

Technical Appendix

A fossil-free Australia

September 2026



The report "A fossil-free Australia" presents the first results of a hybrid modelling framework implemented in the Stockholm Environment Institute's Low Emissions Analysis Platform and the Next Energy Modeling system for Optimization.¹

For this analysis, we built two scenarios. The Current Policy Projections (CPP) scenario primarily follows the government's 2025 Emissions Projections to 2040 and the Net Zero Plan after that, and serves as the baseline for the Fossil Fuel Phase-out (FFPO) scenario.² The FFPO scenario is informed by the macro-regional results from the Highest Possible Ambition (HPA) scenario, developed by Climate Analytics and PIK with the REMIND integrated assessment model, and by Australian and international high ambition studies.³ The model covers all sectors of the economy, with a focus on the energy system. The present document sets out the assumptions used across the model.

Macroeconomic assumptions

Across the CPP and FFPO scenarios, population and GDP are the main drivers of activity levels across many energy-demand sectors. The GDP time series used in the model is sourced from the October 2025 ABS Australian System of National Accounts for historical values through 2025.⁴ For 2026, all scenarios follow the growth rate from the RBA's February 2026 Statement on Monetary Policy.⁵ After that, GDP follows scenario-dependent growth rates based on the AEMO 2025 IASR.⁶

These GDP projections are consistent with those in other studies.⁷ The GDP growth rate in the CPP scenario averages 2.0% between 2025 and 2035 and 1.9% between 2025 and 2050. For comparison, the Step Change scenario from the Deloitte Economic Forecasts 2024-25 commissioned by AEMO and underpinning its results, projects 1.8% CAGR between 2023 and 2058; the 2025 Emissions Projections report projects 2.4% between 2025 and 2040; and the Baseline scenario from Treasury's net zero modelling, Australia's Net Zero Transformation, projects 2.6% between 2026–2035 and 2.3% between 2026–2050.^{8 9 10}

¹ Heaps, C.G., 2022. *LEAP: The Low Emissions Analysis Platform*. [Software version: 2026.7.0.3] Stockholm Environment Institute. Somerville, MA, USA. <https://leap.sei.org>

² Department of Climate Change, Energy, the Environment and Water, *Australia's Emissions Projections 2025*; Australian Government, *Australia's Net Zero Transformation*.

³ Climate Analytics, "Rescuing 1.5°C: New Evidence on the Highest Possible Ambition to Deliver the Paris Agreement."

⁴ ABS, "Australian System of National Accounts (2024-25 Financial Year)."

⁵ RBA, "Statement of Monetary Policy."

⁶ AEMO, "2025-26 Inputs, Assumptions and Scenarios."

⁷ These comparisons are indicative, as different reports may define and report GDP differently.

⁸ Deloitte, "Economic Forecasts 2024-25."

⁹ Australian Government, *Australia's Net Zero Transformation*.

¹⁰ Applying the ABS Population Projections to the Treasury's modelling annual GDP per capita time series.

The FFPO scenario assumes GDP growth averaging 2.6% per year to 2050. This is similar to Treasury's Renewable Exports scenario, which projects growth of 2.6% from 2026 to 2050, and to the Green Energy Exports scenario from the Deloitte study, which projects a CAGR of 2.5% from 2023 to 2058.¹¹

Table 1: GDP growth across different transition scenarios.

	This report	2025 emissions projections	Treasury's Net Zero Transformation	Deloitte's Economic forecasts 2024-25
Current policies aligned scenarios	CPP scenario 1.9% between 2025 and 2050	Baseline 2.4% between 2025 and 2040	Baseline 2.3% between 2026 and 2050	Step Change 1.8% CAGR from 2023 to 2058
Higher ambition scenarios	FFPO scenario 2.6% between 2025 and 2050	N/A	Renewable Export scenario 2.6% between 2026 and 2050	Green Energy Exports 2.5% CAGR from 2023 to 2058

Future population time series are extracted from the ABS Population Projections published in November 2023, with the medium and high series allocated to the CPP and FFPO scenarios, respectively.¹² These follow AEMO's assumption that more climate-progressive scenarios are associated with higher population and economic growth. We apply the same approach to household numbers, using the most ambitious time series from the ABS 2024 Household and Family Projections for the higher-ambition scenario. Despite differences in absolute values, the average household size remains stable across all scenarios, at 2.5 persons per household.¹³

Buildings sector

The building sector is characterised by activity levels, fuel shares and final energy intensity. Across scenarios, activity levels by 2040 for residential buildings are set based on the number of households according to the ABS' Projected households 2024 time series, then extended using the trend to 2050.¹⁴ Comparing these time series with population projections, the number of people per household remains broadly constant throughout the period at approximately 2.5 persons. For non-residential buildings, including commercial, industrial and other buildings, future activity levels are aligned with GDP growth.

Historical energy demand for the residential sector is taken directly from Table F of the 2025 Energy Statistics, while future emissions follow the trajectory set out in the 2025

¹¹ Deloitte, "Economic Forecasts 2024-25."

¹² ABS, "Population Projections, Australia (2022 (Base) - 2071)."

¹³ ABS, "Household and Family Projections, Australia (2021 - 2046)."

¹⁴ Australian Bureau of Statistics, "Projected Households, Australia, 2021 to 2046."

emissions projections.¹⁵ For the residential sector, future energy demand is further shaped by forecasts of fuel share and energy efficiency improvements up to 2040. This is derived from 2021 Residential Baseline Study for Australian and New Zealand for 2000 to 2040.¹⁶

The Commercial Building Baseline Study 2022 is used as a primary source for the non-residential sector.¹⁷ Since the study assessed 15 sub-classes, we categorised them into three sub-sectors based on the Functional Classification of Buildings, published by the Australian Bureau of Statistics.¹⁸ Historical and projected energy demand, including energy intensity forecasts by sub-class to 2050, is drawn from this study. Total electricity demand is then allocated across NEM, DWIS, SWIS and off-grid using a distribution rule that reflects projected changes in population and GSP. The same rule is also applied to the residential sector.

In the FFPO scenario, the fuel mix for each buildings sub-sector converges towards that of the macro-region from the HPA. Because of structural differences between the historical data for the HPA scenario's Canada, Australia and New Zealand region and the data for Australia's subsectors, we use different approaches for residential and non-residential buildings. For the residential sector, we apply the growth rates of fuel shares in the HPA scenario for Canada, Australia and New Zealand to historical fuel shares from the CPP scenario, allowing them to converge with the HPA shares by 2035. We assume that the residual use of biomass is phased out by 2030 in the residential sub-sectors, with its energy consumption displaced by electricity.

For commercial, industrial and other buildings where only gas and electricity are the two fuels consumed, we apply the growth rate of gas's fuel share in the HPA scenario for the macro region to that of Australia's current building stock, and balance the rest with electricity. Finally, total energy demand from both other transport and storage and construction by fuel is scaled to the buildings fuel-by-fuel energy consumption from the HPA scenario, factoring in the impact of fuel substitution from the replacement of biomass in the residential sector.

We also include additional demand from data centres, which is not separately accounted for in the Commercial Building Baseline Study 2022, based on the growth assumptions in Oxford Economics' Data Center Energy Demand report.¹⁹ The CPP trajectory is aligned with the report's Step Change scenario and the FFPO scenario with its Green Energy Exports scenario. Following the Oxford Economics report, we further assume that the NEM's share of total data centre demand stays constant through 2050. This approach

¹⁵ Department of Climate Change, Energy, the Environment and Water, "Australian Energy Update 2025."

¹⁶ Energy Consult, *2021 Residential Baseline Study for Australia and New Zealand for 2000 to 2040*.

¹⁷ Department of Climate Change, Energy, the Environment and Water, *Commercial Building Baseline Study 2022*.

¹⁸ Australian Bureau of Statistics, "Functional Classification of Buildings."

¹⁹ Oxford Economics Australia, *Data Center Energy Demand*.

yields an additional electricity demand for data centres of 35 to 40 TWh by 2050, depending on the scenario.

Transport sector

CPP scenario

Road transport

Historical activity of all road transport is aligned with the Australian Infrastructure and Transport Statistics - Yearbook 2024 by the Bureau of Infrastructure and Transport Research Economics (BITRE).²⁰ Future activity levels are projected based on fleet forecasts from the Step Change scenario in AEMO's 2025 IASR EV workbook.²¹

Historical fuel consumption in the road transport sector in 2018 and 2020 is sourced from the Australian Bureau of Statistics (ABS) Survey of Motor Vehicle Use. As the ABS discontinued the biennial survey in 2020, fuel consumption for the remaining historical years (2019 and 2021–2025) is calculated using AES data, assuming that fuel consumption rates across road transport remained constant between 2020 and 2025.

Statistical fleet numbers of each vehicle are harmonised with AEMO's EV workbook, as its data categories differ from those in the ABS data. While future fuel demand is driven by changes in activity level, special assumptions are taken in articulated trucks, rigid trucks, passenger cars and light commercial vehicles to reflect more conservative emissions reduction forecasts according to the 2025 Emissions Projections.²² To create a similar trend as the Emissions Projections does, we modelled slower increase in the activity level of EVs while keeping the same total activity level, energy intensity and emissions distribution among fossil fuels. The 2025 Emissions Projections provides data up to 2040; thus, post-2040 emissions are assumed to be following similar trends as between 2035 and 2040.

Other freight transport

Historical and future activity of freight rail and coastal shipping are based on 2022 updates to the BITRE Australian aggregate freight forecasts, which assumed that population growth, changing geographies, economic growth and oil prices influence future freight activity. Historical energy consumption is sourced from AES data.²³ Activity level of passenger rail is sourced from the BITRE Yearbook 2024 for historical data and AEMO's Electric Vehicle Projections for future forecasts.^{24 25} The AEMO's projection

²⁰ Bureau of Infrastructure and Transport Research Economics, *Australian Infrastructure and Transport Statistics—Yearbook 2024*.

²¹ AEMO, "AEMO: 2025 IASR EV Workbook."

²² Department of Climate Change, Energy, the Environment and Water, *Australia's Emissions Projections 2025*.

²³ Rail Industry Safety and Standards Board, *National Rail Carbon Footprint Study*.

²⁴ Bureau of Infrastructure and Transport Research Economics, *Australian Infrastructure and Transport Statistics—Yearbook 2024*.

²⁵ CSIRO, *Electric Vehicle Projections*.

provides disaggregated forecasts among passenger demand, road, rail and air in the Step Change scenario.

The 2025 Emissions Projections are used for modelling future energy consumption in coastal shipping. The projection forecasts a slow decrease in total emissions, and we do not include fuel switch over time in the shipping sector. By contrast, future fuel mix in rail is modelled by defining energy savings through electrification in the sector at 56%.²⁶

Domestic aviation

BITRE's Australian Aviation Forecasts - 2024 to 2050 reports revenue based on passenger kilometres.²⁷ We used historical energy consumption from the Energy Statistics to back-calculate energy and emissions intensity, and projected this forward alongside the pace of sustainable aviation fuel phase-in from 2028 onwards, based on the 2025 emissions projections.^{28,29}

FFPO scenario

Each transport sector was treated separately as part of the FFPO scenario, but all use the same methodology. Historical values are aligned with those in the CPP scenario, and future activity levels are derived from the CPP scenario and harmonised with population growth for passenger cars and GDP for the others.

For each road and rail category in the Australian taxonomy (including light commercial vehicles, rigid trucks and articulated trucks), we isolated relevant variables and extracted fuel shares. Fuel baskets within HPA (for example, liquid fuels include liquid biomass, gasoline and diesel) were disaggregated based on energy consumption, with the underlying assumption that fuels within the same category share the same energy intensity.

We then initialised the CPP fuel shares to converge towards the HPA share by exponential interpolation by 2030, as most transport sectors share the same traits, with low electrification and high (if not total) predominance of fossil fuels in the energy mix. This allows us to derive fuel-specific activity levels, the first half of our energy demand equation.

The CPP's final energy intensity of liquid and gas fuels is harmonised with HPA energy efficiency improvements. For electricity, we use the inferred energy intensity improvement per vehicle category from the AEMO 2025 IASR EV Workbook and the AEMO Electric Vehicle Projections 2024.³⁰ As with other activity-based sectors, the

²⁶ Ahmed Aredah et al., *Comparative Analysis of Alternative Powertrain Technologies in Freight Trains: A Numerical Examination towards Sustainable Rail Transport*.

²⁷ Bureau of Infrastructure and Transport Research Economics, *Australian Aviation Forecasts - 2024 to 2050*.

²⁸ Department of Climate Change, Energy, the Environment and Water, "Australian Energy Update 2025."

²⁹ Department of Climate Change, Energy, the Environment and Water, *Australia's Emissions Projections 2025*.

³⁰ AEMO, "AEMO: 2025 IASR EV Workbook."

product of activity levels and energy intensity provides energy consumption, to which we apply fuel-specific emissions factors from the National Greenhouse Gas Accounts Factors.³¹

Special measures were taken in aviation to reflect real world constraints and assumptions. Domestic aviation activity levels under the FFPO scenario are assumed to grow at the rate of GDP, but unlike other modes are adjusted for avoided demand (27% by 2050, in line with IEA's 2022 World Energy Outlook Net Zero Emissions scenario) to reflect both behavioural changes (modal shift, reduced business travel, video conferencing, etc.) and demand saturation in a mature market.^{32,33} This assumption leads to a 1.2% CAGR in activity levels between 2024–2050.

Meanwhile, energy efficiency improves by 2% per year from 2026 onwards, in line with the IEA NZE scenario, compared with the 0.9% annual improvement back-calculated from the Emissions Projections. The 2% assumption is drawn from the International Air Transport Association's Aviation Net-Zero CO₂ Transition Pathways - Comparative Review, which notes that the IEA scenario also assumes "traffic optimisation measures [and] energy efficiency gains".³⁴

International aviation and shipping

International aviation and shipping are modelled separately from the domestic transport sectors described above. While they sit outside Australia's national inventory totals under UNFCCC reporting conventions, they remain part of Australia's energy balance and therefore of the broader fossil fuel phaseout assessed in this study.

International aviation

Historical and future activity levels of the international aviation sector are sourced from BITRE's Australian Aviation Forecasts – 2024 to 2050, using the international passenger activity time series through to 2050.³⁵ This yields activity growth of around 2.7% between 2018 and 2050, close to the median of the pathways reviewed in IATA's Aviation Net-Zero CO₂ Transition Pathways - Comparative Review. In the FFPO scenario, like for domestic aviation, we adjust the activity pathway for avoided demand driven by behavioural changes, this time using the international values from the IEA Net Zero Roadmap, reaching 20% avoided demand by 2050, corresponding to a 2.2% CAGR to 2050.³⁶

³¹ Department of Climate Change, Energy, the Environment and Water, "National Greenhouse Accounts Factors: 2025."

³² IEA, *World Energy Outlook 2022*.

³³ The 2025 World Energy Outlook's Net Zero Emissions scenario uses a 1.9% CAGR for global aviation activity growth between 2024 and 2050. We relied on an older World Energy Outlook datapoint because this is the latest edition that provided a breakdown splitting wealthy, advanced economies, from emerging economies.

³⁴ IATA, *Aviation Net-Zero CO₂ Transition Pathways - Comparative Review* (2024), <https://www.iata.org/contentassets/8d19e716636a47c184e7221c77563c93/nz-roadmaps.pdf>.

³⁵ BITRE, "Australian Aviation Forecasts – 2024 to 2050."

³⁶ IEA, *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach - 2023 Update*.

In the CPP scenario, final energy intensity is back-calculated so that international aviation energy demand matches Emissions Projections to 2040; it is then extended to 2050 using the implied trend.³⁷ Under the FFPO scenario, final energy intensity follows the median of the technological and operational efficiency improvements across IATA's Aviation Net-Zero CO₂ Transition Pathways - Comparative Review, corresponding to around 1.3–1.4% compound annual growth rates to 2050.³⁸

Fuel shares also differ by scenario. Under the CPP scenario, SAF is interpolated from zero at present to 5% in 2035 and 10% in 2050, in line with the IEA's 2025 WEO STEPS scenario, while hydrogen and electricity are excluded.³⁹ Under the FFPO scenario, SAF, hydrogen and electricity are based on the median of IATA's Aviation Net-Zero CO₂ Transition Pathways - Comparative Review.⁴⁰ SAF reaches around 30% in 2035 and 87% in 2050. The remaining 13% in 2050 is split between hydrogen and electricity using the 73:27 ratio from the IEA's Net Zero Roadmap aviation guide.⁴¹

International shipping

Historical activity is represented using BITRE's latest Maritime Australian Sea Freight report, which provides international maritime sea-freight tonnage.⁴² Historical final energy intensity is derived by dividing energy use for international water transport from AES' Table F by the former activity time series. Historical fuel shares are taken from the same AES Table, which provides the split between HFO/LSFO and MDO.

In the CPP scenario, future activity is extrapolated from the last historical year using the midpoint of the lower- and upper-bound growth pathways used in the Climate Action Tracker methodology, themselves based on the OECD_RCP2.6_L and SSP2_RCP2.6_L logistics-model scenarios from the Fourth International Maritime Organisation Greenhouse Gas Study.^{43,44} Because these source scenarios are reported in tonne-miles while the BITRE-driven Australian historical data are reported in tonnes, this approach assumes a constant average haul distance per tonne over time. Under this midpoint approach, activity grows by around 1.9% per year between 2024 and 2050.

Final energy intensity under CPP is derived in the same way, using the midpoint of cumulative fleet-average efficiency improvements from the same IMO scenarios, and harmonised to the last historical year. CPP fuel shares are aligned with the IEA 2025 WEO STEPS: oil remains dominant at 80% in 2035 and 72% in 2050, with the oil component split between HFO and MDO based on their historical ratio. By 2050, in line with STEPS, the remainder is made up of around 13% biofuels, 12% LNG and 3% for methanol,

³⁷ DCCEEW, "Quarterly Update of Australia's National Greenhouse Gas Inventory: December 2024."

³⁸ IATA, *Aviation Net-Zero CO₂ Transition Pathways - Comparative Review*.

³⁹ IEA, *World Energy Outlook 2025*.

⁴⁰ IATA, *Aviation Net-Zero CO₂ Transition Pathways - Comparative Review*.

⁴¹ CSIRO, "Sustainable Aviation Fuel Roadmap."

⁴² Department of Infrastructure, Transport, Regional Development, Communications and the Arts, *Australian Sea Freight 2023–24*.

⁴³ Climate Action Tracker, "International Shipping."

⁴⁴ IMO, *Fourth IMO Greenhouse Gas Study*.

hydrogen and ammonia combined, with intermediate values interpolated and shares normalised to 100%.

In the FFPO scenario, activity follows the IEA 2025 WEO NZE scenario values, resulting in around 0.3% CAGR between 2024 and 2050. Final energy intensity follows the Scenario A/Gradual Response pathway from the University Maritime Advisory Services' 2025 International Maritime Decarbonisation Transitions report, using cumulative fleet-efficiency improvements relative to 2018 and harmonised to the last historical year.⁴⁵ This implies cumulative efficiency improvements of around 24% by 2030, 30% by 2040 and 35% by 2050 relative to 2018. Fuel shares are also based on the same scenario, as synthesised in Climate Analytics' 2025 Real Zero report, with ammonia becoming the dominant fuel by mid-century and the remainder made up mainly of biofuels and small amounts of other zero-carbon fuels.⁴⁶

Power sector

The model identifies five grids: the NEM, the SWIS, the DKIS, off-grid electricity generation (encompassing the NWIS and all demand and generation from remote industrial facilities) and LNG electricity generation at LNG facilities.

Historical electricity generation is calibrated to the Energy Statistics and Open Electricity data for the NEM and SWIS, complemented by the ISP for the NEM, the Whole of System Plan for the SWIS. We separately used the NT Energy Outlook for the DWIS. Off-grid consumption is determined by subtracting demand across all other grids. LNG power consumption is derived from successive Energy Statistics gas flow data, assuming a 35% gas-to-electricity conversion efficiency.

Plant-level details are aggregated by type from the IASR for the NEM, the WOSP for WA (extended with capacity data from Open Electricity for more recent plants) and the NT Energy Outlook for the NT.⁴⁷ Off-grid fossil fuel generators draw on the 2018 S&P Platts dataset, with off-grid renewables estimated by subtracting grid-level from total installed renewable capacity as reported by Ember.⁴⁸

In the CPP scenario, individual oil and fossil gas units across all grids are assumed to operate through their full technical life expectancy. Coal retirement follows facility-level

⁴⁵ Smith, Tristan et al., *International Maritime Decarbonisation Transitions – The Costs and Impacts of Different Pathways for International Shipping to Achieve Alignment to the 1.5°C Temperature Goal – Main Report*.

⁴⁶ Climate Analytics, *Real Zero: Delivering a Fossil Free Future*.

⁴⁷ Energy Policy WA, "Whole of System Plan 2020"; Utilities Commission of the Northern Territory, "Northern Territory Electricity Outlook Report 2023"; Utilities Commission of the Northern Territory, "Northern Territory Electricity Outlook Report Update 2024"; AEMO, "2025 Inputs, Assumptions and Scenarios."

⁴⁸ Ember, "Electricity Data Explorer"; S&P Global Market Intelligence, "World Electric Power Plants Data Base."

schedules from the AEMO ESOO for WA and the AEMO 2026 ISP Step Change scenario for the NEM, in order to reflect 2025 Queensland government announcements and align with the capacity envelope from the emissions projections.⁴⁹

For all scenarios, historical installations are set exogenously, after which the model allocates new capacity under a constrained least-cost pathway (except for rooftop PV). Generators and storage are parametrised using the GenCost 2025/26 techno-economic parameters: the CPP scenario draws on the GenCost Current Policies scenario cost data and the FFPO scenario on the GenCost Net Zero by 2050 scenario data.

Costs for generator types outside GenCost's scope (hydro, biomass, distillate) are calculated by harmonising AEMO IASR 2025 figures to the GenCost framework. Fuel costs follow the high GenCost price in the CPP scenario and the low price in the FFPO scenario. Rooftop PV capacity and generation are set exogenously throughout the period: for the SWIS, based on the AEMO ESOO Expected case for CPP and the High case for FFPO, with a trend extended to 2050; for the NEM, on the ISP 2026 Step Change scenario for CPP and the Accelerated Transition scenario for FFPO.

Availability shapes for utility-scale and rooftop solar, as well as onshore and offshore wind, are drawn from the geospatial potential analysis and hourly generation profiles in Wind and Solar Benchmarks for a 1.5°C World.⁵⁰ They were derived using the open-source Global Land Eligibility for Energy Systems and Renewable Energy Simulation Toolkit packages, applying a comprehensive set of land exclusion factors. Results are aggregated to each grid's geographical boundaries and condensed into the 96 hourly time slices the model uses, representing four representative days across four seasons.

For the storage analysis, the model is stress-tested against availability shapes from the four worst days in the simulated profiles, representing a wind and solar drought.

While, as mentioned, the model deploys capacity and dispatches based on a least-cost logic, all scenarios in this report are heavily constrained. Both the CPP and FFPO scenarios operate under an overarching renewable generation floor for each grid. The least-cost pathway can exceed them where it produces a higher share. The CPP scenario is constrained to endogenously emulate the results from the Emissions Projections, with a renewable target set to align at least with the Emissions Projections to 2040, and later rising linearly to 95% in both the SWIS and NEM.⁵¹

Still under the CPP scenario, gas generation in the NEM is set to evolve in line with national Emissions Projections levels, while coal generation is calibrated to meet the projected emissions trajectory. In the SWIS, coal generation is constrained to not exceed

⁴⁹ AEMO, "2025 Wholesale Electricity Market Electricity Statement of Opportunities"; AEMO, "2026 Integrated System Plan."

⁵⁰ Climate Analytics and New Climate Institute, *Technical Annex: Wind and Solar Benchmarks for a 1.5°C World*.

⁵¹ Department of Climate Change, Energy, the Environment and Water, *Australia's Emissions Projections 2025*.

current levels. There is no cap on maximum production by technology off-grid, but minimum production floors decline linearly from current levels to zero by 2035 to avoid abrupt changes to the system.

Across all scenarios, the share of utility-scale PV is subject to a floor set at the Emissions Projections level. That floor is doubled for off-grid generation, reflecting the isolated nature of many facilities for which decentralised solar is more relevant. In the NEM, we align hydro capacity and maximum generation with the ISP Step Change scenario. Biomass is a marginal component of the power systems modelled, so we assume the limited existing capacity is phased out by 2035 and set maximum capacity additions to zero. We make the same assumption for oil in the NEM, for the same reasons. Off-grid, where it plays a larger role, we assume in the CPP that existing capacity follows its natural, lifetime-set retirement timeline, with no new capacity additions.

In the FFPO scenario, constraints are anchored to an overarching renewable share of generation floor derived from the HPA scenario Canada-Australia-New Zealand region, reaching 87% by 2030, 93% by 2035, 95% by 2040 and 100% by 2050. The coal retirement in the NEM is set to align with the one determined by the AEMO in the ISP 2026 Accelerated Transition scenario.⁵² Apart from coal, existing fossil fuel-fired capacity is phased out exogenously based on the capacity decline rate of the HPA pathway. In addition to these capacity retirement trajectories, fossil fuel generation is capped to the rate of decline from the HPA scenario Canada-Australia-New Zealand region across all power systems.

Table 2: Renewable generation share constraint, by grid, scenario and year (%)

Grid	CPP			FFPO		
	NEM	SWIS	Off-grid	NEM	SWIS	Off-grid
2030	84%	82%	31%	87%	87%	87%
2040	87%	84%	68%	95%	95%	95%
2050	95%	95%	82%	100%	100%	100%

⁵² AEMO, “2026 Integrated System Plan.”

Industry sector

Alumina

Historical production, fuel consumption and emissions by 2024 are sourced from the Australian Aluminium Council's Sustainability Data 2024.⁵³ In both scenarios, production is assumed to stay constant to 2050, in alignment with the Step Change scenario from ACIL Allen's Gas, liquid fuel, coal and renewable gas projections.⁵⁴

In the CPP scenario, we align sectoral emissions to 2035 with those in Emissions Projections 2023, which, unlike more recent editions, reports the sector separately. From these we derive energy demand by applying emissions factor from National Greenhouse Account Factors. After 2035, we assume energy efficiency gains of 1% per annum and a shift to electricity.^{55,56}

In the CSIRO A40/G1.5 scenario, Australia reaches 100% green alumina production with green hydrogen by 2040, and factors in efficiency improvements specific to each production method. For the alternative production route, using electric boilers and hydrogen calcination, we take technological parameters from the Australian Industry Energy Transitions Initiative Pathways to Industrial Decarbonisation.⁵⁷

Aluminium

The same approach is applied for aluminium. Production figures in the CPP scenario are aligned with ACIL Allen's Gas, liquid fuel, coal and renewable gas projections Step Change scenario, which assumes Australia's total production grows from 1.6 Mt in 2024 to 1.9 Mt in 2050.⁵⁸

Electricity accounts for around 90% of total energy consumption, with the remaining 10% met by fossil gas, which delivers the high temperatures needed for cast house operation and carbon anode production.⁵⁹ Under the CPP scenario, following the 2023 Emissions Projection, stationary emissions remain at below 1 MtCO_{2e} to 2035. We assume fossil

⁵³ Australian Aluminium Council LTD, "Sustainability Data Tables 2024."

⁵⁴ ACIL ALLEN, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁵⁵ Australian Government, *Australia's Net Zero Transformation*.

⁵⁶ ITP Thermal Pty Ltd, *Renewable Energy Options for Industrial Process Heat*.

⁵⁷ Australian Industry Energy Transitions Initiative, *Pathway to Industrial Decarbonisation*.

⁵⁸ ACIL ALLEN, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁵⁹ Hydro, "Our Roadmap to Net-Zero Emissions in Aluminium Production."

gas is phased out from the sector by 2050, and that annual energy efficiency improvement is stable at 1% per annum starting 2030.⁶⁰

ACIL Allen's Green Energy Exports scenario projects a similar production profile to Step Change. Under this production profile, the sector is fully electrified by 2030, following CSIRO A40/G1.5 scenario. We use a 23 MWh per tonne electricity intensity for fully electrified aluminium production, and an annual energy efficiency improvement decreasing linearly from 2.1% in 2025 to 1% in 2050 as per the Net Zero Plan, which sourced this assumption from the World Energy Outlook 2024.^{61,62}

Iron and steel

For both scenarios, we assumed the annual production follows the volumes from the Quarterly Resources and Energy dataset to 2030, and holds production at the 2030 volume of 6.1 Mt between 2030 and 2050.⁶³ Historical energy consumption is sourced from the AES Table F, and the future fuel mix is modelled taking into account the potential integration of new technologies.⁶⁴ Stationary emissions from steel manufacturing are a small portion of metal industry emissions, but the fuel switch is expected to contribute to emissions reductions.

Direct reduced iron (DRI) and electric arc furnace (EAF) are potential alternative production routes to replace the current primary method, Blast Furnace – Basic Oxygen Furnace (BF-BOF). The DRI-EAF method consumes fossil gas and green hydrogen at the ratio of 50:50, lowering emissions. In the CPP scenario, we model production capacity for these alternative methods based on the Whyalla steel plant under development in South Australia, which is expected to have 1.8 Mtpa of DRI capacity and 1.5 Mtpa of EAF capacity from the late 2020s.⁶⁵

Input-outputs ratio of each energy by method based on case study in Japan's steel sector is used to determine future energy demand, including gas, green hydrogen and electricity.⁶⁶

For the FFPO scenario, HPA disaggregated fuel consumption into production route and fuel, which allows us to determine each fuel consumption throughout the transition

⁶⁰ Australian Government, *Australia's Net Zero Transformation: Treasury Modelling and Analysis: Technical Appendices* (2025), <https://treasury.gov.au/publication/p2025-700922>.

⁶¹ The Superpower Institute, *The New Energy Trade*.

⁶² Australian Government, *Australia's Net Zero Transformation: Treasury Modelling and Analysis: Technical Appendices*.

⁶³ Department of Industry, Science and Resources, "Resources and Energy Quarterly: March 2025."

⁶⁴ Department of Climate Change, Energy, the Environment and Water, "Australian Energy Update 2025."

⁶⁵ GAF Alliance, "LIBERTY Steel in Whyalla Announces the Phase out of Coal-Based Steelmaking with Purchase of a Low Carbon Emissions Electric Arc Furnace."

⁶⁶ Abhishek Shivakumar and Akira Kanno, "Building TZ-OSeMOSYS-STEEL: Our Methodology."

period. The emissions intensive BF-BOF method is expected to be terminated by 2035, and phase-in of lower emissions intensive technology, DRI-EAF and EAF, is projected to meet the demand by 2040. Fuel use in DRI-EAF method will influence emissions reduction in this sector, and a significant difference between two transition phases exists here. DRI-EAF route during first transition consumes both fossil gas and green hydrogen at equal ratio, and fossil gas phase-out is projected to complete by 2040. Production via zero emission DRI-EAF and EAF is modelled to start operation gradually from 2035 to meet the whole production demand in 2040.

Cement

Historical production is taken from the Resources and Energy Quarterly dataset, compiled by the Department of Industry, Science and Resources, and future production is

developed by harmonising historical value with CSIRO Stated Policies (CSP) scenario, which reports detailed sector-by-sector pathways in Australia.⁶⁷

VDZ Decarbonisation pathways for the Australian Cement and Concrete Sector was a primary source for the modelling.⁶⁸ Assumptions of future fuel mix are modelled based on the report assumptions; renewable fuel share reaches 50%, biomass accounts for 40% of the total renewables, and green hydrogen accounts for 20% of total fuel consumption by 2050.

Emissions from fossil fuel burning in clinker production account for 28% of total sectoral emissions, with a further 12% of sectoral emissions arising indirectly from electricity consumption. Future fossil fuel demand therefore reflects potential thermal energy efficiency improvements in the clinker production process.

Industrial process emissions attributed to chemical reactions during production account for 60% of total emissions.⁶⁹ Based on the 2024 data, we considered that this sector will still account for 50% of mineral industry's IPPU emissions by 2050 due to technical challenges.

While keeping the same production volume as the CPP scenario throughout the projection period, fossil fuel phase-out in the FFPO scenario by 2040 is modelled based on HPA. Use of waste, green hydrogen and biomass is likely to enable coal phase-out by 2035. HPA forecasts annual total energy demand by fuel type in this sector, which enables us to determine energy efficiency improvement throughout the transition by 2050.

Table 3: Activity level forecast in Australia's major industry sub-sectors.

	2024	2030	2040	2050	Source
Alumina	17.5 Mt	17.5	17.5	17.5	Gas, liquid fuel, coal and renewable gas projections by ACIL Allen ⁷⁰
Aluminium	1.6 Mt	1.6	1.7	1.9	Gas, liquid fuel, coal and renewable gas projections by ACIL Allen ⁷¹
Iron and steel	6.1 Mt	6.1	6.1	6.1	Resource and energy historical data and forecasts by Department of Industry Science and Resource ⁷²
Iron ore mining (CPP/FFPO)	958 Mt	1018/1018	1057/1006	1079/1005	Announced Pledges/Net Zero Scenario in IEA WEO 2024 ⁷³
Cement	10.4	11.6	11.8	12.8	CSIRO Stated Policies (CSP) scenario ⁷⁴

⁷⁰ ACIL Allen, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁷¹ ACIL Allen, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

Non-fossil fuel mining

Production profiles under the CPP scenario are aligned with the Resources and Energy Quarterly forecasts up to 2030.⁷⁵ Considering iron ore mining accounts for over 90% of total non-fossil fuel mining output, post-2030 production is derived using growth rates of global crude steel production from the Announced Pledges Scenario (APS) in the IEA's 2024 World Energy Outlook, applied as proxy for iron ore demand.⁷⁶

Bauxite production is assumed to remain constant relative to historical levels. This is aligned with ACIL Allen's Gas, liquid fuel, coal and renewable gas projections, which assumes no further growth in Australian alumina output, on the basis that additional expansion remains too speculative to include.⁷⁷ Their reasoning is that Australia already refines a large share of its bauxite domestically (around 57%), making output less exposed to export market fluctuations than in more export-oriented producers. At the same time, growth potential is constrained by the expected closure of Rio Tinto's Gove bauxite mine by 2030, as well as by environmental and land-use constraints on expanding mining on the Darling Scarp in Western Australia, including concerns over impacts on jarrah forests and water supply.

Conversely, South32's Worsley intends to extend Boddington mine's reserve life to FY36,⁷⁸ and Rio Tinto is advancing the Kangwinan expansion⁷⁹ at Amrun/Weipa to replace tonnages lost from the Gove and Andoom mines. More recent refinery-level announcements point in the opposite direction and weaken the case for sustained growth: Kwinana has already been curtailed and closed, and Rio Tinto has announced a 40% curtailment at Yarwun from October 2026.⁸⁰ Given these contradictory trends, we therefore treat flat national bauxite output as a conservative aggregate assumption, rather than an assumption that every mine and refinery remains constant over time.

⁶⁹ Cement Industry Federation, *2022 Industry Report*.

⁷⁰ ACIL Allen, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁷¹ ACIL Allen, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁷² Department of Industry, Science and Resources, "Resources and Energy Quarterly: March 2025."

⁷³ IEA, *World Energy Outlook 2024*.

⁷⁴ CSIRO, *Pathways to Net Zero Emissions: An Australian Perspective on Rapid Decarbonisation*.

⁷⁵ Department of Industry, Science and Resources, "Resources and Energy Quarterly: March 2025."

⁷⁶ IEA, *World Energy Outlook 2024*.

⁷⁷ ACIL Allen, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁷⁸ South32 (2025). South32 2025 Strategy and business update.

https://www.south32.net/docs/default-source/exchange-releases/strategy-and-business-update-0xc212522a45f5c78e.pdf?sfvrsn=51f6965a_0&utm

⁷⁹ Rio Tinto (2025). Rio Tinto to start early works and final studies to increase Amrun mine's bauxite production on Queensland's Cape York Peninsula.

<https://www.riotinto.com/en/news/releases/2025/rio-tinto-to-start-early-works-and-final-studies-to-increase-amrun-mines-bauxite-production-on-queenslands-cape-york-peninsula>

⁸⁰ Rio Tinto (2025). Rio Tinto to reduce production at Yarwun Alumina Refinery to extend operational life. <https://www.riotinto.com/en/news/releases/2025/rio-tinto-to-reduce-production-at-yarwun-alumina-refinery-to-extend-operational-life>

For remaining minerals - including copper, lithium, nickel and zinc - post-2030 time series are projected using growth rates from the Pathway to Industrial Decarbonisation report from the Australian Industry Energy Transitions Initiative.⁸¹

Given that iron ore mining represents more than 90% of current sectoral output, technological developments across non-fossil mining are assumed to follow the same trend as the iron ore sub-sector. In addition, future electrification rates and electricity savings from changes in on-site generation relate to the projection in the iron ore sector, reported in the CSIRO modelling report.

Similar to coal mining, the electrification rate of the machinery and haulage fleet under the CPP scenario is back-calculated from sectoral on-site emissions reductions reported in the 2025 Australia Emissions Projections.⁸² Again, to convert displaced diesel use into electricity demand, we apply truck-specific diesel-to-electric substitution factors from Advisian for equivalent wheel output.⁸³ In energy terms, this means that replacing 1 GJ of diesel in an ICE haul truck requires about 0.39 GJ of electricity in the electric case (battery or tethered). In addition, these energy substitution factors are combined with exogenously imposed energy efficiency improvements of 0.25% per annum.⁸⁴

Under the FFPO scenario, future iron ore mining activity is modelled based on the Net Zero Scenario in the IEA 2024 World Energy Outlook, and on-site electricity generation and other mineral production levels are based on the A40/G1.5 scenario in the Net Zero modelling report by CSIRO, which provides sector-specific technology pathways and production forecasts.^{85 86}

Under the FFPO scenario, fuel switching and electrification pathways are aligned with projections from the HPA model. In this scenario, diesel use in machinery and haulage is fully phased out by 2045, alongside annual energy efficiency improvements of 0.5%.⁸⁷ The decline in diesel consumption is progressively offset by electrification of the mining fleet, alongside the phase-in of renewable fuels - primarily hydrogen and biomass -

⁸¹ Australian Industry Energy Transitions Initiative, *Pathway to Industrial Decarbonisation*.

⁸² Department of Climate Change, Energy, the Environment and Water, *Australia's Emissions Projections 2025*.

⁸³ Taken from Table 5-3 from the [2022 Advisian Report](#) commissioned by the DCCEEW and used by the 2025 Emissions Projections as on-site abatement estimates from the Safeguard Mechanism model as well as the emissions reduction from technological improvement in non-safeguard mines.

⁸⁴ Advisian, *Stationary Energy (Excluding Electricity) - Mining and Energy Technology and Efficiency Opportunities*.

⁸⁵ IEA, *World Energy Outlook 2024*; EPA, "Global Non-CO₂ Greenhouse Gas Emission Projections & Mitigation Potential: 2020-2080."

⁸⁶ CSIRO (2025). Modelling sectoral pathways to net zero emissions. https://www.csiro.au/-/media/Environment/25-00150_CSIRO-Modelling-and-Additional-Scenario-Summary-Report_FINAL_250903.pdf

⁸⁷ Advisian, *Stationary Energy (Excluding Electricity) - Mining and Energy Technology and Efficiency Opportunities*.

beginning in 2027. Electrification trajectories are calibrated to ensure consistency with the sectoral energy demand pathways provided by HPA.

Grey and green ammonia

Energy consumption and production outputs are modelled at the facility level. Each production facility profile, fossil gas use and hydrogen feedstock requirements for each facility are sourced from ACIL Allen's Gas, liquid fuel, coal and renewable gas projections.⁸⁸

Under both scenarios, total demand aligns with the Step Change scenario in the ACIL Allen report.⁸⁹ In addition to the existing capacity, announced capacity expansion is also taken into account in the model, assuming Kwinana (CSBP) increase capacity from 260 ktpa to 543 ktpa in 2028, and Perdaman comes online in 2028 with a production capacity of 1480 ktpa.^{90 91}

Auxiliary gas consumption across facilities is determined using uniform conversion efficiencies. A conversion efficiency of 70.5% is applied for fossil gas-to-hydrogen, and 87.3% for hydrogen-to-ammonia synthesis.⁹²

In the CPP scenario, future fuel share between grey hydrogen and green hydrogen is sourced from the Step Change scenario in the ACIL Allen report.⁹³ The report assumes a green hydrogen blending ratio at four grey ammonia plants, with the transition beginning in 2030 at the earliest and completed by 2050 across all facilities. Conversely, green hydrogen completely replaces grey hydrogen by 2040 in the FFPO scenario, where fuel blending ratio is projected based on fossil gas demand forecasts in chemical industry under the HPA scenario.

Industrial process emissions from nitric acid production are modelled separately and assumed to remain constant over time. Current total nitric acid production is approximately 2.3 Mtpa, which results in 5.057 kt of nitrous oxide emissions. Emissions are calculated using an emissions intensity of 0.0028 tN₂O per tonne of nitric acid (HNO₃) and a conversion factor of 0.787 kg HNO₃ per kg ammonium nitrate (NH₄NO₃).⁹⁴

⁸⁸ ACIL ALLEN, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁸⁹ ACIL ALLEN, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁹⁰ ACIL ALLEN, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁹¹ ACIL ALLEN, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁹² The U.S. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2026: Hydrogen Market Module*.

⁹³ ACIL ALLEN, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁹⁴ Wolfram Jörß et al., *Mitigation Potentials for Emissions of Nitrous Oxide from Chemical Industry in Industrialised Countries World-Wide* (2023), <https://www.oeko.de/fileadmin/oekodoc/NACAG-N2O-mitigation-potentials.pdf>; Australian Government, *National Inventory Report Volume 1* (2024), <https://unfccc.int/sites/default/files/resource/National%20Inventory%20Report%202022%20-%20Volume%201.pdf>.

Table 4: Production assumptions for grey ammonia plants

	State	Ammonia production capacity in 2025 (PJ) ⁹⁵	Ammonia production capacity benchmark in 2030 (PJ) ⁹⁶
Yara Pilbara Fertilisers	WA	15.62	15.62
CSBP Kwinana Facility	WA	4.74	10.10
Kooragang Island	NSW	6.70	6.70
Phosphate Hill	QLD	5.10	5.10
Gibson Island	QLD	5.58	5.58
Moranbah	QLD	2.79	2.79
QNP	QLD	1.77	1.77
Yarwun	QLD	3.96	3.96
Perdaman	WA	0.00	23.76

Hydrogen

This sector is developed based on 11 facilities that are currently operating in the country and producing 494kt annually.⁹⁷ The majority of grey hydrogen is produced using the Steam Methane Reforming (SMR) method with fossil gas feed. Hydrogen production is determined by the sum of consumption from demand and the energy transformation sector, with capacity and production determined endogenously.

For green hydrogen, two production methods (alkaline electrolysis, proton exchange membrane) are modelled in all grids. Input values for each method are sourced from a proposed and hypothetical project by Aurecon, and hydrogen electrolyser costs are taken from the CSIRO cost projection data file.^{98 99}

⁹⁵ ACIL ALLEN, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁹⁶ ACIL ALLEN, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*.

⁹⁷ Department of Climate Change, Energy, the Environment and Water, *State of Hydrogen 2022*.

⁹⁸ Aurecon, *2024 Energy Technology Cost and Technical Parameter Review* (n.d.), https://www.aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/2025-iasr-scenarios/final-docs/aurecon-2024-energy-technology-cost-technical-parameter-review-report.pdf?rev=5526946b9e3e4db680b7bcc82ecce94b&sc_lang=en.

⁹⁹ CSIRO, "GenCost: Cost of Building Australia's Future Electricity Needs."

Fossil fuel production

Coal mining

Production profiles were developed separately for brown coal and black coal, with black coal further disaggregated by end use into thermal and metallurgical coal.

For brown coal, production is projected to 2040 using the growth rate from the 2025 Australia Emissions Projections under our CPP scenario.¹⁰⁰ In the FFPO scenario, brown coal is fully phased-out by 2035, in line with the retirement of the Victoria lignite fleet.

Under both scenarios, domestic demand for each coal type is aggregated across both end-use sectors (like the industry) and transformation sectors (like electricity). In the CPP scenario, thermal and metallurgical coal export volumes are calculated as the residual between the production forecasts and the aggregated domestic consumption. Under the CPP scenario, for thermal and metallurgical coal, we used production forecasts from the Resources and Energy Quarterly through to 2030.¹⁰¹ Between 2030 and 2040, the time series is harmonised using the growth rates from the 2025 Australia Emissions Projections.¹⁰² From 2040 to 2050, they are following the growth rate reported in the Treasury's Net Zero Transformation modelling report.¹⁰³ Conversely, in the FFPO scenario, exports volumes are calculated based on the approach detailed in the fossil fuels production pathway section below.

Across the sources referenced above, production is reported either as Run-of-Mine (ROM) or saleable coal. To ensure consistency, a saleable-to-ROM ratio of 0.78 is applied when harmonising units. This value corresponds to the average saleable-to-ROM ratio over the historical period (2018-2023). Annual ratios were calculated using historical data from the December 2025 Resources and Energy Quarterly report.¹⁰⁴

Emissions profiles are developed separately for stationary and fugitive emissions, with fugitive emissions further disaggregated by mine type into underground and open-cut operations. Under the CPP scenario, emissions time series are constructed using the National Inventory for historical emissions, the 2025 Australia Emissions Projections

¹⁰⁰ Department of Climate Change, Energy, the Environment and Water, *Australia's Emissions Projections 2025*.

¹⁰¹ Department of Industry, Science and Resources, "Resources and Energy Quarterly: March 2025."

¹⁰² Department of Climate Change, Energy, the Environment and Water, *Australia's Emissions Projections 2025*.

¹⁰³ The Treasury modelling forecasts are themselves derived from IEA's 2023 World Energy Outlook.

¹⁰⁴ Department of Industry, Science and Resources, "Resource and Energy Quarterly: December 2025."

through to 2040 and the Resources Sector Plan from 2040 to 2050.^{105 106 107} In the FFPO scenario, emissions pathways are aligned with projections from the HPA scenario, with the growth rates from the emissions time series for fossil fuel extraction used as a proxy for fugitive emissions intensity, while the emissions time series for the Other Industry sector are used as a proxy for stationary emissions intensity.

Under the CPP scenario, the electrification rate of the machinery and haulage fleet is back-calculated from the sectoral on-site emissions reductions, excluding fugitive emissions, reported in the 2025 Australia Emissions Projections.¹⁰⁸ To convert displaced diesel use into electricity demand, we apply truck-specific diesel-to-electric substitution factors from Advisian¹⁰⁹ for equivalent wheel output. These energy substitution factors are combined with exogenously imposed energy efficiency improvements of 0.25% per annum and the contribution of production declines to emissions reductions. For simplification, on-site electricity use is assumed to be fully supplied by the NEM, considering the off-grid and WA coal mines together contribute 1% of total national coal production capacity.

In the FFPO scenario, electrification rates are aligned with pathways provided by HPA for the sector of freight transport of heavy trucks (>40 tonnes), whereby diesel use is fully phased out by 2045.

Liquefied natural gas

LNG demand is exogenous in the model, based on combined forecasts from the Resources and Energy Quarterly and the Emissions Projections 2025. We assume, in consistency with historical patterns, that all Australian LNG is exported, thus ignoring potential international LNG imports/exports that could occur in the future with the start of operations of LNG import terminals.

For the Northern Territory and East Coast LNG plants, for the CPP scenario, we build bottom-up, facility-level production profiles using publicly available information on historical shipments and plant maintenance schedules, for instance for Darwin LNG.

For the NT, these estimates show a return to full production at DLNG by calendar years 2027 and 2028, following the start of exploitation of the Barossa gas field. Production

¹⁰⁵ DCCEEW, "Australia's National Greenhouse Accounts."

¹⁰⁶ Department of Climate Change, Energy, the Environment and Water, *Australia's Emissions Projections 2025*.

¹⁰⁷ Department of Industry, Science and Resources and Department of Climate Change, Energy, the Environment and Water, *Resources Sector Plan*.

¹⁰⁸ Department of Climate Change, Energy, the Environment and Water, *Australia's Emissions Projections 2025*.

¹⁰⁹ Taken from Table 5-3 from the [2022 Advisian Report](#) commissioned by the DCCEEW and used by the 2025 Emissions Projections as on-site abatement estimates from the Safeguard Mechanism model as well as the emissions reduction from technological improvement in non-safeguard mines.

then declines from 2040, reaching zero by 2050, consistent with Santos' statement that Barossa will extend the lifetime of Darwin LNG for "around 20 years".¹¹⁰ Ichthys is planned by INPEX to operate until 2058; we therefore assume full-capacity operation through to the end of the modelling period, noting that the plant has historically exceeded its nameplate capacity.¹¹¹

For East Coast plants, we estimated production using the APLNG Environment and Social report, Origin's disclosures, Santos' reporting and related press releases, applying a standardised factor of 0.069 Mt per cargo. Results were triangulated against Gladstone Port data, and future projections were harmonised to AEMO's 2024 GSOO LNG export trajectory.¹¹²

Western Australia accounts for most of Australia's LNG production. The WA GSOO takes conservative assumptions regarding the start of operations of new backfill capacity that would maintain current production levels. In comparison, the Emissions Projections production levels stay stable until 2035. To gather time series for WA LNG plants, we rebuild historical production profiles from shipment data, then optimise plant-level WA production under constraints to match the national production profile from the EPs, net of output from the rest of Australia as derived above.

Constraints in this approach were set at maximum production based on either nameplate capacity or the highest historical output for plants that have exceeded nameplate, such as Gorgon and Wheatstone. We consider the closure of one North West Shelf train, and the start of operation of Pluto 2 in 2027.

We then disaggregate LNG emissions by type, using methane SGM emissions as a starting point for methane fugitives, and Browse's 2022 supplement to the draft EIS benchmarking of Australian facilities for fugitive reservoir CO₂ and facility emissions, benchmarked against the 2020 datapoint from the Emissions Projections.¹¹³ For projected years, we scale these metrics to the production profiles, and the resulting sum is then rescaled to match the Emissions Projections.

Each emissions source is treated as a production intensity in the model. In the current policy scenario, intensity declines in line with the government's Emissions Projections. The FFPO scenario includes both a change in production profile, and additional emissions intensity reductions.

¹¹⁰ Santos, "Santos Announced Bid on the Barossa Gas Project for Darwin LNG."

¹¹¹ William Geddes, "Inpex Pushing Ahead with Ichthys Train 3 as Part of Its Long-Term LNG Plans."

¹¹² AEMO, "2024 Gas Statement of Opportunities."

¹¹³ Woodside Energy Ltd, "Proposed Browse to North West Shelf Project."

Fossil fuels export pathway

For Australia's thermal coal, metallurgical coal and gas exports in a Paris-aligned world, we use the methodology from the Reserve Bank of Australia's 2021 report, *Towards Net Zero: Implications for Australia of Energy Policies in East Asia*, that we apply to the HPA data.¹¹⁴

This is done by taking the decline rate of each importing country's relevant consumption variable (coal for electricity in the case of thermal coal, coal in industry for metallurgical coal, and gas for secondary and final energy for LNG), then applying each region's decline rate to Australian exports weighted by that region's historical share of Australia's total fossil fuel exports, with historical export volumes and destinations sourced from the Resources and Energy Quarterly.

REMIND's regional disaggregation treats China, India and Japan as individual regions, while South Korea, Taiwan and the remaining Asian countries are grouped into a single "Other Asia" region. Because the South Korean and Taiwanese economies more closely resemble Japan's than those of the rest of Other Asia, we assume their fossil gas demand follows that of the former. Exports to other destinations follow the same change rate as the global values. As noted by the RBA, this approach assumes implicitly the proportion of fossil fuels sourced from Australia remains constant over time.

In parallel, we factor in the rollout of electric drives and waste heat recovery at LNG plants, based on technical parameters from the 2021 Australian Industry Energy Transitions Initiative (ETI) Phase 1 report.¹¹⁵ Waste heat recovery is assumed to be deployed uniformly between 2028 and 2035 (compared to 2020 in the ETI source), and electric drive progressively from 2030 to 2040 (compared to 2030 onwards in the ETI). These technologies reduce facility stationary emissions but increase electricity demand from LNG plants. As the ETI specifies that they apply only to a share of plant energy use, and assuming all facility level stationary emissions stem from energy use, we equate those shares to the achievable emissions reductions. Methane fugitive emissions decline at the same rate as methane emissions from global fossil fuel extraction in the HPA scenario.

Biomass supply

Biomass has received scrutiny in this analysis, given its interactions with land use, the sustainability concerns it raises and its prominence in ambitious mitigation scenarios. Following the approach of the HPA scenario, we impose stringent upper bounds on biomass reliance, drawing on two primary Australian sources: the Crawford and

¹¹⁴ Reserve Bank of Australia, "Towards Net Zero: Implications for Australia of Energy Policies in East Asia."

¹¹⁵ Australian Industry Energy Transitions Initiative, *Setting up Industry for Net Zero - Phase 1 Highlights Report: Current State and Future Possibilities*.

colleagues geospatial biomass potential analysis (also used in the 2025 CSIRO CDR Roadmap discussed more in details below), and the Australian Bioenergy Roadmap prepared by ENEA and Deloitte for ARENA.^{116 117}

Crawford et al. (2016) break down the potential by feedstock type across different time periods. Of these sources, we exclude grasses, native forests and short-rotation tree crops on sustainability and conservativeness grounds.

After short-rotation tree crops, the biomass source with the highest potential in Crawford et al. is crop stubble. The Crawford values, which sit in the middle of the reported range, are retained but subject to a further conservativeness adjustment limiting the collection rate for soil health and accounting for other inefficiencies. This is in addition to the guardrails already incorporated in the original paper. Only 50% of the theoretical crop stubble resource identified by Crawford is assumed to be practically recoverable.

These potentials, expressed in mass, are then converted to energy units using the energy contents from the respective sources' National Greenhouse Gas Accounts Factors. Crawford does not cover some emerging biomass sources addressed in the 2021 Bioenergy Roadmap, published five years later.¹¹⁸ That report identifies a significantly higher technical bioenergy potential and includes a broader set of feedstocks beyond those covered by Crawford. From the roadmap, this analysis incorporates construction and demolition waste, commercial and industrial waste, livestock residues, food processing residues, horticultural residues, sewage and oil crops. Some further biomass sources present in the roadmap but absent from Crawford are excluded to avoid overlap and double-counting. Landfill gas, for example, is excluded because a substantial share is already utilised and may already generate ACCUs.

The Bioenergy Roadmap further notes that its own economic modelling assumes only 45% of Australia's theoretical bioenergy resource potential would ultimately be available for deployment, after accounting for economic and policy constraints. For additional conservativeness, and to account for friction, differences in conversion factors and process efficiency losses, this analysis assumes that only 33% of the additional roadmap potential is practically available, well below the roadmap's own 45% figure.¹¹⁹

The result is a country-wide upper bound on biomass potential of 887 PJ. Biomass sources are grouped into four archetypes, each represented as a fuel in the model: mixed solid waste, lignocellulosic, wet organic and dedicated crops.

Individual biomass feedstocks can either be consumed directly (for example, wood in the residential sector) or converted into secondary energy carriers such as liquid biofuels, energy inputs or bio-SAF, covered in the transport section. The conversion routes to

¹¹⁶ Crawford et al., "A Spatial Assessment of Potential Biomass for Bioenergy in Australia in 2010, and Possible Expansion by 2030 and 2050."

¹¹⁷ ENEA et al., "Australia's Bioenergy Roadmap."

¹¹⁸ ENEA et al., "Australia's Bioenergy Roadmap."

¹¹⁹ ENEA et al., "Australia's Bioenergy Roadmap."

biofuel and SAF from the CSIRO and Boeing's SAF State of Play, themselves taken from the ICAO, are represented.¹²⁰

For each route from the state of play (FT, ATJ, HEFA, pyrolysis), the distillate yield per tonne of feedstock is converted into an energy ratio based on a gross calorific value associated to each archetype and the National Greenhouse Gas Accounts Factors value for renewable kerosene energy content (36.8 GJ/kL). Routes with an intermediate carrier, like ATJ and HEFA, are assigned an additional yield factor representing intermediate conversion.¹²¹

The calculated total efficiency is then partitioned between aviation and co-produced, non-aviation fuels. Because the scenario assumes limited competing demand for biomass elsewhere in the economy when aviation has few alternative decarbonisation options, we use the high SAF ratio reported in Martulli et al. (2025) for each technology, that aligns with a policy preference for maximising aviation output over other distillate products. Applying that share to total yield gives a feedstock-to-SAF conversion efficiency used as a model input for the SAF module, with the residual share carried as a co-product efficiency for biofuels, meeting demand from road transport and other industries, for the biofuel production module.¹²² For different routes that use feedstock from the same biomass archetypes, like FT with forest residues and agricultural residues, both under lignocellulosic biomass, we take the midpoint efficiency of both. Finally, for each route, we use the auxiliary fuel consumption values (representing the non-feedstock fuel demand necessary for the processes) per energy output from De Jong (2017).¹²³

Power-to-liquid is modelled separately in the SAF and low-carbon fuel production modules. The hydrogen requirement of 1.40 MJ per MJ of final fuel for the Fischer-Tropsch pathway, reported by the German Environment Agency, is inverted to give a hydrogen-to-fuel conversion efficiency.¹²⁴ We then apply the same high SAF ratio from Martulli et al. (2025) to separate the aviation and non-aviation portions.¹²⁵

¹²⁰ CSIRO and Boeing, "Sustainable Aviation Fuel State of Play: One Year from the Australian SAF Roadmap."

¹²¹ 37% for ATJ, based on the midpoint of sugar and sorghum from the CSIRO SAF Roadmap, 40% for HEFA from vegetable oil based on the oil content of canola, and an assumed 15% for HEFA from fat, oil and grease.

¹²² Martulli et al., "The Potential Scale-up of Sustainable Aviation Fuels Production Capacity to Meet Global and EU Policy Targets."

¹²³ De Jong et al., "Life-Cycle Analysis of Greenhouse Gas Emissions from Renewable Jet Fuel Production."

¹²⁴ German Environment Agency, "Power-to-Liquids: A Scalable and Sustainable Fuel Supply Perspective for Aviation."

¹²⁵ Martulli et al., "The Potential Scale-up of Sustainable Aviation Fuels Production Capacity to Meet Global and EU Policy Targets."

Carbon dioxide removal

CDR is parametrised based on the CSIRO Australian Carbon Dioxide Removal Roadmap, a foundational study that provides the CDR marginal cost per tonne of CO₂ sequestered per technology along with a realisable and high ambition potential per technology.¹²⁶

The central FFPO scenario considers only DACCS. This design choice was motivated by the fact that biomass supply is constrained in Australia, that its scale-up has not been seriously investigated by policymakers so far - for example, AEMO publications do not include this power generation technology - and that BECCS potential is relatively limited compared with that of DACCS. More importantly, a potential scale-up of BECCS also raises environmental issues documented by the IPCC, including competition for land with agriculture.¹²⁷ CSIRO has also analysed OAE and ERW: because these two technologies are at an earlier stage of maturity and come with their own underexplored environmental concerns, we did not consider them in this report.¹²⁸

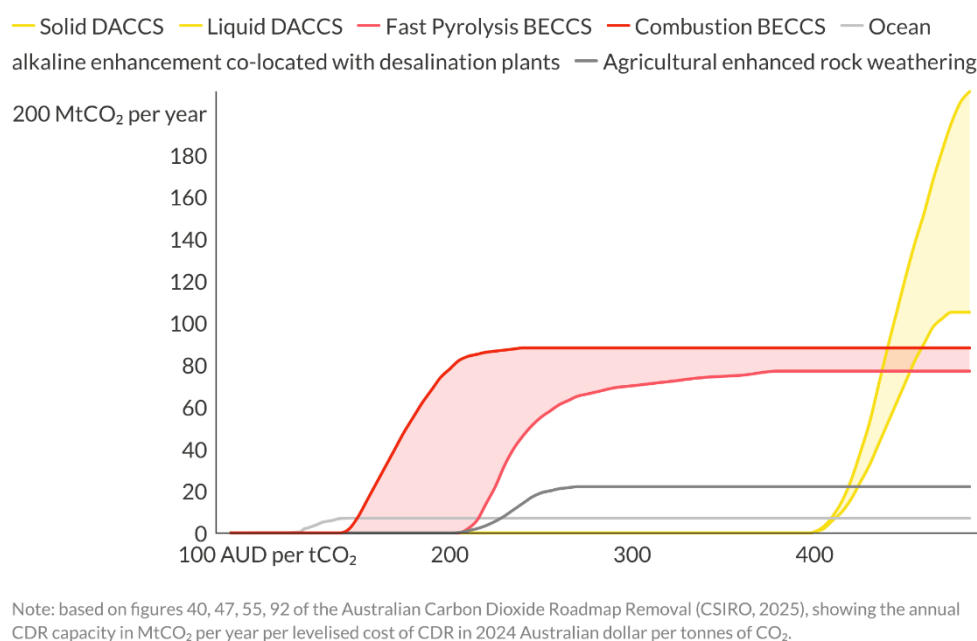


Figure 1: Indicative supply curves for CDR technologies based on the CSIRO Australian Carbon Dioxide Removal Roadmap.¹²⁹

¹²⁶ CSIRO, "Australian Carbon Dioxide Removal Roadmap."

¹²⁷ IPCC, "Interlinkages between Desertification, Land Degradation, Food Security and GHG Fluxes: Synergies, Trade-Offs and Integrated Response Options."

¹²⁸ Ocean alkalinity enhancement creates risks of marine biodiversity perturbation through its adverse effects on seawater pH and the potential release of toxic metals. The impact of water alkalisation and the associated perturbations is also less well understood than acidification. Similarly, ERW can increase the risks associated with mining and alter soil chemistry, including water chemistry through leaching. Both technologies remain at the demonstration stage so far, and much remains to be done to understand their full impact.

¹²⁹ CSIRO, "Australian Carbon Dioxide Removal Roadmap."

We derive the amount of technological CDR needed by working backwards from the mid-century end state in which Australia reaches net zero greenhouse gas emissions in 2050. As discussed in the report, we scale the deployment of DACCS to align with the trajectory of the 3rd State of CDR report's Highest Ambition scenarios, emulating the logistic roll-out characteristic of new technologies. Deployment begins in 2035, consistent with CSIRO's assessment that roll-out could start "within the next decade" and supports the achievement of net zero by 2050.¹³⁰

In practice, DACCS is implemented as an energy sink in the model, with activity levels set exogenously as the amount of CO₂ to be captured and a negative emissions factor based on the technology's assumed energy intensity of 5.6 GJ/tCO₂. The respective share of DAC deployed per grid is derived from the realisable scenario in Figure 39 of the CSIRO CDR Roadmap below.

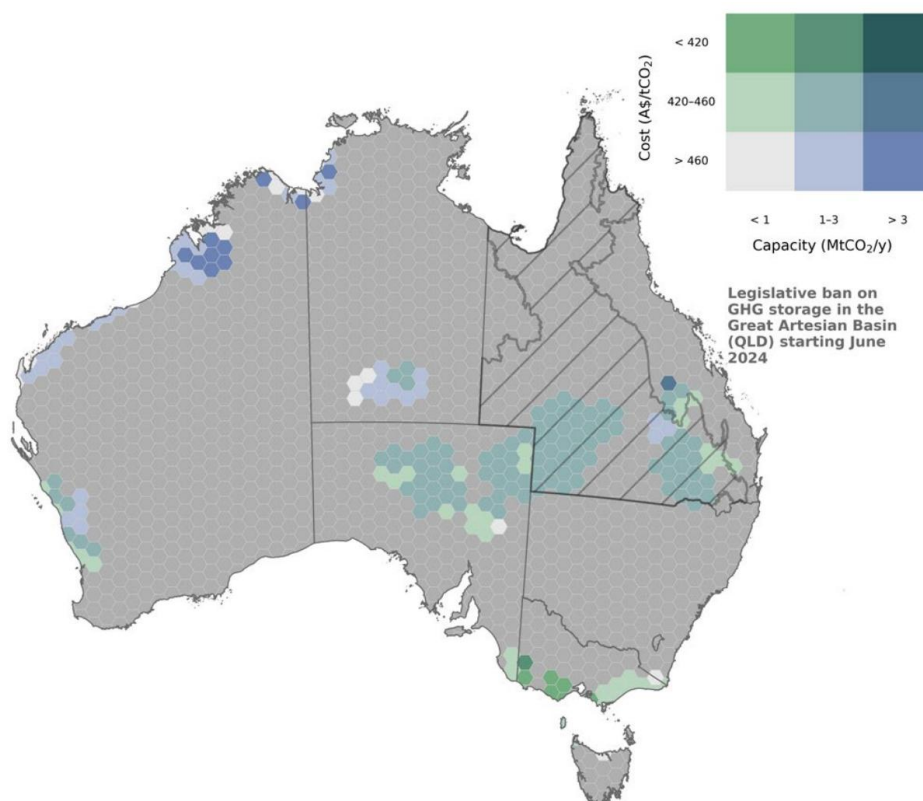


Figure 2: CSIRO Australian Carbon Dioxide Removal Roadmap figure 39, showing the 2050 cost and realisable potential for solid adsorbent DACCS.¹³¹

Different studies suggest efficiency gains are plausible and technology-dependent. The CSIRO CDR Roadmap explores technology-specific performance trajectories and cost ranges; it assumes, for example, that the electricity requirements would decline from 6.6 GJ/tCO₂ in a first-of-a-kind plant to 3.7 GJ/tCO₂ in a nth of a kind facility for solid

¹³⁰ Edwards et al., *The State of Carbon Dioxide Removal - 3rd Edition* (2026).

¹³¹ CSIRO, "Australian Carbon Dioxide Removal Roadmap."

adsorbent DACCS.¹³² The efficiency improvements will depend, in part, on which capture routes end up scaling. For conservativeness, and without visibility on whether DAC will evolve as a winner-take-all field, we retain HPA's assumption of constant energy intensity to maintain a technology-neutral framing in an early-stage landscape. The assumed intensity of 5.6 GJ/tCO₂ is more ambitious than the World Energy Outlook 2025 Net Zero Emissions scenario, in which 1.8 GtCO₂ are captured by 2100 with energy requirements of just over 13 EJ, but is in line with what the literature describes as the “more conservative end of estimates for long-term capture facilities”.¹³³

Non-energy emissions

We represent non-energy emissions, including those from agriculture, LULUCF (land use, land-use change and forestry), waste and industrial processes and product use (IPPU), broken down by gas. For the industrial sectors we model as energy sectors, like iron and steel, ammonia and cement production, we set IPPU emissions separately, using the output of their own modelling as described in their dedicated methodology sections. As discussed in the report, LULUCF emissions are treated separately. In both the CPP and FFPO scenarios they follow the projection trajectory to 2040 and then stay stable to 2050.

For each sector, historical emissions to 2023 are sourced from the Australian National Greenhouse Accounts, and the 2024 datapoint is harmonised with the 2025 Emissions Projections. In the CPP scenario, emissions follow the emissions projections to 2040. Post-2040, agricultural emissions follow, gas by gas, the growth rate of the Net Zero Plan's baseline scenario. For waste and IPPU, post-2040, each gas follows its 2035 and 2040 emissions projections trend.

In the FFPO scenario, non-energy sector gas follows its growth rate in the HPA scenario for the Canada-Australia-New Zealand region, with the exception of methane, which follows the median of the AR6 C1a scenarios for agriculture and waste. Because HFC trajectories depend on country-specific circumstances, HFCs follow the emissions projections to 2040 and then decline at the HPA Canada-Australia-New Zealand macroregion rate.

¹³² CSIRO, “Australian Carbon Dioxide Removal Roadmap.”

¹³³ Hunter-Sellars et al., “The Potential and Cost of Carbon Dioxide Removal Using Direct Air Capture with Land-Based Wind and Utility-Scale Photovoltaics.”