Appendices

APPENDIX

Appendix A Parliamentary referral to undertake this review

On 11 September 2023, the Australian Parliament agreed the following matter be referred to the Climate Change Authority for review, in accordance with section 59(1)(a)(ii) of the *Climate Change Authority Act 2011*.

1. The potential technology transition and emission pathways that best support Australia's transition to net zero emissions by 2050 for the following sectors:

    (i) electricity and energy;

    (ii) transport;

    (iii) industry and waste;

    (iv) agriculture and land;

    (v) resources; and

    (vi) built environment.

2. The review must identify:

    a) existing and prospective opportunities to achieve emissions reductions;
    b) which technologies may be deployed in each sector to support emissions reductions;
    c) how public and private finance can support and align with these emission pathways;
    d) barriers to implementation, such as short-term or longer-term pressures on cost and supply chains and the pace of technology commercialisation;
    e) workforce matters, including skills and opportunities for women;
    f) any gaps in existing evidence and data; and
    g) any other relevant factors;

3. The review must take into consideration:

    a) the principles for the Climate Change Authority set out in section 12 of the *Climate Change Authority Act 2011*, including the global goals in Article 2 of the Paris Agreement and boosting economic, employment and social benefits; and
    b) the range of emissions reductions achievable through the deployment of available and prospective technologies;

4. The Climate Change Authority must give the report of the review to the Climate Change Minister, in accordance with section 60(1)(b) of the Climate *Change Authority Act 2011*, by 1 August 2024 to assist the Government in developing a national net zero by 2050 plan.

APPENDIX

Appendix B Methodology

How the authority has addressed the referral

The authority used six key questions in considering the requirements of the referral and the authority's legislative responsibilities. These questions were:

1. What is the scope of emissions considered in the report?
2. What are the emissions for the six sectors?
3. What are the potential technologies for decarbonising the emissions sources?
4. Which technologies should be focused on?
5. What is the trajectory for sectoral emissions and technology adoption that best supports each sector's contribution to Australia achieving net zero by 2050?
6. What are the relevant barriers, opportunities and enablers for each sector?

The authority engaged Boston Consulting Group (BCG) to assist the authority to develop a methodology to address these questions, drawing on BCG's experience advising on sector pathways for Germany, South Africa and others.

What is the scope of the emissions considered in the report?

The authority's quantitative analysis of emissions focused on scope 1 (direct greenhouse gas emissions) in each of the 6 sectors in the referral. These emissions account for all emissions Australia reports in its National Greenhouse Gas Inventory.

Emissions from electricity use (scope 2) were examined in the analysis of the built environment sectoral pathway, in the context of the to reduce that sector's scope 2 emissions through energy efficiency and distributed renewable energy. Enhancing energy efficiency is an opportunity in all sectors.

Potential process and technology changes to address scope 3 emissions were considered in 'user sectors' where it made sense to do so. For example, process and technology changes in the built environment sector could play an important role in addressing that sector's upstream Scope 3 emissions from cement and steel.

The authority analysed emissions that occur in the countries that consume Australia's exports, focusing on fossil fuel and green economy exports such as clean energy, green materials, and critical minerals. This was to inform our assessment of what global decarbonisation means for the Australian economy and people.

What are the emissions for the six sectors?

Sector pathways emissions mapping

To understand the current emissions and sources of emissions, the authority calculated the emissions for each of the six sectors named in the referral. The Australian Government does not publicly report emissions for these sectors on an individual basis. The authority calculated each of the sectors' emissions by aggregating from relevant sources of emissions data.

For most emissions sources, the authority allocated emissions from sources reported in Australia's inventory submission to the United Nations Framework Convention on Climate Change (UNFCCC) to one of the six sectors. This is based on 2022 emissions data, the most recent at the time of this report's publication.

Table B.1: Emissions and underlying sources for the six sectors

Sector	2022 emissions, Mt CO_2-e	Emissions sources
Electricity and Energy	153	The Electricity and energy sector contains emissions relating to the production of electricity (excepted those associated with mining and oil and gas operations which are not grid connected), and the supply of energy to consumers, this includes: · on-grid electricity generation and non-energy emissions associated with the operation of the physical grid (SF6s in insulation of transmission lines) · production of liquid and solid fuels including emissions from refineries · emissions arising from the movement of gas through the distribution network (fugitives and pipeline transport emissions) · military transport.
Transport	90	Fuel combustion associated with transport activities, (excluding military and pipeline transport, which is in Electricity and energy), plus non-energy emissions from the transport industry's refrigeration and air conditioning use (such as at a car maintenance facilities).
Industry and Waste	64	Emissions associated with fuel combustion for manufacturing processes and process emissions associated with chemical reactions in manufacturing processes. Includes some synthetic gas emissions and the UNFCCC waste sector.
Agriculture and Land	-3	UNFCCC sectors (agriculture and land-use, land use change and forestry) plus fuel combustion associated with machinery use.
Resources	99	Fugitive emissions associated with coal mining and oil and gas extraction, electricity generation emissions for non-grid connected facilities, fuel combustion in haulage machinery and other onsite activities at mine sites, fuel combustions in LNG processing.
Built Environment	28	Fuel combustion (gas) in commercial and residential buildings, and in construction, and emissions associated with refrigerant gases. Fugitive emissions from gas distribution and emissions associated with wastewater. This table presents scope 1 emissions; however, the authority has analysed scope 2 emissions as part of this project.
Total	433	

Source: Sector totals from authority national sectoral pathways emissions mapping based on Australia's National Greenhouse Accounts and emissions reported under the National Greenhouse and Energy Reporting Scheme. See the sector chapters in Part 1 for more infomation about the breakdown of emissions within sectors.
Note: sector emissions may not sum to the total emissions due to rounding.

Emissions mapping for AusTIMES model results

Emissions in AusTIMES are grouped into sectors, some of which are further broken down into subsectors (see the CSIRO's Sectoral Pathways Report's Appendix). The CSIRO calibrate emissions for these sectors to a base year of 2021, based on the Australian National Greenhouse Account's National Inventory by Economic Sector.

For its analysis, the authority has aggregated emissions from the AusTIMES subsectors to the six sectors used in this report (Table B.2). The authority has assigned the AusTIMES subsectors to match as closely as possible to the emissions sources in the sectoral pathways emissions mapping.

The authority's sector pathways emissions mapping and the AusTIMES emissions classification differ. This is partly because the authority's emissions mapping is based on Australia's 2022 inventory which includes revisions to emissions data that are not reflected in AusTIMES. Also, the UNFCCC inventory is more detailed and includes categories that are not represented in the AusTIMES model. Therefore, the AusTIMES classification is not able to allocate all sources of emissions to the report's six sectors as precisely as the sector pathways emissions mapping.

Table B.2: Emissions and the underlying AusTIMES subsectors assigned to the six sector pathways sectors

Sector	2025 emissions, Mt CO_2-e	AusTIMES sectors/subsectors
Electricity and Energy	150	Power (including off-site generation), Petroleum Refinery, Gas Supply, Hydrogen
Transport	92	Transport
Industry and Waste	73	Chemicals, Iron and Steel, Manufacturing (excluding Petroleum Refinery), Waste, Water Supply
Agriculture and Land	34	Agriculture, LULUCF, Land sequestration, Forestry and Logging
Resources	74	Mining and Gas extraction
Built Environment	23	Buildings, Construction, Refrigeration and aircon
Total	446	

What is the economic contribution of the six sectors?

To provide an indication of the economic contribution of each of the six sectors discussed in this report, the authority has compiled indicators of economic activity associated with each sector. These indicators are referenced throughout the report.

The authority is focusing on each sector's Gross Value Added (GVA) and employment numbers. GVA is the value of a sector's output less its intermediate consumption. It is a measure of an industry's contribution to Gross Domestic Product (GDP) (OECD, 2008). The authority's calculation of these economic statistics is shown in Table B.3 and referenced throughout this report.

Table B.3: Economic statistics for emissions sectors, 2022-23

Sector	GVA ($ millions)	GVA (% of GDP)	Employees ('000s)	Female employees ('000s)	Female employees (% of sector's employees)
Electricity & Energy	29,777	1%	91	22	24%
Transport	124,556	5%	861	188	22%
Industry and waste	140,588	5%	916	255	28%
Agriculture and Land	61,044	2%	299	93	31%
Resources	344,351	13%	288	56	19%
Built Environment (Commercial)	1,328,227	52%	10,149	5,828	57%
Built Environment (Construction)	170,488	7%	1,300	176	14%

Note: GVA for the six sectors does not sum to Australia's total GDP as GDP also includes ownership of dwellings and an adjustment for taxes and subsidies on products.
Source: Authority analysis of ABS (2023a, 2023b, 2023c, 2024).

Concordance to emissions sectors

Economic data are often grouped into industries that are defined using official industrial classifications (Box B.1). Employment data are reported in the Australian Bureau of Statistics' (ABS') Labour Force Survey in Australian and New Zealand Standard Industrial Classification (ANZSIC) groups, while GVA is reported using ANZSIC divisions, Input-Output Industry Groups (IOIGs) and the Supply-Use Industrial Classification (SUIC).

As economic data are not explicitly reported for the six sectors referred to in this report, the authority has aggregated official data from the underlying detailed industrial classifications to the six sectors. This aggregation is done using a "concordance table" which describes which detailed industries the 6 sectors are comprised of (Figure B.1).

The authority produced a concordance table that defines how Input-Output Industry Groups (IOIGs) and ANZSIC groups can be aggregated to the sectors used in this report. IOIGs and ANZSIC groups were used as the basis because the ABS commonly reports data for these classifications. IOIG industries and ANZSIC groups are comprised of one or more ANZSIC classes. Therefore, the concordance table was developed based on the authority's assessment of the sector to which the underlying ANSIC classes' emissions were predominantly allocated.

Box B.1: Industrial classifications used in economic statistics

There is often interest in understanding economic indicators for various industries. To do this, data from individual business entities, which include any organisation undertaking productive activities, can be aggregated using an 'industrial classification'. An industrial classification is a standard framework for grouping similar business entities into industries (ABS, 2013). In compiling its economic indicators, the authority uses different industrial classifications.

The Australian and New Zealand Industrial Classification (ANZSIC)

The ANZSIC is a widely used industrial classification, jointly developed by the ABS and Statistics New Zealand. It was most recently updated in 2006 (ABS, 2013). The ANZSIC structure includes industrial categories at 4 levels of detail: classes (most detailed), groups, subdivisions and divisions (least detailed).

A wide range of data is reported using the ANZSIC classification. This includes employment data from the ABS' Labour Force Survey (ABS, 2023c), emissions data from DCCEEW's National Inventory by Economic Sector (DCCEEW, 2024), and economic activity data from the ABS' System of National Accounts (ABS, 2023b).

Industrial classifications used in the Australian System of National Accounts (ASNA)

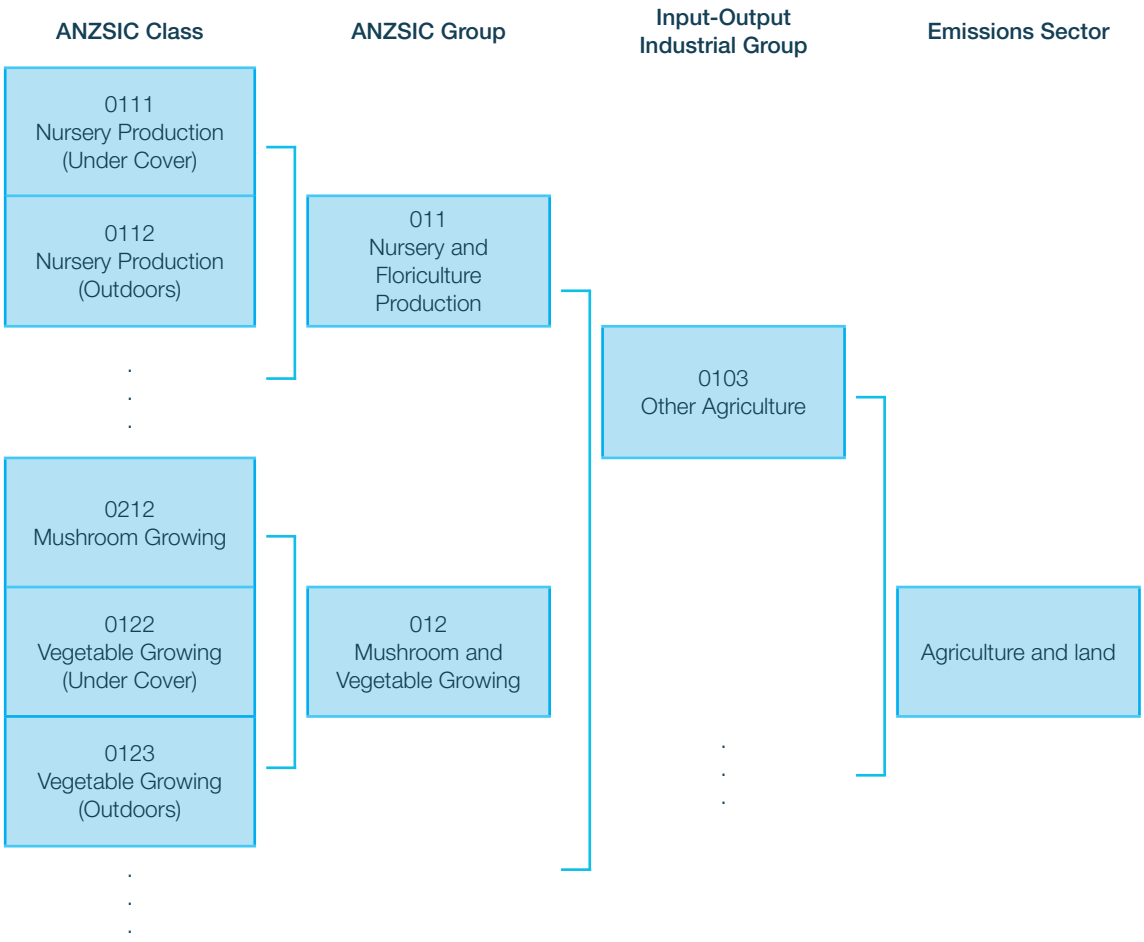
The ASNA uses a number of industrial classifications to report economic statistics (ABS, 2021). The authority uses GVA statistics from the ASNA. In the national accounts, GVA is reported by

- ANZSIC division. Used for reporting GVA in the annual and quarterly Australian System of National Accounts releases.
- Input-Output Industry Groups (IOIG). IOIGs are used for reporting industries in the ASNA's Input—Output Tables. They are comprised of one or more ANZSIC classes and are the most detailed classification that GVA is reported at.
- Supply-Use Industry Classification (SUIC). Used for reporting GVA in the Supply—Use Tables. A SUIC is comprised of one or more IOIGs.

In a limited number of cases, an IOIG may naturally map to more than one sector. In these cases, the authority made an assessment about the most appropriate sector.

To reflect the fact that economic activity in the built environment sector is significantly different depending on whether someone works in a services industry or construction industry, the authority has separated the built environment sector into the built environment (commercial) and built environment (construction) subsectors.

Figure B.1: Illustration of concordance from ANZSIC class to Agriculture and Land



Gross Value Added

GVA is reported by the ABS in its annual and quarterly Australian System of National Accounts (ASNA) at the ANZSIC division level. GVA is also reported at a more detailed level in the ABS' Supply Use Tables and Input—Output Tables, although this data is released after the annual and quarterly ASNA releases (ABS, 2021).

To aggregate the GVA, the authority apportioned the most data at the ANZSIC division into more detailed industrial classifications. This was done by:

- using the current-price GVA from the 2022-23 Australian System of National Accounts for each ANZSIC division (ABS, 2023b)
- apportioning the ANZSIC division-level GVA data into SUIC industries using the share of GVA for each SUIC industry from the 2021-22 Supply Use Tables (ABS, 2023a)
- apportioning the GVA from SUIC industries to IOIGs using the 2021-22 Input-Output Tables (ABS, 2024)
- aggregating GVA by IOIG to this report's 6 sectors, using the authority's concordance table.

Employment

To calculate the total employment by emissions sector, the authority aggregated data from the ABS Labour Force Survey. The total employment by sector was determined by:

- using the average total employment for 2022-23, by ANZSIC group, from the ABS' Detailed November 2023 Labour Force, Detailed release (ABS, 2023c)
- apportioning employed people in not further defined classifications into the underlying classifications, based on the share of employment of the underlying classifications
- aggregating employment from ANZSIC groups to this report's sectors using the authority's concordance table.

What are the potential technologies for the emissions sources?

The authority identified the technologies under the following categories:

Existing technologies are technologies or operational changes currently in use or available to be deployed (mature and demonstrated).

Prospective technologies are emerging technologies or operational changes which are at an early stage of development that could play an important role in future emissions reductions if rapid scaling and commercialisation can be achieved.

Which technologies should be focused on?

The authority used a principles-based assessment of readiness, abatement potential and cost to determine which technologies to focus on in the report. This means the report is not an exhaustive list of emissions reduction activities, but instead evaluates barriers and enablers for the most impactful prospective technologies.

The authority acknowledges the inherent uncertainty in the contribution of specific technologies to Australia's future emissions reductions. The readiness, abatement potential and cost of technologies will not remain static and will evolve over time.

Readiness

Using the ARENA framework, technologies were initially grouped into three phases based on technical and commercial readiness: 'Research and Development' (early-stage), 'Demonstration' and 'Deployment' (mature).

In some sectors, where detailed information on readiness was available, qualitative assessment of technology readiness has also been presented. Operational changes were not assessed for readiness because they generally relate to behavioural shifts.

Technologies at a more advanced level of readiness have a greater capacity to provide short to medium term emissions reductions were an area of focus in the review.

Abatement potential

Abatement potential describes the maximum feasible emissions reductions that an emissions reductions activity could deliver.

Where possible, the authority grouped technologies at a similar level of cost and readiness to assess each group's cumulative 'abatement potential.' Technologies (and groupings) with a greater abatement potential were a greater area of focus in the report.

To determine maximum feasible emissions reductions potential, the authority:

- analysed where top-down outputs (modelling results) show technology being adopted prior to attaining technical maturity or more rapidly than practically possible.
- considered by working back from net zero at a given date, what are the key milestones for transitioning an asset base.
- assessed the challenges of the least cost pathway.

Cost

Cost per quantum of emissions reductions is a useful metric for comparing the potential of different technologies to contribute to sectoral pathways.

In many cases, it is not possible to assign a 'dollar-per-tonne' figure to a technology. For this reason, quantitative analysis is limited to those technologies where costs are well understood. Nonetheless, qualitative cost comparisons are feasible within each sector and can prove useful for assessing where some technologies are orders of magnitude more expensive than others.

Additional technologies

The authority also made note of, and provide limited commentary on, additional technologies that fall into the following categories:

- activities that address a small source of emissions, but are the only option that can feasibly address those emissions
- potential 'game changers' technologies with low readiness today but that have breakthrough potential to deliver significant emissions reductions in the longer-term.

What is the trajectory for sectoral emissions and technology adoption that best supports each sector's contribution to Australia achieving net zero by 2050?

To determine the trajectory for sectoral emissions, the authority used a combination of 'top-down' and 'ground-up' analysis

Top-down analysis

Whole-of-economy ('top-down') and sector modelling provided estimated sector-level technology adoption and emissions under a least cost decarbonisation pathway.

The authority used a combination of the CSIRO's GTEM, AusTIMES and LUTO models. GTEM models whole of economy and global effects, while AusTIMES and LUTO provides greater detail at the sector level. Each of these models is well-established and has been used in previous modelling exercises for the Australian Government.

The authority focused its analysis in this report on two emissions reduction scenarios (Australia in a 1.5°C world and 2°C world) representing potential Australian and global ambition. The modelling scenarios provided insights about possible developments in each sector and across the economy under different emissions pathways.

For further information on the authority's modelling, please see **Appendix C.**

Ground-up analysis

The authority also examined each sector from a more granular, sector-specific and technology-specific perspective ('ground-up') by drawing on diverse inputs from research, analysis and consultation. Ground-up analysis outputs included granular examination of technology adoption over time by sector or abatement potential by technology.

What are the barriers, opportunities and enablers relevant for each sector?

The authority considered the barriers to and enablers of implementing the technologies and operational changes at a sector and whole of economy level. Barriers included cost, workforce shortages, social licence, planning and approval delays, supply chain constraints and data gaps, as well as other matters. Enablers included a supportive policy and regulatory environment, cost incentives as well as other matters.

The authority has had regard to its legislated principles as part of this analysis of barriers, opportunities and enablers of the sector pathway.

Inputs to the authority's advice

Consultation

A review under section 59 of the *Climate Change Authority Act 2011* must make provision for public consultation.

Since May 2023, the authority has released three issues papers to inform our sector pathways and other reports. These were:

- 2023 Issues Paper: Setting, tracking and achieving Australia's emissions reduction target (received 595 submissions)
- Economic modelling of Australia's potential emissions reduction pathways (received 22 submissions)
- 2024 Issues Paper – Targets, Pathways and Progress (received 220 submissions)

The authority met with over 175 stakeholders to inform the authority's sector pathways and 2035 targets advice. These stakeholders included industry, state and territory government agencies, community groups, unions, jobs and skills councils, First Nations experts and youth.

References: Appendices A and B

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APPENDIX

Appendix C Modelling

Modelling background and scope

One source of information that the authority drew upon for this report was whole-of-economy and sector modelling that the authority commissioned from the CSIRO. This modelling project also serves a broader purpose as a source of information to inform the 2035 Targets Advice that the authority will deliver later in 2024.

Purpose and limitations of the modelling

Modelling of emissions in the Australian economy is an analytical approach that can indicate, given certain sets of assumptions, how different sectors could contribute to emissions reductions, and provide insights into interactions and interdependencies across sectors.

All modelling exercises have limitations and are very simplified versions of the techno-economic interactions that occur in the economy. The authority has used the modelling to provide broad indications of trends and interactions; however, the modelling project commissioned by the authority, or any other modelling project, does not provide definitive or conclusive evidence of how the Australian economy would transition to net zero emissions.

In the sectoral pathways report, the CSIRO's modelling is intended to complement the ground-up analysis by providing:

- insights into how abatement could be achieved across different sectors of the economy
- insights into which technologies are taken up in different sectors under modelled least-cost pathways, given the model assumptions
- an economic context under which the net zero transition may occur, including projections of global demand for emissions intensive products.

Modelling approach

Modelling framework

The authority commissioned modelling from the CSIRO using a best-practice suite of models (Table C.1). The models are the CSIRO's Global Trade and Environment Model (GTEM)[1], the Australian implementation of the International Energy Agency's (IEA) energy technology systems model TIMES (AusTIMES)[2], and the CSIRO's Land Use Trade Offs (LUTO)[3] model.

1 The data and theory behind GTEM are outlined in detail in Cai et al. (2015).
2 The TIMES model brings together the Integrated Market Allocation (MARKAL)-Energy Flow Optimisation Model (EFOM) System, and was jointly developed under the IEA's Energy Technology Systems Analysis Project. Documentation of the TIMES model generator is available from the ETSAP website.
3 LUTO was developed as a core model of the Australian National Outlook 2015 initiative. More detail on LUTO can be found on the CSIRO website.

GTEM provides Australia's economic context, including activity in different sectors, given global decarbonisation ambition. AusTIMES and LUTO provide greater detail at the sector level, including possible sectoral decarbonisation pathways. Each of these models is well-established and has been used in other significant modelling exercises (Australian Government 2021; Reedman et al. 2022).

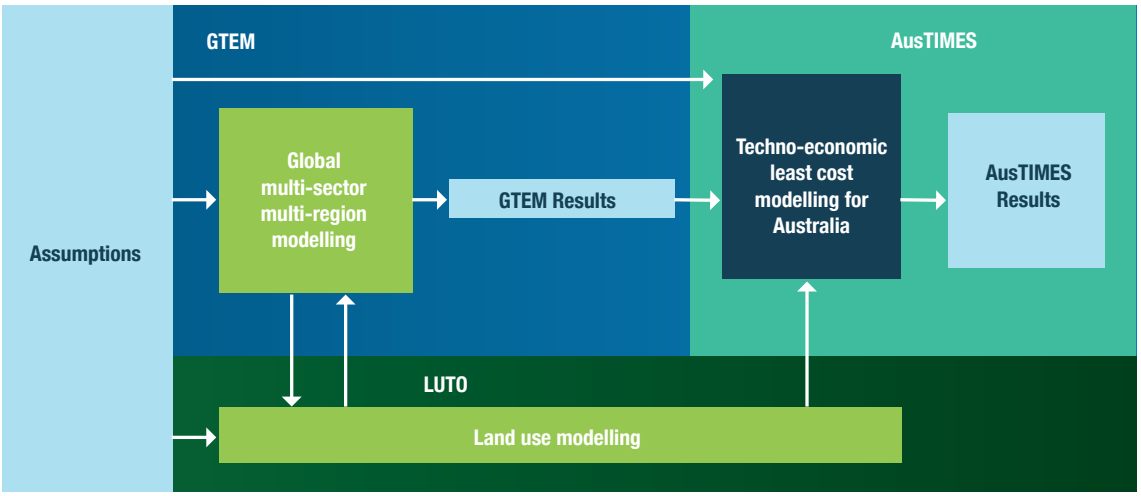
Table C.1: Summary of models used in the sector pathways report

Model	Summary of model	How is it used in this report?
GTEM	GTEM is a global multi-sector multi-region model that combines the top-down macroeconomic representation of a computable general equilibrium (CGE) model with the bottom-up engineering details of energy production and greenhouse gas emissions and abatement. The model features detailed accounting for global energy flows that are embedded in traded energy goods and offers a unified framework to analyse the energy-carbon-environment nexus. It provides projections of economic activity, energy and resource use, and emissions by sector. The global economic structure in GTEM is informed by the Global Trade Analysis Project database (Aguiar et al., 2019). The calibration of emissions by sector for Australia was updated for this exercise using Australia's National Inventory Report 2021 (DCCEEW, 2023a) and the accompanying 2021 National Inventory by economic sector.	GTEM models the global economy, with the Australian economy represented as a single region. This establishes the Australian economic context, given different levels of Australian and global ambition, including the economic activity of different sectors.
AusTIMES	AusTIMES is a techno-economic model covering Australian energy supply and demand and the other sources of emissions within Australia. The model determines least-cost decarbonisation pathways for Australia consistent with the sector activity projections from GTEM.	AusTIMES provides projections of emissions by sector[4] and the uptake of technologies. It provides insights into the relative contributions of sectors and technologies to cost-effective abatement.
LUTO	LUTO is a model of Australian intensive agricultural land use that combines data on existing land use, production functions, input and output prices, and physical variables (including climate) to calculate the relative profitability of a wide range of potential land uses.	LUTO provides projections of land-based carbon sequestration, based on incentive prices from GTEM.

For the sector pathways report the authority used the outputs provided from the CSIRO's operation of the AusTIMES model as this model provides greater sectoral detail. The AusTIMES outputs presented in the sectoral pathways report are consistent with GTEM projections of economic activity in end-use sectors (final energy consumers) and LUTO projections of land sector sequestration for each of the scenarios.

4 AusTIMES native sectors do not directly correspond to the sectors outlined in the referral to the Climate Change Authority for the Sector Pathways Review (Electricity and energy, Transport, Industry and waste, Agriculture and land, Resources, and Built Environment). For the purposes of the authority's analysis, some interpretation has been necessary to imperfectly align AusTIMES sectors with corresponding sectors in the referral.

Figure C.1: Modelling framework and interactions



Consultation on modelling

The authority released a consultation paper on the authority's proposed modelling approach in August 2023 and received 34 submissions. The authority also released an Issues paper in April 2024 that outlined the authority's thinking on its three major projects, the Sector Pathways Review, 2035 Targets Advice and 2024 Annual Progress Report. A number of submissions that the authority received in response to the Issues paper included commentary on the modelling approach.

Some stakeholders have commented on the authority's choice of models. Some were supportive of the choice of models: the Australia Institute noted that 'more recent information about GTEM is available … suggesting the model is a good choice to answer the CCA's questions, provided the modelling is done in an open and transparent manner', while the Energy Efficiency Council indicated '[t]he modelling framework is mainly appropriate'. Some stakeholders suggested alternative or additional models. The CSIRO's GTEM, AusTIMES and LUTO models were chosen to provide whole-of-economy interactions and technology-informed sectoral pathways and have been used in similar exercises previously (BHP, Centre for Policy Development, the Energy Efficiency Council, and the Institute for Energy Economics and Financial Analysis, submissions, 2023). The authority recognises that regional and distributional modelling at a domestic level could provide useful insights that are not produced by the current modelling ensemble.

Due to limited time the authority did not commission additional sector specific modelling, such as an electricity sector or a building stock model. The authority recognises the results for some sectors may not capture 'lumpy' investment decisions and sectoral tipping points (such as when previous infrastructure needs to retire at scale). However, the CSIRO's AusTIMES results will still provide insights about the relative trade-offs between abatement in different sectors.

Some stakeholders also highlighted the need for assumptions to be up-to-date and consistent (the Urban Transformations Research Centre and the Investor Group on Climate Change, submissions, 2023). The CSIRO maintains its models on an ongoing basis and has updated model inputs to the latest release where it has been practical to do so in the time available. The CSIRO, supported by the authority, has reviewed model outputs for alignment and consistency with other modelling exercises. Key assumptions are outlined in this appendix.

Several stakeholders highlighted the importance of learning rates. Learning rates have not been varied across the scenarios (the Centre for Policy Development, the Energy Efficiency Council, submissions, 2023). However, learning rates are considered in several sources of assumptions used in the modelling, such as the CSIRO's GenCost publication. Learning rates are also considered in the authority's ground-up analysis.

Some stakeholders have commented on the breadth of scenarios and the decision not to model a 'business as usual' scenario (The Australia Institute, Beyond Zero Emissions, the Centre for Policy Development, the Insurance Council of Australia, the Lock the Gate Alliance, the Investor Group on Climate Change, Ampol, submissions, 2023). The authority chose not to ask the CSIRO to model a scenario where Australia does not meet its current emissions targets, where the transition is disorderly or a world with a greater than 2°C temperature rise. Modelling a 'business as usual' or a 'no further action' scenario was not the authority's main priority

for this modelling exercise. The authority has asked the CSIRO to model scenarios for 1.5°C and 2°C degree worlds to provide the necessary information for the authority to develop its advice.

Many stakeholders recommended considering the impacts of climate change on economic prosperity when comparing global scenarios. The authority intends to account for climate damages through additional analysis in its forthcoming 2035 Targets Advice.

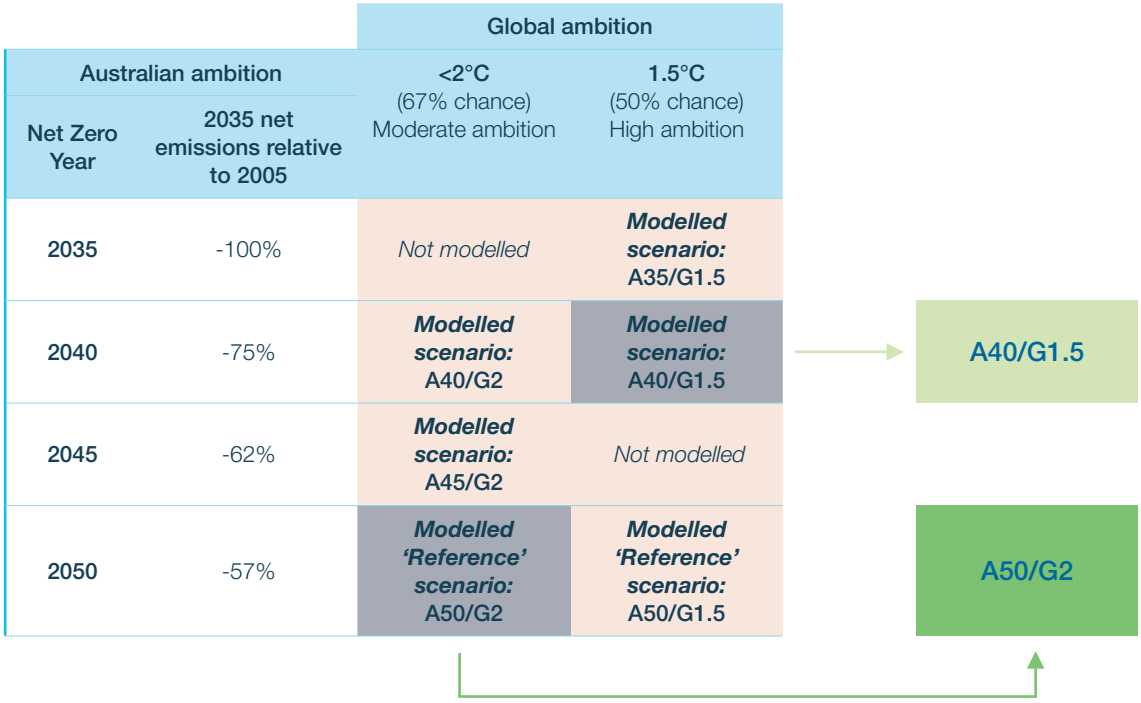
Several stakeholders have identified benefits associated with decarbonisation, such as health benefits (Climate Action Network, Beyond Zero Emissions, the Institute for Energy Economics and Financial Analysis, submissions, 2023), the emergence of new industries (the Investor Group on Climate Change submission, 2023), and reduced risk of major weather events (Beyond Zero Emissions, Climate Action Network, the Insurance Council of Australia, submissions, 2023). Stakeholders generally preferred that the authority integrate these benefits into the economic modelling directly. However, due to limited time, the authority intends to consider these benefits primarily through ground-up analysis.

Scenarios

The scenarios the authority requested the CSIRO model were designed to indicate the effects of various levels of emissions reduction ambition within a broad range that the authority could consider in forming its advice.

It is not possible to explore all possible futures and the scenarios requested by the authority are stylised and indicative, with a focus on different emissions trajectories in Australia and different global emissions reduction ambition. Globally, the modelling considers a '1.5°C world' (broadly consistent with 1.5°C with no or limited overshoot with 50% probability) and a 'less than 2°C world' (broadly consistent with less than 2°C with 67% probability).

Figure C.2: Diagram of modelled scenarios

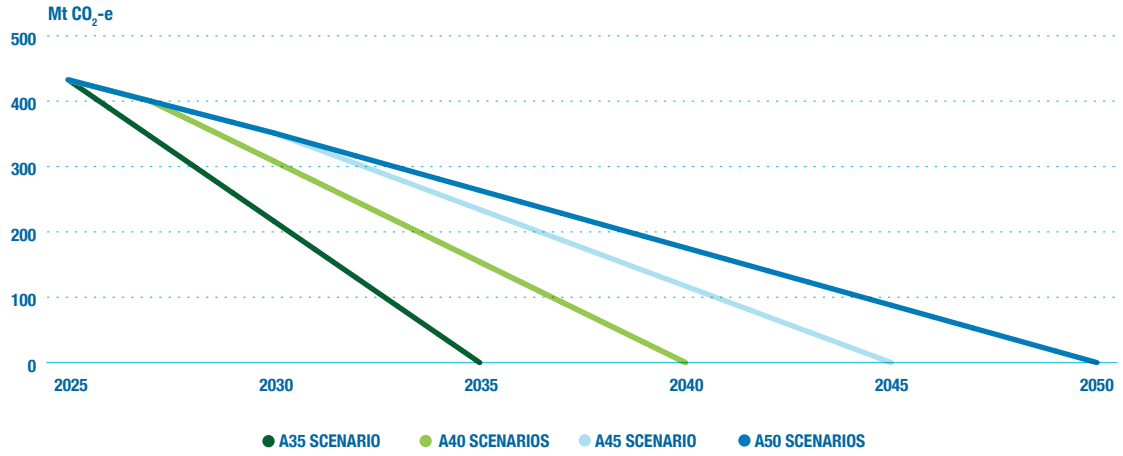


The CSIRO modelled these scenarios as straight-line trajectories to net zero in four different years: 2035, 2040, 2045 and 2050. The trajectories to net zero in 2045 and 2050 pass through the government's emissions reduction target for 2030 (a 43% reduction on 2005 levels), while the trajectories to net zero in 2035 and 2040 overachieve on the 43% target.[5]

These trajectories result in an array of emissions outcomes in 2035 that will be relevant when considering the authority's 2035 Targets Advice later this year. Scenarios are given a name based on a combination of their net zero year (e.g. A50 scenarios reach net zero in 2050), and the 'world' in which they exist (G1.5 scenarios are consistent with 1.5°C with no or limited overshoot, while G2 scenarios are consistent with limiting warming to below 2°C)

This report focuses on the CSIRO's modelling results from the A50/G2 and A40/G1.5 scenarios.

Figure C.3: Net emissions trajectories of modelled scenarios



Modelling different global contexts provides a comparison of the impacts of the level of global decarbonisation on Australia's decarbonisation pathways. These impacts include differing global demands for Australian exports (including fossil fuels and mineral resources), global trends in technology availability and costs, and the availability and deployment of engineered carbon dioxide removals.

These global contexts would likely be associated with different physical climate impacts, particularly beyond 2050, but these are not explicitly represented or accounted for in the models that the authority has asked the CSIRO to work with, other than through productivity impacts that are considered in the LUTO model when determining land sector sequestration. Instead, these impacts will be considered through additional analysis in the forthcoming 2035 targets advice.

The modelling assumptions applied by the CSIRO are consistent with a neutral view of Australia's relative economic positioning and technology deployment in a low emissions world. In most cases, technology cost and availability assumptions are similar across all scenarios, although there are some differences between the 1.5°C and less than 2°C worlds (see the assumptions relating to technology costs in the 'Modelling assumptions for this exercise' section below).

5 Due to the timing of the modelling exercise, emissions trajectories were calibrated to Australia's National Inventory Report 2021 (DCCEEW, 2023a). The more recent National Inventory Report 2022 revises the starting point downward and may imply other slight changes to the modelled trajectories, but was not published in time for incorporation in this modelling exercise.

Focus scenarios for sectoral pathways analysis

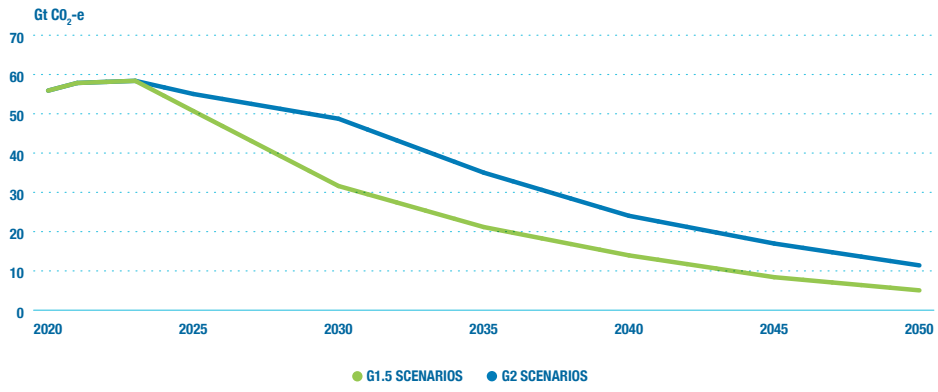
Although all the CSIRO's modelled scenarios inform the sectoral pathways analysis, two illustrative scenarios have been identified to facilitate comparison between possible pathways for sectors.

- The **A50/G2** scenario is consistent with achieving Australia's current emissions reduction targets in a less than 2°C world. Although these targets are challenging, Australia is not a leader in decarbonisation in this world and reaches net zero in 2050, while many other developed nations reach net zero in 2040 or 2045. The global energy mix retains more fossil fuel demand than the 1.5°C world, and Australia's fossil fuel production declines gradually. There is a strong global investment in negative emissions (land-based and technology-based emissions removals) to support the achievement of this goal.
- The **A40/G1.5** scenario is consistent with a 75% reduction on 2005 levels in 2035 and net zero by 2040, reflecting greater ambition and more rapid emissions reductions. Australian targets are consistent with greater ambition from other developed nations as the world cooperates to limit warming to 1.5°C. Fossil fuel demand falls more rapidly globally and in Australia, and there is even stronger investment in negative emissions technologies.

Modelling assumptions for this exercise

The CSIRO maintains and operates the models used for this modelling exercise (alongside Monash University's Climateworks Centre, which jointly maintains and operates the AusTIMES model with the CSIRO). The authority reviewed and provided input into some macro assumptions for each of these models. The models used include thousands if not more than one million assumptions and these have been paramaterised by the CSIRO. A list of significant assumptions is below, with some qualitative analysis of the implications of these assumptions.

Table C.2: GTEM assumptions

Global net emissions trajectory	*Source: Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report Illustrative Mitigation Pathways: IMP-GS (applied to the less than 2°C world) and IMP-Ren (applied to the 1.5°C world) (Byers et al., 2022) – with adjustments to account for historical emissions* IPCC 'Illustrative Mitigation Pathways' were chosen because they reflect a credible established benchmark, with a clearly described underlying narrative. In IMP-GS, mitigation action is gradually strengthened over time, and this is from the IPCC's 'C3' suite of scenarios that limit warming to 2°C with >67% probability. In IMP-Ren, emissions reduction efforts focus on rapid deployment of renewables, and this is from the IPCC's 'C1' suite of scenarios that limit warming to 1.5°C with no or limited overshoot with >50% probability. The authority requested the CSIRO impose versions of these trajectories that were adjusted for historical emissions. Total cumulative emissions up to 2050 are retained as well as the general shape of IPCC trajectories. Other global trajectories with different narratives would be legitimate alternatives. Figure C.4: Global net emissions trajectories 
Global energy mix	*Source: International Energy Agency (IEA) World Energy Outlook (IEA, 2021b) Announced Pledges Scenario (APS) applied to the less than 2°C world, and Net Zero Emissions by 2050 Scenario (NZE) applied to the 1.5°C world.* The IEA 2021 APS reflects a world that is relatively slower to phase out fossil fuels than the NZE scenario.

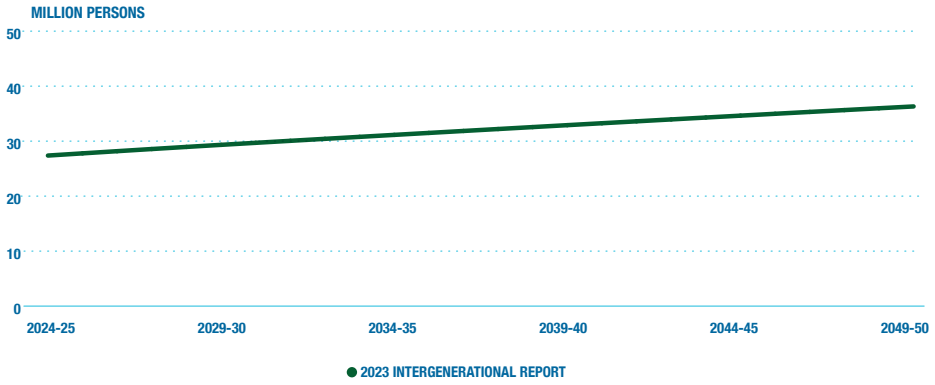
Global and domestic engineered removals	*Source: IEA's 2021 NZE scenario (IEA, 2021a) was used as the source for the amount of global engineered removals in a 2°C world, with adjustments to align with the GTEM model structure (resulting in about 2 Gt CO_2-e of engineered removals worldwide in 2050). Engineered removals are slightly higher in the 1.5°C (around 2.1 Gt CO_2-e). The CSIRO downscaled these global assumptions for Australia, resulting in engineered removals between 20 Mt CO_2-e and 25 Mt CO_2-e in 2050, with no engineered removals assumed to occur in Australia before 2030.* The cost and potential scale of deployment for engineered emissions removals are highly uncertain. These are emerging technologies but they will need to be developed rapidly to support global emissions reduction efforts. The authority considers these assumptions are consistent with other modelling of below 2°C and 1.5°C scenarios but notes they will not be achieved without significant global investments.
Australia's population	*Source: 2023 Intergenerational Report (Australian Treasury, 2023)* Consistent with this source, Australia's population reaches about 36.3 million people by 2050. Figure C.5: Australia's population 
Domestic LULUCF emissions and sequestration	See the LUTO assumptions section below for more details.
Agriculture	Agricultural production and commodity exports were modelled in GTEM. There were two sets of broad assumptions that the authority discussed with the CSIRO: · Crop production – Modelled using GTEM assumptions of ongoing improvements in productivity over time · Livestock production – As described in the Issues paper that the authority released in April 2024 that the authority would include the assumption that cattle numbers would remain relatively stable over time, consistent with the long run historical trend (ABARES, 2022) and ABARES projections (ABARES, 2023a).
Participation in international emissions trading	Assumption: Australia does not engage in international trade of emissions units, either as a buyer or as a seller. Other global regions are not similarly restricted. Due to uncertainty about the future role of international trade of emissions units, the authority has chosen to reflect current policy by asking the CSIRO to impose an assumption that Australia does not engage in international emissions trading. This assumption means Australia cannot purchase lower-cost international abatement (which could disincentivise domestic abatement) or provide emissions units to the international market (which could incentivise Australia to sell land-based offsets to the global market that it may wish to reserve for domestic use in the future).
Global Warming Potential	*Source: All analysis in the CSIRO's GTEM and other models for this modelling exercise relies on estimates for the 100-year global warming potential of gases (GWP 100) from the IPCC's fifth Assessment Report (IPCC, 2013).*

Table C.3: LUTO assumptions

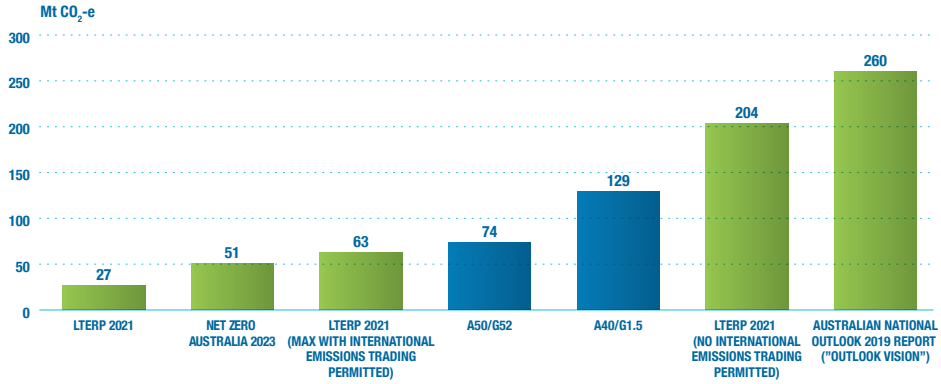
Sequestration from new plantings	Modelled annual land sequestration from new plantings in LUTO as applied in AusTIMES (distinct from the existing LULUCF sink) reaches about 74 Mt CO_2-e in the A50/G2 scenario in 2050, increasing to around 129 Mt CO_2-e in the A40/G1.5 scenario. The chart below compares this to some examples of annual sequestration from new plantings in other modelling exercises. Figure C.6: Comparison of sequestration achieved from new plantings in 2050 across different exercises. (Australian Government, 2021; CSIRO, 2019; Davis et al., 2023)  Note: The LUTO sequestration rates in this figure are the rates that are applied in the corresponding AusTIMES scenarios. This is a modelled outcome in LUTO. The amount of land sequestration from new plantings is used as an input to GTEM and AusTIMES modelling. LTERP is Australia's Long-Term Emissions Reduction Plan.
Profitability threshold	Assumption: The authority has requested that land use does not change to an alternative use until the financial return on the alternative land use is five times the return on the current land use on a net present value basis. For reforestation land uses, LUTO is operated on the assumption that landholders make decisions as if they will receive an annuity payment over 100 years based on the present value of carbon sequestration at a discount rate of 7%.
Planting rate constraint	Assumption: Initial constraint of 22,500 ha per year in 2025. Once the initial constraint is met the planting rate grows to a final cap of 260,000 ha per year. The initial constraint reflects a balance of considerations, including the historically achieved planting rates in the mid-1990s and time needed to upscale a plantation industry that has planted less than 10,000 ha in every year since 2009-10 (ABARES, 2023b). The upper limit is informed by the previous maximum planting area achieved of around 130,000 ha in 1999-2000 with the upper limit set at two times this to reflect future potential financial incentives (such as ACCUs).
Biodiversity plantings	Assumption: Up to 30 per cent of plantings are 'environmental plantings' that support biodiversity in addition to carbon sequestration. The authority's view is that there would need to be a balance of environmental and carbon plantings to reflect the diverse goals under a just transition. This reflects emerging policy approaches such as Australia's commitment to contribute to the goals of the Kunming-Montreal Global Biodiversity Framework through conserving 30 per cent of land and oceans by 2030, and the government's Nature Positive Plan. The LUTO model is calibrated to keep environmental plantings at approximately 30% of total plantings cumulative to 2050.
Water use	Assumption: All plantings in class C and D water stressed catchments are required to account for water entitlements or allocations, in line with managing competing water uses.

Table C.4: AusTIMES assumptions

<table>
<tr><th colspan="3">GTEM and LUTO outputs used as inputs in AusTIMES</th></tr>
<tr><td colspan="3">AusTIMES targets the gross value added for each sector from GTEM modelling results, as well as mirroring GTEM assumptions about population growth and the amount of engineered removals. For land sector emissions and sequestration AusTIMES uses LUTO model outputs in combination with the 2023 Emissions Projections (DCCEEW, 2023b).</td></tr>
<tr><th colspan="3">Electricity</th></tr>
<tr><td>Transmission</td><td colspan="2">Transmission options and costs are drawn from the Draft 2024 ISP (AEMO, 2023). Generators are mapped to transmission zones. Interconnector limits apply to interstate trade of electricity. Where new transmission is needed, for example to support new renewable generators, this is factored in as the model solves to minimise total discounted system costs over the projection period.</td></tr>
<tr><td>Technology costs</td><td colspan="2">Electricity technology costs are based on the CSIRO's 2023-24 GenCost consultation draft (P. Graham et al., 2023) rather than the final 2023-24 GenCost report released in May 2024 (P. Graham et al., 2024). The final version of this report was not available when the CSIRO finalised the assumptions to be used for this modelling exercise. The final report features several revisions, including upward revisions to the outlook for onshore wind and large-scale solar capital costs.</td></tr>
<tr><td>Renewable energy policies</td><td colspan="2">AusTIMES represents a range of state or territory and national renewable energy targets and objectives, including Australia's 82% renewable energy target for 2030 (assumed to apply to major grids) , the New South Wales Electricity Infrastructure Roadmap, the Northern Territory, Queensland, Tasmania and Victoria Renewable Energy Targets, and the Victorian Offshore Wind Target. While the CSIRO modelling achieves the 82% renewable energy target for the major grids where it applies, when examining the Australia-wide share (which includes off-grid generation) it is slightly less than that target.
<table>
<tr><th>Scenario</th><th>Renewable energy share in 2030</th></tr>
<tr><td>A50/G2</td><td>77%</td></tr>
<tr><td>A40/G1.5</td><td>79%</td></tr>
</table></td></tr>
<tr><th colspan="3">Transport</th></tr>
<tr><td>Technology costs</td><td colspan="2">Road vehicle costs are aligned with the CSIRO's EV Projections (P. Graham, 2023) for the 'Step Change' scenario. Cost assumptions have not been varied across scenarios.</td></tr>
<tr><td>Fleet turnover</td><td colspan="2">For road transport, existing vehicle stock (20.1 million registered motor vehicles with various characteristics as at 31 January 2021) is based on the ABS Motor Vehicle Census (ABS, 2021) and AusTIMES models the change in vehicle stock over time. Changes to the mix of vehicles and other assets in shipping, rail and aviation are not explicitly modelled in AusTIMES.</td></tr>
<tr><td>New Vehicle Efficiency Standard (NVES)</td><td colspan="2">A simplified implementation of the NVES is used in AusTIMES, with headline targets for emissions intensity applied to sales of passenger vehicles and light commercial vehicles from 2025 to 2029.
<table>
<tr><th colspan="3">Maximum emissions intensity of light vehicle sales (g CO_2/km)</th></tr>
<tr><th>Year</th><th>New passenger vehicles</th><th>New light commercial vehicles</th></tr>
<tr><td>2025</td><td>141</td><td>210</td></tr>
<tr><td>2026</td><td>117</td><td>180</td></tr>
<tr><td>2027</td><td>92</td><td>150</td></tr>
<tr><td>2028</td><td>68</td><td>122</td></tr>
<tr><td>2029</td><td>58</td><td>110</td></tr>
</table></td></tr>
</table>

Industry and Resources	
Technology costs and options	Technology options for emissions reductions in the industry and resources sector are consistent with the analysis undertaken for Climateworks' Industry Energy Transition Initiative (ETI) (Climateworks Centre & CSIRO, 2023). Hydrogen production costs are based on the same source as electricity technology costs (the 2023-24 GenCost consultation draft). Where data on technology costs was not available, the authority has relied on advice from the CSIRO and Climateworks, with additional advice from EY on abatement of fugitive emissions from coal mining.
Built Environment	
Technology costs and options	Assumptions about the technologies available to reduce emissions from buildings are consistent with those used in other AusTIMES modelling exercises – see the Climateworks Centre Decarbonisation Scenarios 2023 report (T. Graham et al., 2023). No explicit technologies are included for the built environment sector outside of residential and commercial buildings. The authority has relied on the expertise of the Climateworks Centre and the CSIRO for plausible assumptions for the costs and options of technologies to decarbonise buildings.
Agriculture	
Technology costs and options	Assumptions about the technologies available to reduce emissions from the agriculture sector are consistent with those outlined in the Climateworks Decarbonisation Scenarios 2023 report (T. Graham et al., 2023).

Key uncertainties to consider alongside the modelling

There are a range of reasons why modelled outcomes may not be achieved in the real world. The issues below have been identified as some (but by no means all) of the key uncertainties that should be considered when evaluating the likelihood of the different modelling results.

Supply chains

As outlined in many of the sector chapters, supply chain risks exist for many of the key technologies to support decarbonisation in Australia and globally. This includes not just the relevant materials for production, but also the necessary public and private investment, and the workforce required to deliver the transition.

Global coordination

All the scenarios assume orderly global action to achieve a global emissions trajectory consistent with the relevant long term global temperature outcome. In practice, differences in policy settings across different countries could well impact on the commercial viability of deploying available abatement technologies in Australian energy and emissions-intensive trade-exposed industry sectors.

Smooth uptake of new technologies

Some parts of Australia's economy are made up of only a few facilities throughout Australia. Both GTEM and AusTIMES often represent smooth changes in production or gradual transitions to a new technology. In reality, capital turnover in these sectors is likely to be more 'lumpy' as a small number of facilities are established, or switch to a new production or abatement technology.

Electricity mix and renewables buildout

The modelling exercise shows a plausible electricity capacity and generation mix, but does not fully capture all aspects of the technical requirements of the system, commercial viability of generation assets, impacts on electricity prices, or potential restrictions on the rate of expansion of renewable electricity. Any of these factors could influence real-world outcomes in the electricity sector, and slower buildout of renewables in particular could make rapid decarbonisation of the economy more challenging.

Competition for land use

There may be increasing competition for land use as demand grows over time for renewable energy, biofuels and biomass, agricultural commodities and land sector sequestration. Some of this competition may be offset by improving agricultural efficiency, co-benefits (e.g. shelterbelts), and co-use (e.g. co-location of renewable energy generation and grazing).

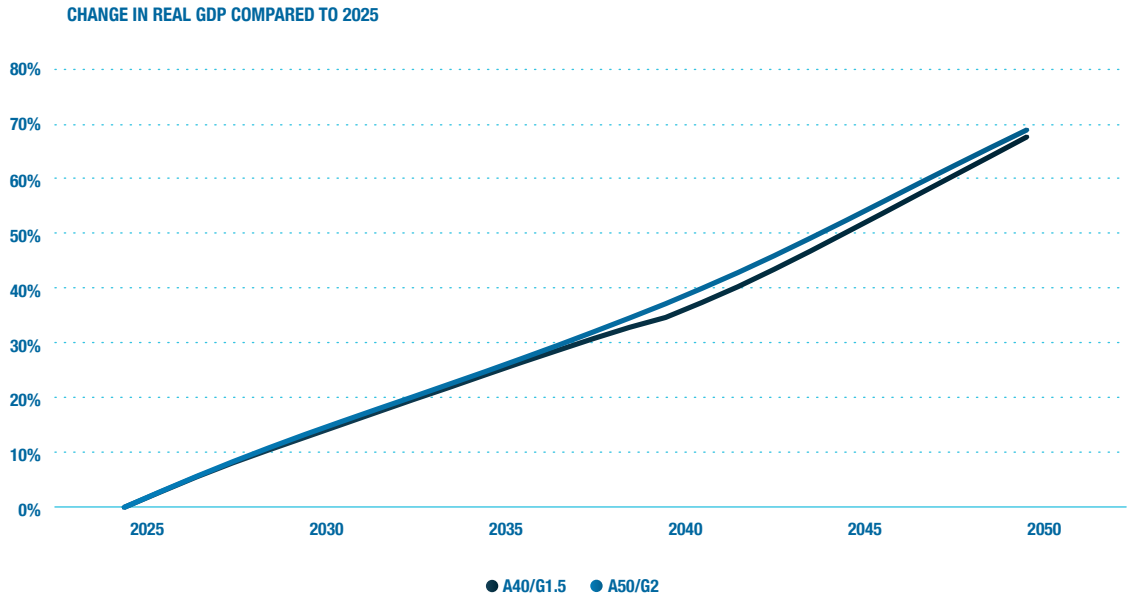
GTEM – High level GDP results and marginal cost of abatement

Gross Domestic Product

In the A40/G1.5 and A50/G2 scenarios modelled by the CSIRO for the authority, Australia continues to experience economic growth that is broadly in line with recent Treasury projections. In both scenarios, the Australian economy grows in real terms by an average of 2.1% per year between 2025 and 2050 (Figure C.7). The Australian Treasury's 2023 Intergenerational Report projects an average growth rate of 2.2% per year over the next 40 years (Australian Treasury, 2023).

The modelling undertaken for the authority does not the incorporate the potential impacts of climate change on Australia's economy. It also takes a neutral view of the extent to which Australia takes advantage of the economic opportunities in international trade of the global transition to net zero. It does not, for example, incorporate assumptions and policies reflected in the modelling undertaken to support the forthcoming update to the National Hydrogen Strategy, or in the measures in the 2024 Budget to support the government's Future Made in Australia agenda.

Figure C.7: Change in gross domestic product, 2025 to 2050



Source: CSIRO modelling in GTEM commissioned by the Climate Change Authority

Marginal cost of abatement

GTEM solves for the marginal cost of abatement necessary to meet the net emissions constraint that it is given under each scenario modelled, based on the suite of technologies and technology cost assumptions that are included in the model. The marginal cost of abatement motivates the avoidance or reduction of emissions, or an increase in removals, across the economy.

Although this is sometimes described as a 'shadow carbon price', it is an abstract modelling mechanism and does not imply a true carbon price. It may require producers in the model to switch to higher cost (lower emissions) production methods, but it is not a carbon tax, where revenue would be collected (and potentially redistributed by government), nor is it necessarily enforced through a cap-and-trade or baseline-and-credit mechanism (see section NP.6 for a discussion of ways to signal the cost of carbon across the economy).

The table below compares the marginal cost of abatement from GTEM in the year 2050 under the A40/G1.5 and A50/G2 scenarios with estimates of the values of emissions reductions that have been developed for different purposes (see Table C.5, notes). The comparisons are provided for general, illustrative purposes only and should be interpreted with caution, given the different approaches used to develop the estimates and the different purposes for which they have been prepared.

Table C.5: Marginal cost of abatement / value of emissions reductions in 2050

Source	Scenario	$ (2023 Australian dollars)
Climate Change Authority /CSIRO GTEM results	A40/G1.5	477
	A50/G2	518
Australian Energy Market Commission[1]		420
Infrastructure Australia[2]	Central	377
	High	469
	Low	287

Notes:

1 From Australian Energy Market Commission (2024). Value of emissions reductions to be used by a government or regulatory entity where quantitative analysis is required of costs and benefits of projects relating to emissions reduction in the National Electricity Market. This interim value was calculated based on the methodology approved by the Ministerial Council on Energy and will remain in force until 2025 unless superseded by an updated instrument, rule or regulation.

2 From Infrastructure Australia (2024). This Infrastructure Australia Guidance Note sets out the monetised value of GHG emissions for use in economic analysis of a new proposal, including cost-benefit analysis (CBA) and cost effectiveness analysis (CEA). The values are based on the estimated future costs of abatement necessary for the Australian economy to meet national emissions reduction targets and international commitments. The 'High' and 'Low' cases are for use in sensitivity analysis.

Further information on the GTEM modelling results will be provided in the report of the authority's 2035 targets advice.

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Acronyms and abbreviations

#

3-NOP	3-Nitrooxypropanol

A

A40/G1.5	Scenario modelled for the authority by the CSIRO. See Appendix C for details.
A50/G2	Scenario modelled for the authority by the CSIRO. See Appendix C for details.
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABCB	Australian Building Codes Board
ABS	Australian Bureau of Statistics
ACCU	Australian Carbon Credit Unit
ACOSS	Australian Council of Social Service
ACSI	Australian Council of Superannuation Investors
ACT	Australian Capital Territory
AEIC	Australian Energy Infrastructure Commissioner
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AFI	Australian Farm Institute
ANU	Australian National University
ANZSIC	Australia and New Zealand Standard Industrial Classification
APR	Annual Progress Report
APRA	Australian Prudential Regulation Authority
APS	Announced Pledges Scenario
ARENA	Australian Renewable Energy Agency
ASX	Australian Securities Exchange
ASBEC	Australian Sustainable Built Environment Council
ATIC	Australian Trade and Investment Commission
ATO	Australian Taxation Office
AusTIMES	Australian implementation of The Integrated MARKAL-EFOM System

B

BCA	Business Council of Australia
BCG	Boston Consulting Group
BESS	Battery and Energy Storage Systems
BITRE	Bureau of Infrastructure and Transport Research Economics
BNEF	Bloomberg New Energy Finance

C

CAPEX	Capital Expenditure
CBA	Cost-Benefit Analysis
CBAM	Carbon Border Adjustment Mechanism
CCA	Climate Change Authority
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Utilisation and Storage
CDR	Carbon Dioxide Removal
CDU	Collie Delivery Unit
CEA	Cost-Effectiveness Analysis
CEC	Clean Energy Council
CEDA	Committee for Economic Development of Australia
CEFC	Clean Energy Finance Corporation
CEIG	Clean Energy Investor Group
CER	Clean Energy Regulator
CFFR	Council on Federal Financial Relations
CFI	Carbon Farming Initiative
CGE	Computable General Equilibrium
CIM	Clean Investment Monitor
CIS	Capacity Investment Scheme
CO_2	Carbon Dioxide
CO_2-e	Carbon Dioxide equivalent
COP	Conference of the Parties
CPI	Climate Policy Initiative
CSIRO	Commonwealth Scientific and Industrial Research Organisation

D

DAC	Direct Air Capture
DAFF	Department of Agriculture, Fisheries and Forestry
DAT	Act Data Availability and Transparency Act 2022
DCCEEW	Department of Climate Change, Energy, the Environment and Water

DISR	Department of Industry, Science and Resources

E

E3	Equipment Energy Efficiency program
EPBC	Environment Protection and Biodiversity Conservation Act 1999
ESG	Environmental, Social, and Governance
ETI	Energy Transitions Initiative
ETSAP	Energy Technology Systems Analysis Program
EU	European Union
EVs	Electric Vehicles

F

FNCEN	First Nations Clean Energy Network
FPIC	Free, Prior, and Informed Consent
FY	Financial year

G

GBCA	Green Building Council of Australia
GDP	Gross Domestic Product
GEMS	Greenhouse and Energy Minimum Standards
GLaWAC	Gunaikurnai Land and Waters Aboriginal Corporation
GO	Guarantee of Origin
GRDC	Grains Research and Development Corporation
Gt	Gigatonne
GTEM	Global Trade and Environment Model
GVA	Gross Value Added
GW	Gigawatt
GWP	Global Warming Potential

H

HFC	Hydrofluorocarbons
HTS	High Temperature Superconductors

I

IA	Infrastructure Australia
ICCPR	International Covenant on Civil and Political Rights
ICE	Internal Combustion Engine
ICIN	Indigenous Carbon Industry Network
IEA	International Energy Agency
IEEFA	Institute for Energy Economics and Financial Analysis
IGCC	Investor Group on Climate Change
ILSC	Indigenous Land and Sea Corporation
IMP	Illustrative Mitigation Pathway
IMP-GS	Illustrative Mitigation Pathway ('Gradual Strengthening')
IMP-Ren	Illustrative Mitigation Pathway ('Renewables')
IOIG	Input-Output Industry Group
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IRA	Inflation Reduction Act 2022 (United States)
ISP	Integrated System Plan
ITMO	Internationally Transferred Mitigation Outcome
IUCN	International Union for Conservation of Nature

J

JSA	Jobs and Skills Australia

L

LNG	Liquified Natural Gas
LPG	Liquid Petroleum Gas
LULUCF	Land Use, Land-Use Change and Forestry
LUTO	Land Use Trade Offs (model)
LVA	La Trobe Valley Authority

M

MARKAL-EFOM	Market Allocation-Energy Flow Optimisation Model
MERiL	Methane Emissions Reduction in Livestock
MERNAP	Maritime Emissions Reduction National Action Plan
MLA	Meat & Livestock Australia
MRV	Measurement, Reporting and Verification
Mt	Megatonne

MW	Megawatt

N

NABERS	National Built Environment Rating System
NatHERS	Nationwide House Energy Rating Scheme
NCC	National Construction Code
NDC	Nationally Determined Contribution
NEM	National Electricity Market
NEPS	National Energy Performance Strategy
NFF	National Farmers' Federation
NGER	National Greenhouse and Energy Reporting
NGFS	Network for Greening the Financial System
NIAA	National Indigenous Australians Agency
NRF	National Reconstruction Fund
NSW	New South Wales
NVES	New Vehicle Efficiency Standard
NZA	Net Zero Australia
NZE	Net Zero Emissions by 2050 Scenario

O

OCGT	Open Cycle Gas Turbines
ODP	Optimal Development Path
OECD	Organisation for Economic Cooperation and Development
OPEX	Operating Expenses

P

PBC	Prescribed Body Corporate
PCA	Property Council of Australia
PHES	Pumped Hydro Energy StoragePFAS Perfluoroalkyl and Polyfluoroalkyl Substances
PM&C	Prime Minister & Cabinet
PV	Photovoltaic

Q

QFF	Queensland Farmers' Federation
QNI	Connect Queensland New South Wales Interconnector Connect

R

R&D	Research and Development
RBA	Reserve Bank of Australia
RD&D	Research, Development and Demonstration
REZ	Renewable Energy Zones
RIT-T	Regulatory Investment Test for Transmission

S

SAF	Sustainable Aviation Fuel
SBTi	Science Based Targets initiative
SCM	Supplementary Cementitious Materials
SMCs	Safeguard Mechanism Credits
SRES	Small-scale Renewable Energy Scheme
STEM	Science, Technology, Engineering, and Mathematics
SUIC	Supply-Use Industry Classification

T

TAFE	Technical and Further Education
TCO	Total Cost of Ownership
TNFD	Taskforce for Nature-related Financial Disclosures

U

UDIA	Urban Development Institute of Australia
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNHRC	United Nations Human Rights Committee
UQ	The University of Queensland
USD	US Dollar

V

VET	Vocational Education and Training
VNI	West Victoria New South Wales Interconnector West

W

WEM	Wholesale Electricity Market