's Low Pollution Future: The Economics of Climate Change Mitigation (Australian Government 2008); Strong growth low pollution: modelling a carbon price (SGLP 2011); Australian National Outlook (ANO 2015). Historical Australian emissions are sourced from DISER's Emissions Projection; global historical emissions are consistent with the ANO 2015.*

Source: *DISER economic modelling for the Plan, Government 2008, Australian Government 2011, CSIRO 2015).*

APPENDIX B: GTEM overview

The economic modelling for this project used the Global Trade and Environment Model (GTEM), a multi-sector multi-region global computable general equilibrium (CGE) model. GTEM was originally developed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (Pant, 2007) and is currently maintained and developed by CSIRO (Cai, Newth, Finnigan, & Gunasekera, 2015). GTEM has an established track record, and has been featured in several government reports, including:

- Australia's Low Pollution Future (2008) (Australian Government, 2008);
- Strong Growth Low Pollution (2011) (Australian Government, 2011); and
- Climate Change Mitigation Scenarios (2013) (The Treasury, 2013).

Model overview

GTEM is a dynamic global computable general equilibrium model with the capability to address total, sectoral, spatial, and temporal efficiency of resource allocation. Modelling outputs include global and regional projections of emissions and economic activities across a wide range of potential scenarios and outlooks. This includes shifts in technology costs, production and consumption patterns, economic structures, trade in goods and services, international investment flows and trade in emissions units.

Results capture the impact of policy changes on large numbers of economic variables in all sectors of the economy, including gross domestic product, prices, consumption, production, trade, investment, efficiency, competitiveness, and greenhouse gases. GTEM has been used to analyse a range of issues such as the climate mitigation policies under the Kyoto Protocol and Paris Agreement, trade reform under the World Trade Organisation, and trends and issues in international commodity and energy markets.

GTEM models each region as a stylised economy consisting of households, government and producers (industries or sectors). Household and governments consume a fixed proportion of national income, with the remainder allocated to national savings. Households and governments allocate their consumption expenditure to individual commodities according to an optimisation framework (to maximise their utility). Producers source inputs to minimise the production cost of their output. The savings from each region are pooled globally to fund investment across regions based on relative rates of return. Domestic and international trade enables all markets to clear. All prices are expressed relative to the global nominal exchange rate (which is the model numeraire used in this modelling).

A key feature of GTEM that makes it particularly well suited for modelling climate change policies is that it integrates economic, energy and emissions data across sectors and regions. The optimising behaviour means that producers, for example, minimise their cost of producing a given level of output by switching between inputs (land, labour, capital, natural resources, different sources of energy (coal, oil, gas, petroleum products, electricity and, in some cases, hydrogen) and other intermediate inputs based on their relative cost). Producers are also able to switch between domestically produced and imported goods and services in a similar manner. Scope also exists to improve the efficiency with which all or specific inputs are used in production (resulting in productivity improvements). Households and governments behave in similar ways to maximise their wellbeing (utility).

GTEM abatement processes, functions and outcomes are summarised in Appendix C below.

Model dynamics

GTEM is a recursive dynamic CGE model. This means that the behaviours of agents within the model are based on past and current outcomes, and the current modelled relative prices (in each year), rather than forward looking expectations of the future. Recursive dynamic models sequentially solve a series of yearly static economic models under conditions of certainty in competitive markets.

Prices provide a signal for producers, households, and governments to alter their mix of inputs in production and consumption. If the price of emissions intensive fuels (such as coal and petroleum) rise relative to low or zero emission energy sources (such as hydroelectricity, wind and solar), firms and households will switch towards low or zero emission sources of energy and away from emissions intensive fuels. Model parameters determine the extent to which substitution is possible and may vary across inputs and regions. The model also enables international trade in emission permits. This means that a region may be able to source cheaper abatement opportunities in other regions. Regions can increase (decrease) their national income if they export (import) emission permits.

The model also includes 'learning by doing' (LBD) for technology-bundle sectors and sector-level abatement functions for many sectors. LBD reduces the unit cost of production for new and emerging technologies (such as biogas and carbon, capture and storage), and the extent of any cost reduction is based on the global cumulative production of that technology. Abatement functions represent the adoption of different technologies and processes that reduce emissions per unit of output. No additional costs are associated with LBD and the use of abatement functions.

The labour force is assumed to be a fixed proportion of the working age population, and labour market participation rates do not respond to changes in wages.

Regional savings

The default assumption in the version of GTEM used is that each region saves a fixed share of its gross national income. Regional savings are pooled to give global savings, which fund global investment. The assumption of fixed regional savings rates means that changes in the composition of global economic activity across regions may alter the level of global savings.

Regional investment

Investment decisions in a recursive dynamic CGE model are generally modelled in a stylised way. This is because return to the investment made in the current period is only realised in future periods when the investment becomes productive capital. This is one of the key differences between recursive dynamics and forward-looking dynamics with foresight. Nevertheless, static expectation has widely been used in CGE models to approximate rational expectations.

GTEM assumes there is a global investment pool, which is equal to global savings. The global investment pool is allocated to each region based on a stylised functional form. In this modelling, the allocation of investment to each region in the current period is determined by the current regional investment to capital ratio and the current regional rates of return converging in the long run. This approach is an improvement to the investment allocation used in previous climate change modelling with GTEM. The speed of convergence of regional rates of return is given by a model parameter which is 0.1, meaning that the difference between the rate of return in each region and the global rate of return is reduced by 10% per year.

Current account balance assumption

The current account balance in each GTEM region is the difference between regional savings and regional investment. It is equal in value to, but has the opposite sign of, that region's capital account, such that the balance of payments in each region is zero.

The default is to allow the ratio of the current account to GDP in each region to vary. This default assumption can be overridden to enable the ratio to adjust over time to ensure that persistent global imbalances do not occur. This is achieved by allowing the savings rate in each region to vary.

Model structure

In the version of GTEM used for this project Australia is represented as one of 27 regions (individual countries or groups of countries) that together make up the global economy. Each region has 28 industrial sectors and a representative household for that region (for each regional society). Trade and investment link the regions and a range of taxes and subsidies capture government policies. The model assumes multiple production technologies for three energy-intensive sectors: the electricity, land transport, and iron and steel sectors.

Table 11 below provides information on the country and regional structure used in this project. Table 12 below sets out the GTEM industry structure, and major aggregations of sectors used in this report.

The model has multi-technology production for electricity, iron and steel, land transport, and negative emissions, as shown in Table 13 below. These are complemented by new technology options developed during this exercise to represent the realisation of Technology Investment Roadmap priority technologies, such as access to soil carbon, accelerated cost reduction of carbon capture and storage, reductions in system costs and the development of a bespoke hydrogen sector. These new technology options provide additional detail about technology deployment in response to policy settings and changes in technology costs over time.

The model covers emissions of all greenhouse gases included under the Paris Agreement: carbon dioxide (CO_2); methane (CH4); nitrous oxide (N2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); and sulphur hexafluoride (SF6). Each gas is weighted by its global warming potential to give units of 'carbon dioxide equivalent' (CO_2-e) to enable comparisons, given their different impacts and lifespan in the atmosphere. The model provides projections of emissions from all activities modelled. These emissions projections can be reported by UNFCCC emission categories. Emissions from waste are not represented explicitly in the model.

The modelling draws on land sector sequestration information from the Global Biosphere Management (GLOBIOM) model of agriculture, forestry and land use, and the Land Use Trade-Offs (LUTO) environmental-economic model of land use and ecosystem services for Australia, particularly in relation to emissions and sequestration associated with land use change.

Model database

The starting GTEM database is derived from version 10A of the GTAP model database (Aguiar, 2019), first released in 2019. The CSIRO updated the database including, among other things, updating the database for technology bundles in the electricity, iron and steel and other transport sectors, energy use and sources of negative emissions to be aligned with GTAP V10A, building on previous work (Cai, Newth, Finnigan, & Gunasekera, 2015). Greenhouse gas emissions were also sourced from GTAP (Chepeliev, 2020). The resulting GTEM database (including emissions) represents the global economy in 2014. Previous GTEM-based analysis, including CSIRO (2015) and IRP (2019), was based on earlier versions of GTAP database.

Aspects of the GTEM database were further updated to 2020 , including gross domestic product, population, energy use, emissions and technology shares, and key variables calibrated to 2020 as part of development of the modelling baseline for this project (as described in Appendix D). The final GTEM database for this modelling consists of 24 regions (a combination of individual countries and groups of countries) that together make up the global economy (Table 11). Each region has 28 industrial sectors (Table 12).

Representation of hydrogen as an energy carrier

A new hydrogen sector was added to the GTEM database to enable it to model development of the sector. This was done by disaggregating the chemicals sector in the initial model database into two new sectors: a hydrogen sector; and a residual chemicals sector. In 2014, the year of the GTEM database, there was limited production of hydrogen globally and, where it did occur, facilities were generally small scale 'proof of concept' ones rather than the large commercial facilities envisaged. Given this, the hydrogen sector in each region was made small relative to the initial size of the chemicals sector (0.212% of the initial sector in all regions). The resulting 'embryonic' hydrogen sector in each region can subsequently grow in each modelling scenario, either by directly applying shocks to the sector or as a result of changes in the price of hydrogen relative to other fuels. Where growth rates are specified, it is assumed that this growth arises from productivity improvements that reduce the unit cost of hydrogen (arising from economies of scale in production). Hydrogen was added to the set of fuels that each industry in the model uses, enable industries to change the share of hydrogen used as energy input in response to relative prices.

Table 11. GTEM countries and regions for this project

Geography	Regions	Income status	Underlying GTAP countries and regions
Asia-Pacific	Australia	High	Australia
	China	Medium	China, Hong Kong
	India	Low	India
	Indonesia	Medium	Indonesia
	North Asia	High	Japan$^{-g\,7}$, Korea-g, Taiwan*
	New Zealand	High	New Zealand
	Rest of ASEAN	Medium	Cambodia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam, Rest of SouthEast Asia
	South Asia	Low	Bangladesh, Nepal, Pakistan, Sri Lanka, Rest of South Asia
	Rest of Asia and World	Low	Mongolia, Rest of East Asia, Rest of Oceania, Rest of World
North America	Canada	High	Canada
	Mexico	Medium	Mexico
	United States	High	USA
South and Central America	Argentina	Medium	Argentina
	Brazil	Medium	Brazil
	Central America	Low	Belize, Bermuda, Caribbean, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama
	South America	Medium	Bolivia, Chile^, Colombia^, Ecuador°, Paraguay, Peru, Uruguay, Venezuela°, Rest of South America
Europe	EU-27	High	Austria, Belgium, Bulgaria*, Croatia*, Cyprus*, Czech Republic, Denmark, Estonia, Finland, France$^{-g\,7}$, Germany$^{-g\,7}$, Greece, Hungary, Ireland, Italy$^{-g\,7}$,Latvia*, Lithuania*, Luxembourg, Malta*, Netherlands, Poland, Portugal, Romania, Spain, Slovakia, Slovenia, Sweden
	Rest of Western Europe	High	Iceland, Liechtenstein*, Norway, Switzerland
	United Kingdom	High	United Kingdom
Eastern Europe and West Asia	E. Europe & W. Asia	Medium	Albania, Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Ukraine, Turkey^{-g}, Rest of the Former Soviet Union
	Russia	Medium	Russian Federation
	Middle East	Medium	Bahrain, Iran°, Iraq°, Israel^, Jordan, Kuwait°, Lebanon, Oman, Palestine, Qatar°, Saudi Arabia° $^{-g}$, Syria, United Arab Emirates°, Yemen, Rest of Western Asia
Africa	Other Africa	Low	Algeria°, Botswana, Cameroon, Cote D'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Lesotho, Libya°, Madagascar, Malawi, Mauritius, Morocco, Mozambique, Namibia, Nigeria°, Senegal, Swaziland, Tanzania, Tunisia, Uganda, Zambia, Zimbabwe, Other Central Africa Rest of Eastern Africa, Rest of North Africa, Rest of South African Customs Union, Rest of Western Africa
	South Africa	Medium	South Africa

Key: ** indicates non-OECD country in a region treated as a High Income Nation grouping*
^ indicates OECD country in a region not treated as a High Income Nation grouping
° indicates OPEC member
$^{-g\,7}$ *indicates a country that is both G7 and G20 country within a region – all G7 are also G20 countries*
$^{-g}$ *indicates G20 country within a region*

Notes: *Includes 3 of 7 G7 and 12 of 19 G20 members as individual countries, including EU as the sole G20 region*

Table 12. GTEM industry sectors for this project

Industry description	
Agriculture, fishing and forestry	crops
	cattle and sheep
	other animal products
	forestry
	fishing
Mining	coal extraction
	oil extraction
	gas extraction and distribution
	other mining extraction
Heavy industry	wood and paper products
	petroleum and coke
	hydrogen
	chemical products
	rubber and plastic products
	non-metallic minerals
	iron and steel
	non-ferrous metals and metal products
Electricity	electricity
Light industry	food processing
	electrical and electronic products
	machinery, equipment and vehicles
	other manufacturing
	water supply; sewerage, waste
	construction
Transport	water transport
	air transport
	other transport
Other services	other services

Table 13. GTEM technology bundles

Sector	Existing technology descriptions
Electricity	Coal
	Oil
	Gas
	Nuclear
	Hydro
	Wind
	Solar
	Biogas
	Other bioenergy
	Waste & other combustibles
	Geothermal, Wave, and other renewables
	Coal + CCS
	Oil + CCS
	Gas + CCS
	Bioenergy + CCS (BECCS)
Iron and Steel	Blast furnace
	Electric arc furnace
Other transport	Non-road OTP (i.e. rail and pipeline)
	Conventional Internal Combustion Engine (ICE) vehicles
	Advanced ICEs (super-efficient, known technologies)
	Hybrids
	Non-fossil (i.e. electric, hydrogen etc)

APPENDIX C: Abatement mechanisms and assumptions

This Appendix:

- Provides an overview of how GTEM models emissions and abatement outcomes.
- Reports the implied economy-wide abatement outcomes for the assumptions used in this report.
- Reports abatement outcomes from this study in comparison to previous GTEM analysis.
- Outlines the role and contributions of international offsets.
- Details sector-level abatement functions and outcomes.
- Documents the assumptions and results for land sector offsets, with particularly attention to Australian supply.

Representing low emissions pathways in GTEM

A key feature of GTEM is the way it integrates economic, energy and emissions data across sectors and regions to explore and assess different scenarios. This incorporates the costs of different approaches to producing goods and services (shaping supply), and the demand for each of those goods and services, for each country and region in the model, for each year of the scenario.

Economic activity generates demand and supply of resources, energy (in different forms), inputs to production (including labour, capital, and intermediate goods), and final goods and services.

Greenhouse gas emissions can enter this economic calculus in a number of ways:

- an abatement incentive can be introduced, which motivates economic agents to avoid (or reduce) emissions wherever the cost of doing so is equal to, or below, the level of the incentive; or
- a constraint on the volume of emissions can be imposed (on a sector, or country, or group of countries); or
- emissions can be treated as costless and unconstrained, so that producers and consumers have no motive to reduce their emissions, with decisions that give rise to emissions made only on the basis of other factors.

The first two of these approaches is often referred to as introducing a ‘marginal cost of abatement’, either directly or indirectly, as discussed below. This is a stylised mechanism used to drive technology switches in the model, but does not represent a real world ‘tax’ or ‘carbon price’. This is because in the real world these incentives can arise in a number of ways, including through voluntary action (for example firms adopting low emissions technologies to gain market advantages or meet investor or shareholder expectations), or consumers choosing to purchase lower emissions products. For this reason the modelling does not necessarily assume that abatement incentives are imposed by government.

In scenarios which include an emissions constraint or abatement incentive, GTEM accounts for a variety of abatement mechanisms:

- Changes in the relative cost of different electricity generation and land transport options drive changes in the mix of generation and transport technologies to solve for the lowest cost options. This leads to reduced emissions from these sources, and incentivises the deployment of BECCS and DAC negative emissions technologies where relevant. Producers and households also substitute between available energy and fuel inputs based on relative prices.
- Learning by doing reduces the cost of emerging technologies (including variable renewables, CCS-based electricity generation, and fully electric vehicles) over time as the efficiency of production increases when cumulative global deployment or production increases.
- In scenarios that allow land sector sequestration, the supply of land offsets is calculated on the basis of other analysis (see section on Land Sequestration) as a function of the marginal cost – here it represents a payment to landholders – and the volume of land offsets is included in the modelling.
- Marginal abatement costs associated with the supply of goods and services flow through to final prices, shifting demand towards lower emissions intensity options (all else equal), and flowing through to relative returns on investment and other factors of production.
- The marginal abatement cost also drives non-CO_2 emissions reductions using emissions response functions, reducing the emission intensity of sector output. This represents changes in production methods, such as the use of feed supplements to reduce livestock methane emissions, or improved management processes to prevent leakage of HFC gasses from refrigeration units.

Each of these mechanisms operates in the context of supply, demand, and prices of all goods, services, and inputs to production represented in the model.

Taken together, these mechanisms enable industries, households and regions to reduce the emissions intensity of economic production and consumption in the most efficient way possible, in each year, given relevant scenario assumptions.

Because GTEM does not incorporate the physical or economic impacts of climate, recognition of marginal costs of abatement typically results in negative economic impacts, as abatement incentives drive producers to shift to relatively less efficient higher cost production inputs. In the cases of electricity and transport, for example, abatement incentives drive the sectors to use relatively high cost technologies (with low emissions) for their production.

The features of GTEM discussed above show the model is suited to analyse emissions reductions in a variety of ways. In this modelling, GTEM is used to implement global emissions reductions in the following ways:

- First, each country or region is allocated an emissions budget. GTEM then determines the economy-wide marginal cost of abatement so that each region's emissions, including all offsets, are consistent with and do not collectively exceed the emissions budget constraint incorporated into the design of each scenario. Emissions trading is implemented either within a defined group of regions or all regions, subject to the emissions trading limitations imposed in each relevant scenario. This results in a uniform abatement cost within each group or 'trading bubble'.
- Second, each country or region or specific sector can be made subject to an assumed economy-wide marginal abatement cost, and therefore make GTEM implement all abatement options that cost less than this.
- Third, the model can assess the implications of imposing specific technological assumptions for emissions and abatement outcomes. This could include things such as changes to energy efficiency and energy intensity in specific sectors, or scenarios exploring different pathways for electricity generation or road transport technology shares.

The modelling for the Plan assumes the first of these approaches, implementing a global emissions trajectory that limits warming to below 2°C, and allocating an emissions budget to each country (as described in Appendix D below). This gives rise to a global marginal abatement incentive as a modelling result, with the level of incentive influenced by the global trajectory and the technology assumptions of different scenarios. The No Australian Action scenario assumes Australia does not participate in this global action, and does not adopt a 2050 target. All scenarios assume abatement incentives are universal (motivating action in all sectors), and uniform (applying at the same level) across all sectors in any given country or region. Box B2 in the main report provides additional detail on interpreting abatement incentives in the economic modelling.

Marginal abatement costs motivate mitigation action within the model by encouraging industries and households to take up the lowest-cost opportunities to reduce emissions. All scenarios explored in the modelling assume that each sector is willing to pay for each tonne of abatement unlocked in the most cost-effective way in a given year. The modelling assumes that this management of emissions is considered part of production costs, with the cost of achieving emissions reductions passed on to final consumers, including overseas consumers of exported products.

This approach to achieving abatement through an explicit 'marginal abatement cost' is widely used across all computable general equilibrium modelling in assessing changes in production and technology deployment in response to policies aimed at reducing greenhouse gas emissions. This approach and the use of marginal abatement costs is also widespread in other modelling frameworks, such technology-based electricity systems models, and partial static land use models.

The marginal cost of abatement does not represent a carbon tax, and no revenue is collected or paid to government within the model when it is implemented, and as such it should not be interpreted as a government levied or sanctioned charge or cost impost upon any sector of the economy.

Implied economy-wide abatement outcomes

The mechanisms described above together result in total economy-wide abatement that increases as a function of the marginal cost of abatement.

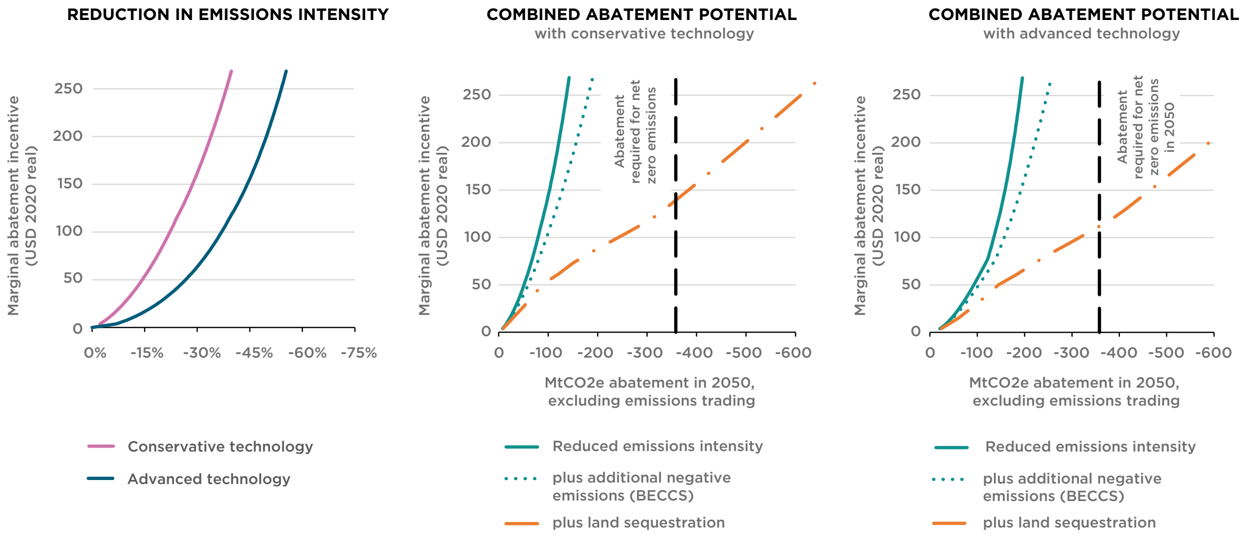
Figure 25 below presents analysis of these economy-wide abatement potentials for conservative and advanced technology in 2050 relative to the No Australian Action scenario. This framing focuses on the additional abatement associated with Australian emissions reductions efforts. (Appendix E presents information on Australian abatement outcomes assessed relative to the Pre-Glasgow underlying baseline.)

The analysis illustrates how abatement becomes more costly, per unit, as the task increases. For example, increasing the national abatement task by half (from 30% to 45% of total emissions) results in the marginal cost of abatement more than doubling – as shown in the left panel of Figure 25.

These abatement estimates include the effects of changes in electricity and transport technologies and fuel mixes, along with reductions in sectoral emissions intensity achieved through sector-level abatement functions. Together these drive reductions in the emissions intensity of economic activity, shown in the left panel as a percentage reduction in emissions. The centre and right panels show abatement potential in Mt CO_2-e, where 536 Mt of abatement represents achieving net zero emissions. These panels show the total abatement potential from reductions in emissions intensity, plus the deployment of additional negative emissions technology, along with a commercially attractive volume of land sector sequestration for a range of marginal abatement costs. The panels do not show abatement available through international emissions trading, which is able to offset up to an additional 160 Mt CO_2-e at the global market price of USD $60/t (A$86/t) with conservative technology and USD $30/t (A$43/t) with advanced technology.

The method used to derive these estimates represents the aggregate GTEM abatement potential in any one year, assuming no changes to Australia's economic structure. The estimates thus understate total abatement potential over time, as they do not include abatement that would occur through changes in global and domestic economic structures, including fuel and energy input switching (outside electricity generation and road transport), and increased production and use of hydrogen.

Figure 25. Economy-wide abatement outcomes as a function of marginal abatement costs, with conservative and advanced technology



Notes: *Abatement relative to the No Australian Action scenario in 2050, which has projected gross emissions of 358 MtCO$_2$-e. Reductions in emissions intensity represent shown do not account for structural change, including fuel switching, and thus understate total abatement, as discussed in the text.*

Source: *DISER economic modelling for the Plan.*

The assumptions and approach adopted to modelling of abatement with advanced technology are summarised under Key Finding 1 in the main report. Details of sector-level abatement functions are set out below. Appendix E reports GTEM abatement outcomes and economic impacts in this project relative to previous studies.

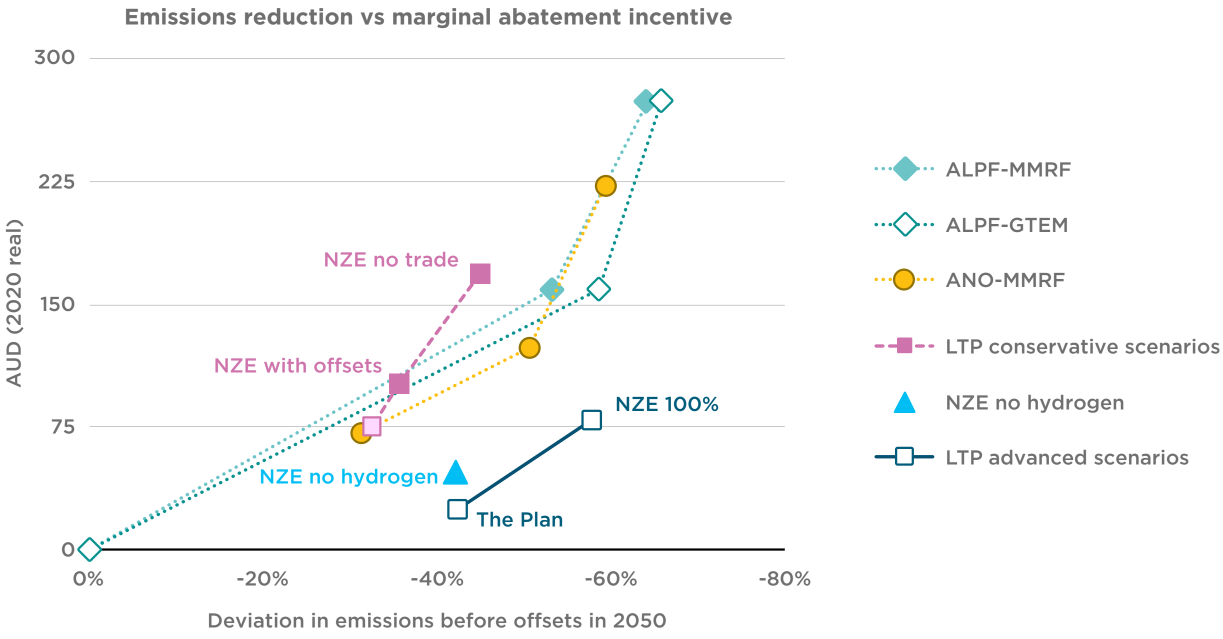
Comparison of abatement outcomes to previous studies

Figure 26 shows emissions reductions in 2050 relative to emissions levels in the 'current policies' or 'material intensive' baseline scenarios for this project and two previous studies, the Treasury (2008) Australia's Low Pollution Future and the CSIRO (2015) Australian National Outlook. These emissions reductions are shown versus the marginal abatement incentive in 2050, converted to real 2020 values. The figure includes results for two background LTP scenarios: one with advanced technology but no global or Australian hydrogen production, used to assess the contribution of hydrogen to outcomes in the other advanced technology scenarios, and a conservative scenario with no constraints on emissions trading (resulting in a $80/t abatement incentive).

For conservative technology scenarios, the projected emissions reductions relative to the 'current policies' baseline are similar to results from previous GTEM studies. The results indicate that abatement costs rise more steeply than in previous studies, as shown by results of the NZE no trade scenario in Figure 26. This is consistent with higher uptake of renewable energy in the Pre-Glasgow underlying baseline scenario, which reduces the extent of abatement potential in the electricity sector relative to previous studies.

For advanced technology scenarios, projected emissions reductions are substantially larger than those suggested by previous studies, particularly for lower levels of abatement incentives. The modelling finds that the NZE 100% scenario (with an $80/t incentive) achieves around double the abatement achieved in the ANO 'moderate effort' scenario ($70/t incentive) and in the background LTP conservative scenario with no limits on trade ($75/t incentive). The effect of advanced technology is smaller at higher levels of incentive, increasing abatement by around 50% with a $200/t incentive in 2050 (see Figure 25 above).

Figure 26. Emissions reductions versus marginal abatement scenarios in comparison to previous studies



Notes: *Referenced previous studies are Australia's Low Pollution Future: The Economics of Climate Change Mitigation (ALPF 2008); Australian National Outlook (ANO 2015).*

Source: *DISER economic modelling for the Plan.*

The logic and contributions of emissions trading

The modelling allows regions to meet their net emission budget through emissions trading, in which the purchasing region is able to offset some of their emissions by supporting additional abatement in other regions.

This trade in emissions units provides win-win opportunities for both regions. Trade enables the purchasing region, typically a high-income region, to meet its emissions abatement target at a lower economic cost than would occur if it undertook that abatement domestically. The region supplying the emissions units, typically a lower-income region, gains economically as the payment received brings benefits and opportunities to the economy. In aggregate, this results in a net transfer to medium and low income countries, while reducing the costs and economic impacts of global action on high income countries.

The opportunities offered by emissions trading reflect the burden sharing approach used in the modelling to achieve global emissions reductions. This approach assumes – consistent with the principle of common but differentiated responsibilities – that high income countries accept and achieve much deeper and rapid reductions in net emissions than low and medium income countries. To illustrate the extent of the abatement task for different groups: each high income country or region achieves net zero in 2050, reducing their net emissions by 100% from the level they would be in a Pre-Glasgow, while global emissions in aggregate are around 50% below the Pre-Glasgow underlying baseline. Because marginal abatement costs, per tonne, increase as the size of the abatement task increases (as shown in Figure 25 above), these differentiated obligations give rise to gains from trade between countries with different relative abatement tasks, and provide a durable and ongoing basis for emissions trading.

Sector-level abatement response functions

GTEM uses marginal abatement response functions (also referred to as MAC curves) to represent how industries are likely to reduce their emissions per unit of output in response to different levels of marginal abatement costs. This represents industry responses to a range of real world motivations to reduce the emissions intensity of production, including government regulations, industry codes of practice, or measures undertaken to meet investor expectations or consumer preferences (including certification systems). Response functions are commonly used tools in computable general equilibrium modelling to reflect adoption of new or different production processes and technologies in response to policies intended to reduce greenhouse gas emissions, or the voluntary actions of companies and consumers to choose lower emissions goods and services. The response functions do not impose additional productions costs, however as noted above the aggregate value of residual emissions are included in the cost of production based on the marginal cost of emissions in each year.

These abatement response functions are an established feature of GTEM, and have been used in all previous GTEM analysis. The response functions used in the current modelling are based on a similar approach used by Treasury (2008) and have a similar functional form with updated parameters.

The parameters are selected to model the selected industries as best as possible based on sector specific information on technology and production possibilities.

Table 14 sets out outcomes of the sector-level abatement functions used in the modelling. The parameters used for conservative technology are based largely on those used in CSIRO (2015) analysis, while the advanced technology parameters were developed as part of the project, drawing on the LETS 2021 and other sources. Output abatement functions are applied to process emissions from production, while input abatement functions adjust emissions from the use of inputs (such as traditional energy sources) in the transport sector. As shown in the table, the implementation of advanced technology in the modelling has little or no impact on the emissions intensity of electricity or stationary energy. Changes in relative prices will influence the mix of energy sources, however. For example, electrification of industrial processes will reduce the use of gas and increase the use of electricity, with flow on effects for total emissions.

Table 14. Sector-level abatement outcomes for non-combustion emissions and transport biofuels

	Conservative technology		Advanced technology	
Marginal incentive (AUD 2020 real)	$50	$200	$50	$200
Combustion emissions				
Electricity	-10%	-34%	-10%	-33%
Stationary Energy	-4%	-14%	-4%	-14%
Transport	-12%	-27%	-32%	-53%
Non-combustion emissions				
Agriculture (all)	-22%	-46%	-42%	-68%
Agriculture: livestock	-22%	-46%	-42%	-67%
Agriculture: other	-26%	-46%	-40%	-81%
Industrial	-13%	-27%	-42%	-78%
Fugitives	-7%	-17%	-15%	-31%
All emissions				
Total abatement	-11%	-27%	-22%	-43%

Source: *DISER economic modelling for the Plan. Modelling assumptions informed by analysis by McKinsey and DISER.*

Land sequestration supply

The modelling accounts for potential voluntary supply of land sequestration, motivated by payments to landholders at levels that match marginal abatement costs in each scenario. These payments provide an incentive for landowners to manage their soils and plant trees to absorb (sequester) greenhouse emissions from the atmosphere and generate accredited offsets, thereby reducing net emissions. This results in landowners providing land sector offsets at a lower cost than faced by other actors in the economy to reduce their emissions. The purchase of land sector offsets by other actors provides additional income to landholders, and enables net emissions to be reduced at a lower overall cost to the economy.

Emissions reduction from land use change is modelled as a market-driven voluntary activity, which only occurs where it provides economic benefits to landholders. The modelling incorporates land sequestration in all scenarios, as described below. Information on supply as a function of payment levels (aligned to the marginal cost of abatement in each country, in each year) are sourced primarily from two specialist landuse models:

- Australians supply is sourced from the CSIRO Land Use Trade-Offs (LUTO) model (Connor, et al., 2015); and
- Supply in all other countries and regions is sourced from the International Institute for Applied System Analysis's Global Biosphere Management Model (GLOBIOM) (Havlík et al., 2018).

Australian land sector supply

For Australia, the modelling accounts for three sources of domestic land sequestration: soil carbon, on-farm plantings and reafforestation, and off-farm supply (including savannah management and native forest management). It does not include avoided land sector emissions from deforestation or other sources.

As reported in Australia's Long-Term Emissions Reduction Plan (Commonwealth of Australia, 2021b), the modelling finds that up to 63 Mt CO_2-e of accredited carbon offsets could be produced each year by 2050, involving 1.5 million hectares of on-farm plantings (equivalent to 2% of total agricultural land). This assumes advanced technology with an abatement incentive of \$80/t CO_2-e, generating \$5.0 billion in new landholder revenue in the NZE 100% scenario. The sequestration is made up of 26 Mt CO_2-e from soil carbon, 21 Mt CO_2-e from on-farm plantings, and 15 MtCO_2-e from other sequestration. As described below, the analysis finds this level of sequestration can be achieved from targeted environmental plantings without any negative impact on farm output. All domestic offset are provided voluntarily on the basis that they produce a more profitable business outcome for the farmer.

Soil carbon

There are a wide range of estimates of the potential to permanently store additional carbon in farm soils (see Box 2.4 on page 56 of Australia's Long-Term Emissions Reduction Plan, Commonwealth of Australia, 2021b).

The modelling assumes soil carbon volumes at the lower end of the range, reflecting requirements for accreditation and permanence, as shown in Table 15 below. This implies that the projected contributions of soil carbon in the Plan scenario could be materially exceeded.

The modelling also assumes lower measurement costs will allow an increased supply soil carbon offsets. This reflects the Australian Government's technology stretch goal to decrease the cost of soil carbon measurement from current levels of around \$30 per hectare per year down to less than \$3 per hectare per year before 2030. Achieving this goal will require advances in modelling and remote sensing to reduce the frequency of physical testing.

On-farm plantings

The modelling assumes that policy settings or market expectations require on-farm plantings to provide some biodiversity co-benefits in addition to carbon sequestration. This results in a lower level of supply and smooths the supply of sequestration over time, reducing the extent of land use change before 2050, all else equal. The analysis of on-farm plantings accounts for the area of plantings, and the extent to which plantings can be implemented without reducing traditional agricultural output (such as through establishing shelter belts), rather than requiring a withdrawal of land from agricultural production.

The LUTO modelling indicates the extent of feasible abatement over time from land use changes for a series of marginal abatement costs. It details sequestration, land use, and agricultural production in physical units across a range of scenario assumptions. The CSIRO LUTO analysis adopts the method from CSIRO (2015) with minor adjustments, as set out below. The primary focus is on the potential supply 'at scale' from plantings with establishment costs, and the method is likely to understate low cost niche sequestration (such as assisted regeneration).

The CSIRO LUTO analysis models a range of scenarios with marginal abatement costs starting between USD $20 and USD $50 in 2025, rising between 2% and 4% per year (in real terms) to 2075. The analysis is spatially detailed, and accounts for a large number of variables.

- The analysis assumes plantings occur when the expected returns are at five times the expected returns to current land use, consistent with Denis-Ryan et al. (2014), shown as the 'high threshold' supply in Figure 27 and Table 15, below. The assumption recognises that farmers need to have confidence in additional returns to invest the time and effort required to change their activities and participate in new markets, and is consistent with the Government's preference to limit the conversion of agricultural land to carbon farming. Table 15 also provides information on projected supply with a two times threshold, for comparison.
- The analysis assumes landholders are required to cover the cost of water interceptions in water limited catchments, where relevant, equivalent to buying annual water allocations.
- The analysis also accounts for central estimates of the impacts of climate change on rainfall (using the assumptions from CSIRO (2015)). The supply of sequestration is subject to a risk buffer. Given uncertainties around future bushfire risk, the analysis doubles the bushfire risk buffer from the previous CSIRO estimate.
- All changes in land use increase total land sector incomes, but in some instances may involve reduced income from traditional agricultural sectors (such as livestock) which is more than offset by an increase in carbon and biodiversity payments.
- Reporting of raw LUTO results for land use and the value of agricultural output assumes all land use changes at that specific location, with supply of sequestration in line with the physical life cycle of new plantings.

This analysis finds relatively low volumes of sequestration where payments to landholders are less than USD $40, with substantially higher volumes supplied at higher payments levels.

The CSIRO LUTO analysis is supplemented by other estimates of supply from soil carbon and from savannah and land management outside the intensive agricultural land use zone, as described below.

Biodiversity co-benefits

The LTP modelling assumes plantings are required to provide some biodiversity co-benefits. This is achieved in two ways in the CSIRO LUTO analysis:

- All plantings in bioregions with less than 30% remaining native vegetation are mixed species plantings.
- The modelling assumes that landholders deliver biodiversity outcomes in addition to carbon when they supply land sector offsets. This is consistent with work underway through the Agriculture Biodiversity Stewardship Program to develop a market-based approach to rewarding farmers for improving on-farm biodiversity. For regions with more than30% remaining native vegetation this is implemented using an approach adapted from CSIRO (2015, pp.28-29), and calibrated to deliver around half the biodiversity benefits of the 'balanced scenario' in CSIRO's 2015 analysis with a carbon price of $80/t CO_2-e.

Apportioning plantings to on-farm versus enterprise change

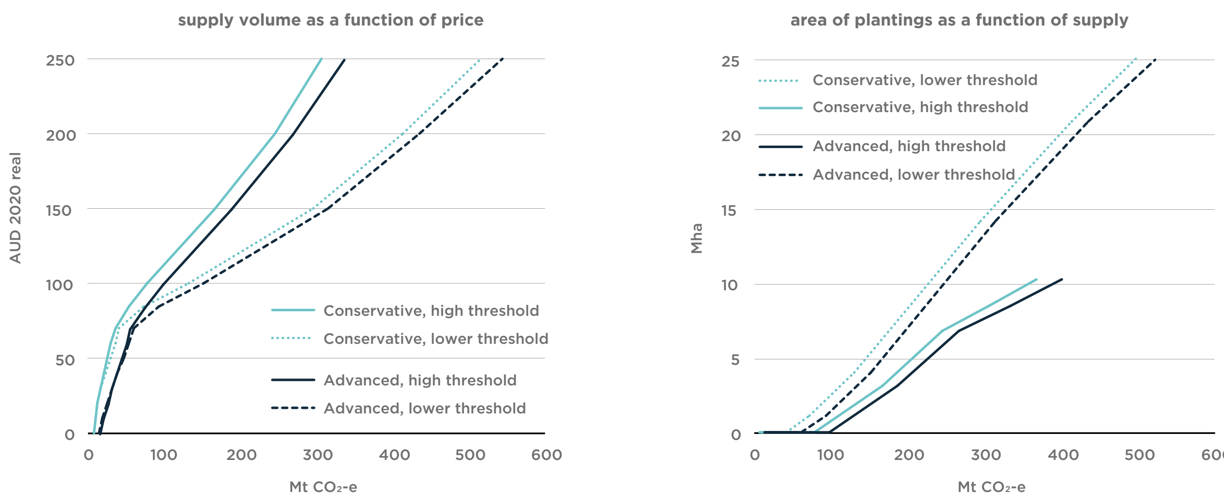
CSIRO advice on abatement potential estimates up to 10% of agricultural land could be replanted with no negative impacts on agricultural output. The GTEM modelling assumes this could occur on up to 7% of highly cleared land, equivalent to around 3% of all cleared agricultural land.

The analysis uses estimates from Paul et al (2016) for sequestration potential and land area from on-farm plantings that could be achieved without a net negative impact on productivity, noting findings by other authors that replanting an average of 5% or more of farm area would generally have positive productivity impacts.

- Paul et al (2016) analyses sequestration and biodiversity outcomes from different on-farm plantings, such as shelter belts and targeted revegetation of gullies and riparian areas. This analysis estimates environmental plantings on 5% of cleared agricultural land would sequester 25.1 Mt CO_2-e per year from 2.26 Mha. Narrow belts of monoculture eucalyptus on 5% of cleared marginal land would sequester 16.8 Mt CO_2-e per year from 0.93 Mha.
- The GTEM modelling assumes these plantings account for up to two thirds of the LUTO estimates of supply, up to a maximum of 7% of highly cleared agricultural land.
- In addition, the analysis assumes a further 2.8 Mt CO_2-e per year from plantings in gullies and riparian zones, involving 0.25 Mha in 2050, based on DISER estimates.
- This gives total potential supply of 25-51 Mt CO_2-e from 3.2 Mha of on farm plantings with no net productivity loss (with supply volume depending on the assumed profitability threshold).
- The analysis assumes no supply is provided by farm forestry.

The results of these calculations are shown in Figure 27 and Table 15 below.

Figure 27. Land sequestration supply and land use impacts, 2050



Source: *DISER economic modelling for the Plan. Modelling assumptions based on projections from LUTO and other sources as described in the text.*

Land sector sequestration in all other countries

Data for land sequestration potential in all other countries is drawn from the GLOBIOM model. This data is used to calculate supply curves as a function of marginal abatement costs and payments to landholders on for each country and region in the GTEM model, other than Australia (see Table 11).

This is generated from a specially prepared GLOBIOM land surface data cube, matching the GTEM country aggregation, based on scenario projections from Frank et al (2021). This method is broadly similar manner to the way LUTO is used to determine the supply of land sequestration in Australia. The projections used are for the SDG scenario (RCP2.6, SSP2) with a zero biomass price.

Table 15. Australian land sequestration by source in 2050 as a function of payment level

Supply price (A$/tCO2-e)		0	10	20	30	40	50	60	70	85	100	150	200	250	300
Conservative, high threshold															
Total LUC supply	$MtCO_2$-e	8.1	10.0	11.9	16.4	21.1	25.9	30.7	35.4	54.0	77.7	167.2	245.0	306.3	367.5
Soil carbon	$MtCO_2$-e	3.0	3.3	3.7	4.1	4.4	4.8	5.2	5.6	6.3	7.2	10.3	13.5	16.8	20.2
On-farm plantings	$MtCO_2$-e	1.4	2.1	2.8	5.3	8.0	10.7	13.4	16.1	32.3	54.6	139.1	209.8	262.2	314.7
Other supply	$MtCO_2$-e	3.7	4.5	5.4	7.0	8.7	10.4	12.0	13.7	15.4	15.9	17.9	21.7	27.2	32.6
Area of on-farm plantings	Mha	0.1	0.2	0.2	0.4	0.6	0.8	1.0	1.2	2.2	3.5	6.6	10.9	13.6	16.3
Area removed from production	Mha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	6.9	8.6	10.3
Advanced, high threshold															
Total LUC supply	$MtCO_2$-e	13.9	19.2	24.4	30.4	36.4	42.4	48.4	54.5	74.0	97.6	186.5	267.2	333.9	400.7
Soil carbon	$MtCO_2$-e	8.8	12.5	16.2	18.1	19.7	21.3	23.0	24.6	26.3	27.1	29.6	35.6	44.5	53.4
On-farm plantings	$MtCO_2$-e	1.4	2.1	2.8	5.3	8.0	10.7	13.4	16.1	32.3	54.6	139.1	209.8	262.2	314.7
Other supply	$MtCO_2$-e	3.7	4.5	5.4	7.0	8.7	10.4	12.0	13.7	15.4	15.9	17.9	21.7	27.2	32.6
Area of on-farm plantings	Mha	0.1	0.2	0.2	0.4	0.6	0.8	1.0	1.2	2.2	3.5	6.6	10.9	13.6	16.3
Area removed from production	Mha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	6.9	8.6	10.3
Conservative, lower threshold															
Total LUC supply	$MtCO_2$-e	8.1	10.0	11.9	17.6	23.6	29.6	35.7	41.7	72.5	131.1	295.3	413.4	516.8	620.1
On-farm plantings	$MtCO_2$-e	1.4	2.1	2.8	6.5	10.5	14.4	18.4	22.4	50.8	107.9	267.1	378.2	472.7	567.3
Area of on-farm plantings	Mha	0.1	0.2	0.2	0.4	0.6	0.8	1.0	1.2	3.4	7.6	17.6	24.9	31.1	37.3
Area removed from production	Mha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	4.1	14.2	20.9	26.1	31.3
Advanced, lower threshold															
Total LUC supply	$MtCO_2$-e	13.9	19.2	24.4	31.6	38.9	46.1	53.4	60.7	92.5	151.0	314.6	435.6	544.5	653.3
On-farm plantings	$MtCO_2$-e	1.4	2.1	2.8	6.5	10.5	14.4	18.4	22.4	50.8	107.9	267.1	378.2	472.7	567.3
Area of on-farm plantings	Mha	0.13	0.18	0.24	0.42	0.61	0.80	0.99	1.18	3.38	7.55	17.62	24.85	31.06	37.28
Area removed from production	Mha	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	1.16	4.11	14.18	20.86	26.07	31.28

Source: *DISER economic modelling for the Plan. Modelling assumptions based on LUTO and GLOBIOM.*

APPENDIX D: Key modelling assumptions

Assumptions are the building blocks of each modelling scenario, as they shape what a scenario looks like and how it functions. Assumptions can cover a wide range of economic, social and environmental variables.

This appendix groups assumptions into two main categories:

Calibration of the underlying baseline, which are modelling assumptions that create the foundation on which the defined scenarios are built and underpins all scenarios, unless varied by the other categories of assumptions.

Global action assumptions, which establish the global context of the Australian scenarios and analysis.

Details on the third group of assumptions – Specific Australian scenario assumptions —are provided in Appendix A.

The final section of the appendix reports technical details relating to the implementation of the modelling.

Assumptions used to calibrate the Pre-Glasgow underlying baseline scenario

Table 16 provides a summary and overview of the assumptions used to calibrate the Pre-Glasgow underlying baseline for the modelling and analysis.

Table 16. Calibration of Pre-Glasgow underlying baseline

	Calibration	Source data
Socio-economic	Actual real GDP growth to 2020 Real GDP growth projections 2021 to 2050; extrapolated to 2100	Australia: 2021 Intergenerational Report (Australian Government, 2021) World: Long Term International GDP Projections (Au-Yeung, Kouparitsas, Luu, & Sharma, 2015)
	Population growth projections to 2100	Australia: 2021 Intergenerational Report (Australian Government, 2021) World: World Population Prospects 2019 (UN, 2019)
Technology	No additional productivity improvement in hydrogen production	Not applicable
	Technology shares for electricity generation and road transport are calibrated to DISER projections for Australia and IEA current policies scenario for the world to 2030	Australia: Australia's Emissions Projections 2021 (Commonwealth of Australia, 2021) World: World Energy Outlook, 2021 (IEA, 2021)
	Efficiency gains parameters	Modelling assumption (detailed below)
	Renewable energy cost reductions	Modelling assumption (detailed below)
Emissions	Australian baseline emissions are calibrated to Australia's 2021 emissions projections by aligning sectoral emissions in 2020 by UNFCCC category, and calibrating electricity, agriculture, and LULUCF emissions to 2040 and total net emissions to 2040 to Australia's Emissions Projections 2021 trajectory	Australia's Emissions Projections 2021 (Commonwealth of Australia, 2021)
	High income countries meet their Nationally Determined Contributions (NDCs) in 2030	Detailed below
Industry Output	Australian agriculture production to 2040 linked to ABARES estimates	Snapshot of Australian Agriculture 2021 (ABARES, 2021)
	Consumption mix adjusted to reflect the effects of incomes growth.	Modelling assumption (detailed below)

Source: *LTP GTEM modelling assumptions.*

Economic and population growth

The real GDP and population growth rates for Australia have been imposed in the baseline for the period 2020 to 2100. Growth rates to 2050 are sourced from the Treasury's 2021 Intergenerational Report. Real GDP and population growth rates for the remaining 23 GTEM regions are also imposed from 2020 to 2050 using unpublished projections from the Treasury, summarised below. These have been developed using the Long-term international GDP projections framework (Au-Yeung, Kouparitsas, Luu, & Sharma, 2015). Growth rates to 2050 were extrapolated out to 2100.

National production (GDP) in each region is normally determined by GTEM. To enable it to be calibrated in the underlying baseline, real GDP growth is fixed (made exogenous) by allowing all input-augmenting technical change to be determined by the model (made endogenous). Changes in real GDP growth in all other scenarios are determined by GTEM.

Table 17. Annual average growth rates for Australian population and real GDP

Decade	Population (%)	Real GDP (%)
2020s	1.0	2.5
2030s	1.2	2.9
2040s	1.0	2.5
2050s	0.9	2.3

Source: *The Treasury (unpublished).*

Table 18. Average annual growth rates for world population and real GDP

	Population (%)				Real GDP (%)			
Regional grouping	2020s	2030s	2040s	2050s	2020s	2030s	2040s	2050s
High Income	0.2	0.1	0.0	-0.1	2.0	1.2	1.3	1.3
Medium income								
High Emissions intensive	0.5	0.2	0.0	-0.1	4.3	2.4	1.9	1.3
Low Emissions intensive	0.7	0.5	0.2	0.0	3.1	1.7	1.3	1.1
Low Income	1.6	1.3	1.1	0.9	5.2	3.3	2.7	2.2

Source: *The Treasury (unpublished).*

Energy efficiency

A uniform efficiency improvement is assumed for each energy commodity used in production across all sectors in all regions. This reflects the regulatory requirements to meet energy rating standards together with autonomous improvements due to technological process.

Table 19. Average annual energy efficiency improvements, 2020-2050

Energy commodity	Efficiency improvement (%)
Coal	1.0
Gas	1.0
Petroleum and coal product	1.0 for all sectors except road transport; 2.0 for road transport
Hydrogen	1.0 (if applicable)
Electricity	1.0

Note: *These efficiency improvements are applied to the baseline between 2020 and 2050.*

Source: *LTP GTEM modelling assumptions.*

Technology mix for electricity and transport

The modelling baseline calibrates the shares of relevant electricity technologies and the share of electric vehicles to the IEA's latest projections (IEA, 2021) for selected world regions till 2030, where GTEM electricity technologies and regions could reasonably be mapped to IEA's. For Australia, these technology shares are imposed based on DISER's latest projections (Commonwealth of Australia, 2021a). Technology shares are shocked by allowing changes in demand to occur beyond those implied by price changes alone.

Bioenergy with carbon capture and storage (BECCS)

The GTEM technology bundle database assumes that a small amount of electricity is generated by BECCS. This assumption is a standard approach in CGE modelling that allows embryo technologies to grow in the modelling when relative costs of production change as a result of policy incentives or technological breakthroughs. Europe and the United States together account for about 90% of the small amount of BECCS assumed in the database, with the remainder is allocated to all other regions. Australia accounts for less than 2% of the global total.

The volume of BECCS does not grow under the assumptions in the baseline scenario, as the technology is not economically viable in the absence of incentives.

Cost reduction of electricity technologies and electric vehicles

The world has experienced significant cost reduction in solar and wind technologies for electricity generation over the past decade. Global production of electric vehicles has also risen significantly recently. To reflect these trends in the LTP modelling, production efficiency improvements are assumed for renewable technologies for electricity generation and for electric vehicles for use in road transport across all regions.

Generally, high income countries have greater capacity to adopt these technologies than mid to lower income countries. This is captured in the model through differentiated cost reductions across regions.

Table 20. Average annual efficiency improvement for relevant technologies, 2020-2050

Technology	Electricity (%)	Road transport (%)
Wind	3.5	
Solar	3.5	
Bio-energy (BECCS)	3.5	
Waste & other combustibles	3.5	
Geothermal, wave and other renewables	3.5	
Electric vehicles		1.5

Source: *LTP GTEM modelling assumptions.*

Agricultural output

The modelling baseline calibrates Australian agriculture, fisheries and forestry production volumes to align with the latest published data from the Australian Bureau of Agricultural and Resource Economics and Sciences (Weragoda & Duver, 2021). Table 21 shows the assumptions for these projections. These projections assume historical rates of productivity growth are maintained into the future, embedding continued investments in research and development and continued market-based policy reforms into the baseline. The projections do not account for year-on-year variability in production associated with climate variability, and do not account for the impacts of climate change. Australian agricultural output is shocked by allowing output-augmenting technical change to vary in those industries.

Table 21. Annual average output volume growth for Australian agriculture, 2020-2040

Sector	Output growth (%)
Crops	1.5
Cattle and sheep	0.3
Other animal products	1.0
Fisheries	1.2
Forestry	1.0

Source: *ABARES (2021)*

Taste shifts towards services, reflecting income elasticity

The modelling baseline projections include additional household taste shifts towards services as income rises, depending on the stage of development in each region. High income regions experience relatively slower shifts than middle to low income regions, as adjustment has already taken place in high income regions. These taste changes are calibrated in the modelling baseline so that the projections of household expenditure share of services is broadly consistent with the observed historical trend across world regions at different levels of per capita income.

Current account balance

It is assumed in the modelling baseline that the ratio of the current account balance to GDP in each region stays within a 5% range either as a deficit or surplus in the long run. Outside this rage, the current account balance gradually adjusts over time, using an adjustment parameter of 10%, meaning a 10% reduction of the range per year until it falls into the targeted range. This focus on achieving an appropriate current account balance ratio for each region leaves the saving rate in each region flexible. This approach is different to the closure used in previous GTEM modelling, which assumed a fixed saving rate in each region.

Resulting global emissions trajectory for the Pre-Glasgow underlying baseline scenario

The modelling established an underlying baseline scenario reflecting the policies and commitments of major countries (as at early April 2021), and associated technology trends, and assumes these policies continue without adjustment through to 2100. This scenario assumes all high income countries meet their 'Nationally Determined Contributions' (NDC) commitments in 2030, with no additional policy action after that; Australian emissions match DISER projections; energy technology deployment consistent with IEA 'current polices' projections; and country-level economic growth consistent with the Intergenerational Report 2021 (see Table 18 for more details).

These assumptions result in projected global emissions falling gradually to 42.2 Gt CO_2-e before 2060, and then trending upward as income and population growth outweigh trend reductions in emissions intensity. Emissions in 2100 are 51.0 Gt CO_2-e, higher than the IPCC RCP6.0 benchmark trajectory, which is trending down. This underlying baseline trajectory – which does not take account of additional commitments announced before Glasgow –would see global mean temperatures increase by 0.21-0.24°C each decade from 2030, reaching 3.1°C above pre-industrial temperature in 2100, and on track to substantially exceed 4.0°C over the long term.[10]

10 (1) Riahi et al (2017), (2) Calculated using live MAGICC (http://live.magicc.org/) from Meinshausen, M., S. C. B. Raper and T. M. L. Wigley (2011). "Emulating coupled atmosphere-ocean and carbon cycle models with a simpler model, MAGICC6: Part I – Model Description and Calibration." Atmospheric Chemistry and Physics 11: 1417-1456. doi:10.5194/acp-11-1417-2011. Calculation assumes gasses not covered by GTEM follow the same pathway as in the RCP4.5 CMIP5 dataset.

Global action assumptions

Table 22. Global action assumptions

	Assumption	Source data
Emissions	• All high income countries other than Australia track from their 2030 NDC baseline emissions to net zero in 2050. • China tracks from 2030 baseline emissions to net zero in 2060, in line with its NDC. • Middle income countries take on abatement obligations from 2035. • Low income countries take on abatement obligations between 2045 and 2055. • Change in land use emissions in each region based on GLOBIOM given their abatement incentive • International offsets (trading) is allowed for high income countries up to a maximum of 30% of their 2020 level of emissions in 2050, with the remaining coming from domestic reduction.	Modelling assumption (detailed below)
Technology	BECCS is assumed to grow for high income countries from 2040 and other countries after 2050 Global learning-by-doing further reduces the costs of BECCS as the global cumulative production of BECCS increases	Modelling assumption
	Renewable electricity technologies productivity improvements lead to additional cost reductions	Modelling assumption (detailed below)
	The existence of marginal abatement incentives give rise to efficiency improvements that reduce emissions from each unit of output	Modelling assumption (detailed in Table 13)
Land use change	Details provided in Appendix C	See Appendix C

Note: *A small amount of BECCS is assumed in the database (see BECCS assumption for the modelling baseline). BECCS does not grow in the baseline. In scenarios with global action, BECCS starts to grow from 2040 if it is cost-competitive.*

Source: *LTP GTEM modelling assumptions.*

Global emissions trajectory

All global action scenarios assume effective global action to reduce emissions and limit global warming (Appendix A).

The global emissions trajectory modelled in the conservative policy scenarios is consistent with the benchmark RCP2.6 trajectory from the International Panel on Climate Change (IPCC), based on the average of all emission of trajectories in the IIASA SSP database (Riahi, et al., 2017). This trajectory is likely (with a two thirds probability) to result in long term global temperature increase of 2oC or lower, and is thus described as a below 2oC trajectory in this report.

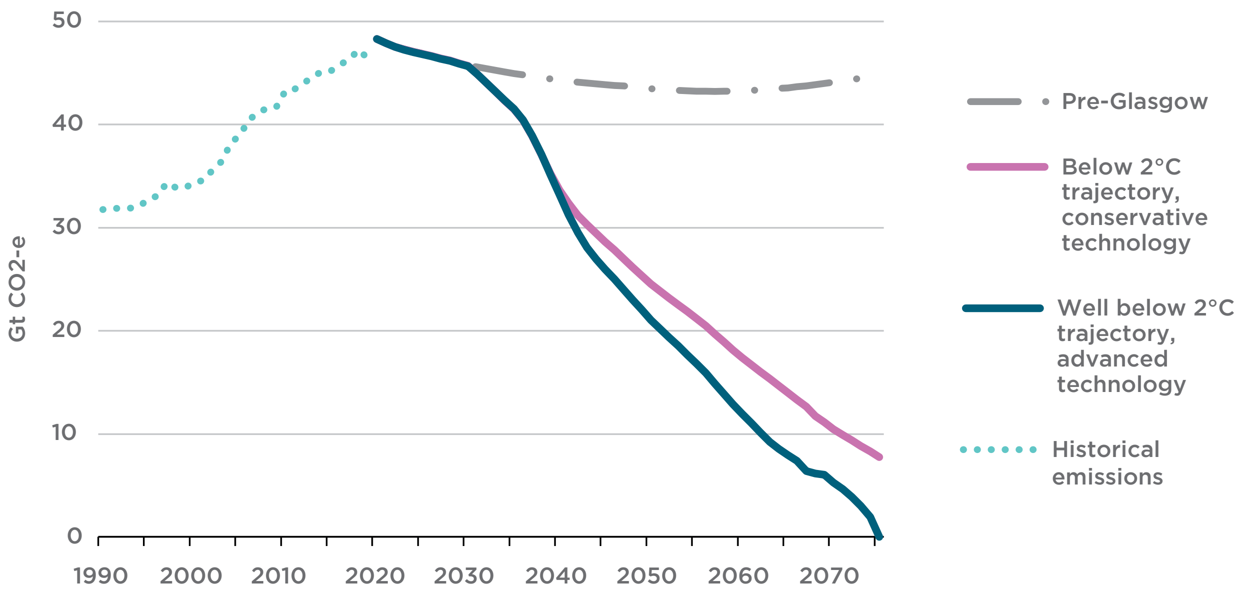
The global emissions trajectory modelled in the advanced technology scenarios involves global emissions that are 15% lower in 2050 than the conservative technology scenario, and tracks towards the lower end of the RCP2.6 range. This is described as a 'well below 2oC' trajectory in this report.

The method used to calculate this trajectory includes an assumption that benefits are shared two thirds as a reduction in the level of abatement costs, as described in the 'establishing the context' section of the report. This benefit sharing assumption is required because the framing of global action is predicated on achieving an assumed global emissions trajectory, which is allocated to each country and region in the model on the basis of the benefits sharing approach outlined below. This sets an assumed volume of emissions as the budget, and solves for the required marginal abatement cost, for each region, to achieve that budget. Given this framing, in the absence of an explicit benefit sharing assumption, all the benefits of advanced technology would appear as lower abatement costs. This result would be inconsistent with observed impacts of technological innovation.

The benefit sharing assumption is implemented using three additional background scenarios. The first scenario establishes the global marginal abatement cost trajectory that would occur with no change in the global emissions budget (using RCP2.6). A second scenario is then run that imposes global abatement cost trajectory and leaves emissions unconstrained. The cost trajectory is uniform across all countries and sources of emissions, with the cost per unit of emissions set in each year at two thirds of the observed gap between the new advanced technology RCP2.6 run and the equivalent scenario with conservative technology. The cost trajectory imposed yields the new global emissions trajectory for advanced technology as a modelling result. This trajectory is then imposed in the normal way in all other advanced technology runs.

These global trajectories are shown below.

Figure 28: Global net emissions trajectories, 2020–2075



Note: *Historical emissions are sourced from the Plan (Commonwealth of Australia, 2021b).*

Source: *DISER economic modelling for the Plan.*

Burden sharing and regional emissions trajectories

The modelling uses a stylised burden sharing formula to allocate available global emissions to each region in the model, with the allocation and timeframe over which adjustments occur varying across four groups. The allocations for:

- ***High income regions***: fall in a straight line from their 2030 NDC commitment to net zero in 2050;
    - The high income regions in the modelling are Australia, Canada, EU-27, New Zealand, North Asia, Rest of Western Europe, the United Kingdom and the United States (Table 10).[11]
- ***China***: fall in a straight line from its 2030 entitlement to net zero in 2060;
- ***Medium income regions***: emissions budgets for most regions follow their baseline emissions to 2035, while for the Middle East Other (MEO) region the emission budget is assumed to be plateaued at 2030 level till 2035 (preventing excessive windfall gains), after which they all begin to take on abatement obligations as set out below;
- ***Low income regions***: emissions budgets follow their baseline emissions to 2040, and then begin to take on abatement obligations

This logic defines a substantial fraction of global emissions which is allocated to countries other than high income countries and China using a criteria based formula:

- Two thirds of available entitlements are allocated in proportion to each country's share of emissions in the baseline (excluding emissions from land use change), recognising current endowments and patterns of development; and
- The remaining one third is allocated in proportion to each country's population, distributing the available entitlements as equal per capita emissions across all countries (other than high income countries and China).
- The allocation is subject to two constraints, that no country's entitlement can:
    - be higher than the country's emissions in the baseline in the corresponding year (preventing excessive windfall gains); and
    - decline more year-on-year than it would do in a straight line decline to net zero in 2070.

This gives an assumed emissions entitlement trajectory for each country and region for each year, with total emissions that are consistent with aggregate global emissions trajectory.

Limited emissions trading

The model determines the marginal abatement cost for each region and each year so that each region reduces its emissions to achieve the assumed trajectory specified above.

The global action scenarios all allow limited emissions trading globally, although in some scenarios Australia chooses not to fully participate in this trade. High income countries are required to achieve emissions reductions of at least 70% from their 2020 gross emissions levels by 2050, and thus are only able to purchase emission trading units up to 30% of this volume in any year. China is subject to the same constraint, set at 30% of its emissions in 2030.

The modelling assumes Australia does not supply land sequestration offsets to other countries through emissions trading.

11 The regional aggregations in GTEM mean that individual countries that have high incomes may form part of a region that is classified as being middle or low income.

Renewable electricity technologies

The global action scenarios assume additional cost reductions of renewable electricity technologies, reflecting accelerated research and development and technology deployment when the world takes action to reduce emissions. An additional annual 1% cost reduction on inputs is assumed for renewable electricity technologies globally between 2030 and 2050. For BECCS, while it is assumed to start to grow from 2040 in the global action scenarios, it is also assumed high income countries and China will adopt the technology earlier than other regions – consistent with this assumption, the global action scenarios assume an average annual 3% cost reduction on inputs of BECCS in high income countries and China between 2030 and 2050.

Global hydrogen production

In advanced technology scenarios, it is assumed that global hydrogen production is consistent with IEA's projected volumes in the 2°C Sustainable Development scenario (IEA, 2020). That is, global production of hydrogen grows to 290 Mt by 2050, with Australian production growing to 27 Mt. This is achieved through imposing an input neutral reduction in hydrogen production costs, calibrated to be just sufficient to result in this production volume. A uniform reduction in hydrogen production costs is assumed across all regions other than Australia in all hydrogen scenarios.

Current account balance

Implementation of the global action scenario assumes that the ratio of the current account balance to GDP in each region matches the ratio in the Pre-Glasgow baseline in each year. This is achieved by allowing the savings rate in each region to vary.

Modelling implementation and interpretation

Implementation of the global action scenarios

The modelling developed a series of scenarios from the Pre-Glasgow underlying baseline, through the following steps:

- First, implementing a global trading scenario without limits on permit trade to achieve the assumed global emissions trajectory as discussed above. This run provides inputs for subsequent runs. The inputs include the global marginal abatement cost for each year, the number of permits traded (exported or imported) for each region
- Second, the number of permits traded is then checked against whether a limit on international offsets applies in limited trade scenarios.
- If the limit binds for relevant regions (i.e. high income regions and China), the domestic marginal abatement costs for those regions increase to a level above the global marginal abatement cost required to meet their assumed trajectories.

Depending on a specific scenario, relevant assumptions discussed above are input into the implementation, which includes assumptions on technology, land use sequestration supply and limits on international offsets.

To interpret the effects of each modelling assumption, particularly, on the abatement options, results can be compared between pairs of relevant scenarios, and impacts of abatement options can be decomposed.

Given the focus of the analysis on impacts and pathways to 2050, most scenarios were only solved to 2060. Two exceptions include that the Pre-Glasgow underlying baseline was solved to 2100 and two advanced technology runs used to establish benefits sharing were solved to 2075.

Model closures

CGE modelling generally uses different closures between baseline and policy scenarios. This modelling assumes a typical closure for the baseline, where macro-economic conditions, i.e. GDP, population and labour supply projections, are imposed onto the model. With this closure, the model calibrates economy-wide productivity in the baseline for each region. GTEM has 4 types of primary factors which are used in production, including labour, capital, land and natural resources.

Labour is derived from the labour supply projections imposed, and land and natural resources are assumed to stay constant during the projection period. Capital is determined in the model according to the standard capital stock and investment flow equation. Given GTEM is a recursive dynamic model, productive capital in each year is pre-determined based on previous year's capital stock and investment.

The closures used for global action scenarios are also standard in CGE modelling, where macroeconomic variables such as GDP are determined by the model, while economy-wide productivity calibrated in the baseline remains the same as it is in the baseline. In doing it this way, economic impacts of actions to reduce emissions can be assessed. It is assumed that labour supply, land and natural resources stay the same as in the baseline, while capital stock varies between baseline and global action scenarios because the economic impacts affect investment in each region.

A key difference in the modelling closure from previous modelling using GTEM is the assumption on the ratio of current account balance to GDP. As discussed in detail in the modelling assumptions, it is assumed that the ratio of current account balance to GDP stays the same between baseline and global action scenarios, where the saving rate in each region is flexible in both the baseline and global action scenarios.

Closures between global action scenarios may vary, depending on the description of each scenario. For example, for the scenario of global emissions trading without limits on trade, the global abatement cost is determined by the model, which is then passed through into each region; for the scenario with limited trade, regional abatement cost is determined by the constraint on its emissions trajectory.

Modelling results should be interpreted according to the model closures, as fixed factors in the model affects modelling outcomes.

Table 23 provides more details on the scenarios used in the modelling.

Table 23. Full set of scenarios used in the analysis

		Global assumptions					Australian assumptions		
	Reference No.	**Trajectory**	**Technology**	**Hydrogen**	**Capital risk premium**	**Global trade**	**Aust target and incentive**	**Aust trade**	**Aust land**
Core scenarios									
Pre-Glasgow	1	4°C	C	no	N/A	N/A	no.$0	N/A	C
No Australian Action	2	< 2°C	C	no	CRP	LT	no.$2	no	=4°W
The Plan	3	WB2	A	yes	no	LT	gap	yes	A
Alternative scenarios									
NZE with offsets (2°C, limited trade benchmark)	4	< 2°C	C	no	no	LT	-100%	yes	C
NZE no trade	5	< 2°C	C	no	no	LT	-100%	no	C
NZE no offsets	6	< 2°C	C	no	no	LT	-100%	no	no
NZE 100%	7	WB2	A	yes	no	LT	-100%	cap	A

Trajectory	4°C: Pre-Glasgow; < 2°C: below 2°C (RCP2.6); WB2: well below 2°C
Technology	C: conservative technology; A: advanced technology;
Hydrogen	no: hydrogen sector does not emerge
Retaliation	no: no global retaliation against Australia; CRP: capital risk premium applied to Australia
Global trade	LT: limited trade, high income countries purchase no more than the equivalent of 30% of their 2020 gross emissions each year; for China, the cap is 30% of its 2030 gross emissions
Aust target and incentive	Australian target for net emissions in 2050 and assumed abatement incentive.
	no.$0: no target, no abatement incentive; no.$2: no target, $2/t incentive each year 2031-2050; gap: modelled emissions are 85% below 2005 levels in 2050, abatement incentive cannot exceed $24/t by assumption
	All others: -100%: net zero 2050 target (100% below 2005 levels), abatement incentive arises as a modelling result
Aust trade	No: Australia does not use international offsets. Yes: Australia participates in global emissions trading, subject to global emissions trade assumptions for each scenario. Cap: Australian use of international offsets capped at 17% of 2020 gross emissions (94 Mt CO2-e) each year
Aust land	=4°W: volume of Australian land sequestration matches Pre-Glasgow each year. All others: Volume of land sequestration is determined as a function of abatement incentive in 2050, as shown in Table 14. C: conservative technology, high threshold; A: advanced technology, high threshold

APPENDIX E:
Modelling a capital risk premium

Introduction

DISER sought Treasury advice on modelling potential global retaliation in the event that Australia did not adopt a 2050 target. This advice was provided in August, based on the set of scenarios being modelled at that time, and is provided below.

DISER implementation of the capital risk premium drew on this advice. Some aspects of the modelling are implemented differently to the Treasury advice, reflecting GTEM model dynamics and some technical changes in the set of scenarios, as set out in the section following the Treasury advice. DISER consulted Treasury on the implementation, and they consider the macroeconomic results from DISER's implementation in GTEM of a capital risk premium to be credible and reasonable.

Treasury advice

Treasury has prepared a preliminary assessment of the 'costs of inaction' under DISER's 'adverse global reaction' scenario in their Long-Term Emissions Reduction Plan modelling. Treasury's assessment is consistent with this scenario, in which:

- all developed countries bar Australia adopt, and subsequently meet, a net zero target by 2050 and developing countries meet Net Zero by at least 2075
- Australia does not take action above current policy settings, which are equivalent to an Australian shadow carbon price of approximately $A5 in 2050[12]
- the world moves to an 'advanced technology' state, with global carbon prices of around $A40 in 2050
- Australian firms are able to access the advanced technology available to firms overseas, thereby marginally reducing their emissions intensity.

Introduction

Australia will likely face a 'cost of inaction' for not adopting (and therefore not meeting) a Net Zero Greenhouse Gas emissions target. Australia's 'cost of inaction' will likely be transmitted via two channels: trade action against Australian exports, and increased capital costs for Australian governments, firms and households.

Likely trade action

Treasury assesses that countries that commit to ambitious emissions reduction action (by adopting net zero) are likely to impose import charges, also known as Border Carbon Adjustments policies (BCAs), against countries that do not. This reflects the growing incentive other countries (specifically, Net Zero adopters) will have to take countervailing actions to limit any 'advantage' experienced by those countries that don't adopt Net Zero. The EU's Carbon Border Adjustment Mechanism regulation provides an early indication of the likely future direction of this countervailing trade action. However, other countries, including the US, the UK, Japan and Canada, have begun expressing interest in the policy.

Any BCA under DISER's 'adverse global reaction scenario' is likely to be broad based, covering all goods and upstream emissions. This is consistent with the goal of limiting any 'advantage'. Full implementation, by all countries, from 2035 appears a reasonable assumption. A conservative BCA charge could reflect the difference between DISER's modelled Australian and global shadow carbon prices. As this price difference is driven, in part, by technology assumptions, the import charge for Australia is likely to be higher under conservative technology than advanced technology.

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12 DISER comment: The marginal abatement incentive in the No Australian Action scenario changed from $5/t (in August) to $2/t (in the final modelling runs) in response to changes associated with updating the modelling to be consistent in latest DISER emissions projections.

Likely cost of capital increase

Global financial institutions and policymakers have begun taking co-ordinated steps to align public and private investment with Paris targets. This includes measures to hard-wire climate goals into prescriptive sustainable finance taxonomies (as in the EU), economic growth and recovery strategies (as in the US), or both (as in China). Shifting consumer and investor preferences and emerging technological pathways are also rebalancing investment towards Net Zero-aligned activities.

To date, the above has resulted in a financing discount on so-called green instruments, and an increase in financing costs and/or challenges in obtaining finance for the most carbon-exposed projects and industries. Given the carbon-intensive nature of Australia's economy, as these trends accelerate to 2050, they will impact Australian firms that access global equity and debt markets, as well as the investment preferences of global and local institutions operating in Australian markets. They could also impact demand for Australian government debt, resulting in higher financing costs. This would be particularly the case under DISER's 'adverse global reaction' scenario.

There is no precedent for quantifying the increase in the cost of capital that Australia would face for not adopting a net zero target.[13] However, under DISER's 'adverse global reaction' scenario and with the trade actions outlined above, initial Treasury analysis suggests a central estimate of 100 basis points is reasonable. This cost-of-capital increase is consistent with Australia losing access to preferred capital markets and intermediaries, and being forced to obtain financing from Tier 2 sources. The increase is assumed to occur above and beyond the BCA impact outlined in the 'Likely Trade Action' section above.

Treasury's estimate is based on the premium currently attached to green bonds (often referred to as the 'greenium'). Estimates of the 'greenium' from sovereign bonds range between 0-5 basis points. Estimates of the 'greenium' from corporate bonds range from 0-60 basis points. While the 'greenium' includes a range of factors and risks, some of which will be less relevant by 2050, the preferences driving it are likely to increase over time. Given this, and the fact that most climate action by governments and firms has yet to crystallise, Treasury recommends a slightly higher central estimate of 100 basis points.

It is possible that our cost of capital will rise further than our central estimate of 100 basis points under the 'adverse global reaction' scenario, given the strict assumption that Australia is the only developed country not to adopt a net zero target. Treasury considers that 300 basis points provides a feasible upper bound for these increases. While extreme, this indicates the possible cost impacts of well-coordinated, targeted and enforced global action to restrict access to international capital markets. Such an approach is considered less likely, but is feasible under DISER's scenario, given the assumptions of coordinated, concerted global emission reduction action.

Treasury notes increases in the global cost of action would likely push up Australia's capital costs further. Under DISER's 'conservative technology' assumptions, where the global carbon price broadly doubles, our central estimate would be 150 basis points.

The timing of the above cost-of-capital increases is highly uncertain and contingent on global developments. However, Treasury considers a gradual, linear increase to 2050 to be a reasonable representation. Noting markets often rapidly discount future risks into current prices, a significant portion of the macroeconomic impact of this premium increase is likely to coincide with early repricing, and may have dissipated somewhat by 2050. Any interpretation of modelling results must therefore incorporate transitional impacts.

13 This is challenging, in part due to the complexity of disentangling a) the preferences to hold green assets that are likely to persist to 2050 (a measure of Australia's penalty for failure to meet Net Zero by 2050), vs b) the current risks associated with carbon-intensive goods and services that may not be relevant by 2050. Ideally, any premium increase used in this exercise should not include the effects of demand changes brought about by global emissions reduction efforts, climate damages, or climate policy uncertainty as these are assumed to already be included in any modelled baseline, or to have materialised well before 2050.

Treasury acknowledges that action towards Net Zero by individual businesses may offset some of the above capital cost increases. This includes financial re-structuring to remove carbon intensive assets or reduce reliance on capital markets. However, these changes will likely shift costs and/or risks, rather than remove them. Further, firms may independently reduce emissions. Noting that the different Australian emissions outcomes between DISER's scenarios are driven by a carbon price, it would not be consistent to assume high levels of voluntary abatement, absent an Australian carbon price similar to the two technology scenarios. Independent actions would both reduce Australia's cost of inaction and of action, and therefore should not be included.

Modelling implementation

Consistent with Treasury advice, the modelling assumes capital markets impose a risk premium on top of current financing costs. The risk premium is set at 100 basis points, the central estimate in a world with advanced technology. This is somewhat higher than the observed positive premium on 'green bonds', which currently ranges up to 60 basis points for corporate bonds, reflecting that global climate action is not yet consistent with the Paris temperature targets, and that in this scenario investors are guarding against perceived downside risks (rather than expressing a more altruistic willingness to pay for sustainability outcomes). The risk premium is imposed from 2031, at the same time the world shifts to its new below 2°C global emissions trajectory.

The risk premium is imposed on a scenario that includes the impacts of global action to achieve a below 2°C global emissions trajectory, but which does not include global retaliation. This scenario assumes conservative technology.

This was implemented as follows:

- The risk premium is defined as the additional return required to the risk-free rate of return on investment to account for the perceived risks associated with the investment.
- In GTEM, the global rate of return on investment can be considered as the risk-free rate of return, while the rate of return actually realised in each country or region can be considered as the risk adjusted rate of return. The difference between regional rate of return and the global rate of return can thus be considered as the regional risk premium in GTEM.
- The capital risk premium for Australia was therefore imposed as an increase in the difference between Australia's rate of return and the global rate of return, adding the additional risk premium discussed below. This effectively increases the required rate of return on investment into Australia, leading to a decrease in investment and lower level of capital stock in Australia (resulting in adverse impacts summarised below).

As GTEM does not incorporate forward looking economic behaviour, the modelling assumes the premium is introduced at full value in 2031 and then declines over time. This assumes a constant annual decline, to be around 30% of full value after three years and around 2% after 10 years. This resulting in economic impacts that peak and then moderate out to 2050, mimicking the way financial markets 'price in' or bring forward expected future changes in asset values.

This implementation differs from the Treasury advice in three ways.

First, the analysis only models the impact of a capital risk premium, implemented without other forms of retaliation, and uses this as a minimum estimate of combined impacts of likely global retaliation of all forms if Australia does not adopt a 2050 target. This differs from Treasury advice that retaliation would be expected to be via two channels: trade action against Australian exports, and increased capital costs for Australian governments, firms and households.

Second, Treasury provided central estimates of an appropriate capital risk premium for two scenarios: 100 basis points in a scenario with global deployment of advanced technology, and 150 basis points in a scenario with conservative technology, as defined in the DISER modelling. This modelling applies a 100 basis points risk premium to a conservative scenario to establish the No Australian Action scenario, and assesses economic outcomes and impacts against this scenario. (The advanced technology scenarios used in the modelling all assume a 2050 target, and so do not include retaliatory action.)

Third, the technical implementation assumes the capital risk premium is introduced at full value, but then declines over time. This approach is used to mimic expected market dynamics, which are not properly reflected in GTEM (which does not embody forward looking behaviour). In practice, the capital risk premium would be expected to continue or increase to 2050 (rather than decline) in a scenario with well-coordinated global action on climate where Australia does not take on a 2050 target. This implementation gives more weight to Treasury's other advice on expected impacts of the risk premium, that markets often rapidly discount future risks into current prices, and so a significant portion of the macroeconomic impact is likely to coincide with early repricing of assets, resulting in impacts dissipating to some degree by 2050

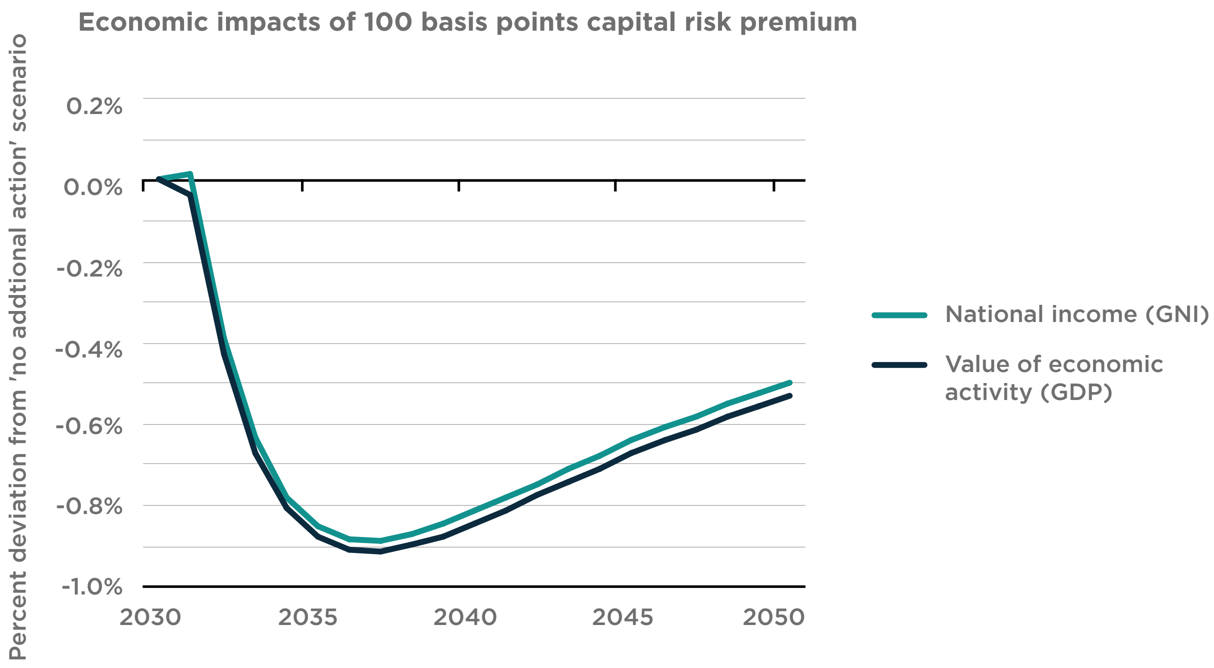
In each case, these differences in implementation will reduce the size of the economic impacts of retaliatory action in 2050.

Modelling results

The implementation of the capital risk premium raises the effective cost of capital in Australia. This results in investment being 2.7% lower on average to 2050, peaking at a 17% reduction a few years after 2030. This flows through to reduce the value of economic activity (GDP) and national income (GNP), with the impact peaking at 0.9% and then declining to about 0.5% by 2050, as shown Figure 29. Additional details are provided in Table 9 in Appendix A.

DISER consulted Treasury on modelling implementation and results, and they confirmed they consider the macroeconomic results to be credible and reasonable.

Figure 29. Economic impacts of a capital risk premium



Notes: *The risk premium analysis is based on a scenario with concerted action to achieve a below 2°C but no Australian 2050 target, and no capital risk premium or global retaliation.*

Source: *DISER economic modelling for the Plan.*

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