Australian Government
Department of Climate Change, Energy, the Environment and Water

Methodology for the 2022 projections

Australia's emissions projections incorporate a variety of data inputs, assumptions and methods. This methodology document outlines how the Department of Climate Change, Energy, the Environment and Water (DCCEEW) has estimated the 2022 projections of greenhouse gas (GHG) emissions (DCCEEW 2022a).

The emissions projections are prepared at a sectoral level consistent with international guidelines adopted by the United Nations Framework Convention on Climate Change (UNFCCC). The projections use public data sources, from government agencies and other bodies, to inform production estimates. Emissions factors used are consistent with Australia's national greenhouse gas inventory.

The projections are published on the DCEEW and Australia's National Greenhouse Accounts (DCCEEW 2022b) websites.

This methodology document does not include all the data and processes involved in producing Australia's emissions projections due to constraints and sensitivities relating to specific inputs. For example, facility level information has not been included due to commercial-in-confidence company data considerations.

Reporting years for all sectors are financial years, consistent with Australia's national greenhouse gas inventory. For instance, '2030' refers to financial year 2029–2030.

Sector specific methodologies are discussed in greater detail in the following sections.

Electricity

Modelling approach

The electricity sector emissions projections have been prepared by DCCEEW using PLEXOS (market forecasting software) modelling for the National Electricity Market (NEM), Western Australia's Wholesale Electricity Market (WEM) and Darwin Katherine Interconnected System (DKIS), and DCCEEW's internal modelling for off-grid electricity generation and the North West Interconnected System (NWIS).

NEM, WEM and DKIS

DCCEEW used PLEXOS to project emissions from Australia's NEM, WEM and DKIS electricity grids to 2035. PLEXOS is used for simulating energy market outcomes, including long-term investment planning and short-term half-hourly market behaviour. The PLEXOS model framework includes an investment model and a dispatch model that is based on the 2021 Electricity Statement of Opportunities (ESOO). The investment model determines the capacity mix to meet demand at the lowest system cost. The dispatch model dispatches a given set of generation assets to simulate detailed market outcomes. New large interconnector projects in the NEM are exogenous inputs into the model, in line with the progressive change pathway under the Australian Energy Market Operator's (AEMO's) Integrated System Plan (AEMO 2022a), 2021–22 Inputs, Assumptions and Scenarios (AEMO 2022b) and advice from DCCEEW.

Off-grid

DCCEEW modelled emissions from Australia's off-grid electricity networks. Off-grid refers to all locations where small electricity networks operate, and includes 'microgrids'. Off-grid electricity demand is predominantly from industrial users for mining and liquefied natural gas (LNG) production.

Off-grid electricity emissions are calculated using 2 models. The first is a bottom-up model that is driven by the production of LNG at individual facilities, with production assumptions in line with estimates under the fugitive emissions sector modelling and electricity use assumptions based on information reported by facilities under the National Greenhouse and Energy Reporting (NGER) scheme. The second is a top-down model that is driven by demand for off-grid electricity excluding LNG and assumptions of changes in the fuel mix, in particular the uptake of solar technology.

For off-grid generation, emissions are calculated by the following equations for LNG and non-LNG off-grid electricity, respectively:

$$E_t = \sum_i (EF_{it} \cdot EC_{it} \cdot P_{it})$$

Where:

E_t = LNG off-grid electricity emissions in year *t* (Mt CO_2-e)

EF_{it} = facility-specific electricity emissions intensity factor in year *t* (Mt/MWh)

EC_{it} = facility-specific electricity consumption factor for unit of production in year *t* (MWh/Mt)

P_{it} = production at facility *i* in year *t* (Mt).

$$E_t = \sum_i (Ef_i \cdot Fc_i \cdot G_{it})$$

Where:

E_t = annual non-LNG off-grid electricity emissions in year t (Mt CO_2-e)

Ef_i = emissions factor for consumption by fuel *i* (Mt CO_2-e /PJ)

Fc_i = fuel consumption factor per unit of electricity generation (PJ/GWh)

G_{it} = electricity generation by fuel *i* in year *t* (GWh).

Activity data

NEM, WEM and DKIS

Forecasts of electricity demand are a key input into the electricity sector emissions projections. DCCEEW has sourced data from the AEMO's NEM ESOO (AEMO 2022c) to inform electricity demand projections for the NEM, and from the WEM ESOO to inform projections for the WEM (AEMO 2022d). The demand scenarios included in the projections were the ESOO 2022 progressive change scenario for the NEM and the expected growth scenario for the WEM. These demand scenarios include AEMO's forecasts for energy efficiency.

The electricity emissions projections include consumption of electricity from electric vehicles (EVs) consistent with estimates in the transport sector and electrification assumptions consistent with estimates in the stationary energy sector.

Data and information from the Utilities Commission of the Northern Territory (Utilities Commission of the Northern Territory 2022), which include demand forecasts by AEMO for the Commission, and trends from PLEXOS analysis are used in modelling the DKIS.

Small grids and off-grid

In the NWIS, electricity demand has been calculated using regression analysis between electricity generation and iron ore output.

Off-grid demand is derived using production estimates of LNG in line with assumptions in the fugitive emissions sector, and estimates under the report commissioned by DCCEEW from Advisian on electrification opportunities in Australian mining (Advisian 2022).

Renewable capacity

The Clean Energy Regulator's (CER's) pipeline of large-scale renewable projects at July 2022 was used in the 2022 projections (CER 2022). The pipeline provides renewable uptake to the mid-2020s, after which new renewable capacity is induced by the PLEXOS modelling.

The CER's modelling of rooftop solar was used in the projections to 2027. After 2027, the projections adopt growth rates from AEMO's 2022 Inputs, Assumptions and Scenarios workbook (step-change scenario[1]) (AEMO 2022b).

Wind and utility solar are projected to meet a growing share of the underlying demand. To limit the emergence of negative demand events in the projections modelling, a level of curtailment was

[1] The step-change scenario aligns best with the CER rooftop solar trends to 2027. AEMO's progressive change scenario is used to inform all other inputs because it best reflects current policies.

assumed to apply to some solar generation. In 2030 and 2035, this curtailment was assumed to reduce the output of rooftop photovoltaic systems by less than 1% of NEM demand.

Data sources

Table 1 Data source for electricity demand projections

Grid	Data source for electricity demand
National Electricity Market	AEMO Electricity Statement of Opportunities for the NEM
Wholesale Electricity Market	AEMO Electricity Statement of Opportunities for the WEM
Darwin Katherine Interconnected System	Northern Territory Electricity Outlook Report (Utilities Commission of the Northern Territory 2022)
North West Interconnected System	Iron ore production outlook (OCE 2022a; NIEIR 2021)
Off-grid	LNG production consistent with production assumptions in the fugitive emissions sector

Transmission

Transmission networks transport electricity from generators to distribution networks and then to customers. In Australia, there are transmission networks in each state, and both territories are serviced by a distribution network. The NEM is an interconnected transmission network on the east coast of Australia connecting Queensland, New South Wales, the Australian Capital Territory, Victoria and Tasmania.

The emissions projections are developed on the basis of adopted policies and measures. The projections assume that state renewable energy targets will be met in Queensland, Victoria, Tasmania, the Northern Territory and include the New South Wales Electricity Infrastructure Road Map.

When a data model is constrained with certain parameters, it can lead to the model making supplementary assumptions to meet a set requirement. In constraining the electricity model to meet state targets, the electricity emissions projections modelling assumes that the necessary transmission will be available to achieve the renewable targets.

Stationary energy

Emissions from the stationary energy sector are projected using modelling processes developed by DCCEEW. Projections are aggregated from 6 subsectors: energy; mining; manufacturing; buildings; agriculture, forestry and fishing and other, which is solely fuel used by military vehicles within Australia.

Modelling approach

The stationary energy models are a combination of facility-specific and top-down models depending on the emission source and the availability of data. The models are maintained and updated within DCCEEW. The structure of these models is provided in Table 2.

The production data for LNG are estimated at the facility-level, because each facility has a different emissions intensity. Emissions intensities are calculated based on emissions reported through the NGER scheme. The emissions intensity is updated yearly for each facility if new data are available.

Activity data

Activity data used in the stationary energy subsectors are presented in Table 2.

Emissions projections in the stationary energy sector are estimated using activity data from various sources including Office of the Chief Economist (OCE) commodity forecasts (OCE 2022a,b), Australian Energy Update (DCCEEW 2022e), Wood Mackenzie long-term outlook reports, IBISWorld industry reports, AEMO's Gas Statement of Opportunities (GSOO) (AEMO 2021, 2022e) and *Ammonia: Australia Market Outlook 2021* (MRC 2021). The emissions reductions from policies and measures were also included.

Table 2 Summary of activity data and calculation methods for each stationary energy subsector

Emissions subsector	Activity data	Calculation method
Energy		
LNG (facility-level model)	Production data from the gas fugitives sector and emissions intensity from the NGER and various environmental impact studies; fuel savings and efficiency factors from Advisian (2022)	$E_t = \sum_i (EF_{it} \cdot P_{it})$ Where: E_t = emissions in year *t* (Mt CO_2-e) EF_{it} = facility-specific emissions factor in year *t* P_{it} = production at facility *i* in year *t*
Other oil and gas extraction (top-down model)	Western Australia gas demand from AEMO (2021); East Coast gas demand from AEMO (2022e); crude and condensate oil demand from OCE (2022a,b); fuel savings and	$E_t = E_{t-1} \cdot \Delta\text{Production}$ Where: E_t = emissions in year *t* (Mt CO_2-e) E_{t-1} = emissions in the previous

Emissions subsector	Activity data	Calculation method
	efficiency factors from Advisian (2022)	year ΔProduction = change in production between year *t* and year *t* − 1
Manufacture of solid fuels (top-down model)	Iron and steel growth rates from OCE[a] (2022a,b) and Wood Mackenzie long-term outlook report	
Domestic gas production and distribution (top-down model)	Western Australia gas demand from AEMO (2021); east coast gas demand from AEMO (2022e)	
Petroleum refining (top-down model)	Total refinery output from OCE (2022a,b)	
Mining		
Coal mining (top-down model)	Production data from the coal fugitives sector; fuel savings and efficiency factors from Advisian (2022)	$E_t = (Fc_{t-1} \cdot Ec \cdot Ef \cdot \Delta P) \times (1 - Eti_t)$ Where: E_t = emissions in year *t* (Mt CO_2-e) Fc_{t-1} = fuel consumption in the previous year *Ec* = energy contents of the fuel *Ef* = emissions factors of the fuel *ΔP* = percentage change in production between year *t* and year *t* − 1 Eti_t = emissions reduction (percentage) from technological improvement in coal mining/ other mining in year *t*
Other mining (iron ore, gold, copper, nickel, zinc, bauxite lithium, and manganese) (top-down model**)**	Production data from OCE (2022a,b) and Wood Mackenzie long-term outlook report; base year proportion of the type and amount of fuel used in each commodity derived from NGER energy data, fuel savings and efficiency factors from Advisian (2022)	
Manufacturing (top down model)		
Nonferrous metals (alumina; aluminium; refined nickel, copper, zinc, lithium, lead/	Production data from OCE (2022a,b) and Wood Mackenzie long-term outlook report; base year proportion of the type and amount of fuel	$E_t = Fc_{t-1} \cdot Ec \cdot Ef \cdot Fs_t \cdot \Delta P$ Where: E_t = emissions in year *t* (Mt CO_2-e)

Emissions subsector	Activity data	Calculation method
acid battery, battery recycling, recycled metal, and e-waste)	used in each commodity derived from NGER energy data; fuel savings and efficiency factors from Advisian (2020)	Fc_{t-1} = fuel consumption in the previous year Ec = energy content of the fuel Ef = emissions factor of the fuel Fs = fuel saving estimates (due to fuel switching, technology and efficiency opportunities) ΔP = change in production between year t and year $t-1$
Nonmetallic minerals (cement, lime, plaster and concrete; ceramics; glass and glass products and other)	IBISWorld industry reports analysis and Cement Industry Federation (CIF 2020); Decarbonisation Pathways for the Australian Cement and Concrete Sector (VDZ 2021); base year proportion of the type and amount of fuel used in the process derived from NGER energy data; fuel savings and efficiency factors from Advisian (2020)	
Iron and steel	Production data from OCE (2022a,b) and Wood Mackenzie long-term outlook report; fuel savings and efficiency factors from Advisian (2020)	
Pulp, paper and print	Data from DCCEEW (2022d); final data point (2022) held constant	
Chemicals (other petroleum and coal product and basic chemical, chemical and plastic)	*Ammonia: Australia market outlook* (MRC 2021) and derived proportion of the base year from NGER data; fuel savings and efficiency factors from Advisian (2020); other petroleum and coal product and plastic held constant at 2022 level	
Food processing, beverages and tobacco	n/a	10 year historical average emissions growth
Other manufacturing	n/a	
Buildings (top down model)		

Emissions subsector	Activity data	Calculation method
Residential and commercial	Annual gas consumption data from AEMO (2021, 2022c); wood and wood waste fuel use from DCCEEW (2022e); derived proportion of emissions from wood biomass and others from DCCEEW (2022c)	$E_t = E_{wt} + E_{ot}$ $E_{wt} = E_{wt-1} \cdot \Delta\text{Consumption}$ $E_{ot} = E_{ot-1} \cdot \Delta\text{Demand}$ Where: E_{tr} = emissions in year *t* (Mt CO_2-e) E_{wt} = emissions in year *t* (Mt CO_2-e) from burning wood biomass at residential buildings $E_{o/wt-1}$ = emissions in the previous year from consumption of wood or other fuels ΔDemand = change in gas consumption in commercial/ residential buildings between year *t* and year *t* − 1 ΔConsumption = change in wood consumption between year *t* and year *t* − 1
Construction	Activity data from Australian Construction Industry Forum (ACIF 2022)	$E_t = E_{t-1} \cdot \Delta\text{Activity}$ Where: E_t = emissions in year *t* (Mt CO_2-e) E_{t-1} = emissions in the previous year ΔActivity = change in activity between year *t* and year *t* − 1
Agriculture, forestry and fishing **(top down model)**	Farm production data from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (2022a,b); average rate of change in diesel consumption derived from NGER data	$E_t = (E_{t-1} \cdot \Delta\text{Production}) \times (1 - Dcr)$ Where: E_t = emissions in year *t* (Mt CO_2-e) E_{t-1} = emissions in the previous year ΔProduction = change in production between year *t* and year *t* − 1 *Dcr* = average rate of change in diesel consumption per unit of production

Emissions subsector	Activity data	Calculation method
		Emissions held constant at 2027 level.
Other (military) (top-down model)	Data from DCCEEW (2022c)	10-year average of historical emissions

a Production data for most commodities are sourced from the OCE, which is provided to 2027. Growth rates from Wood Mackenzie long-term outlook reports have been used for 2028 and beyond.

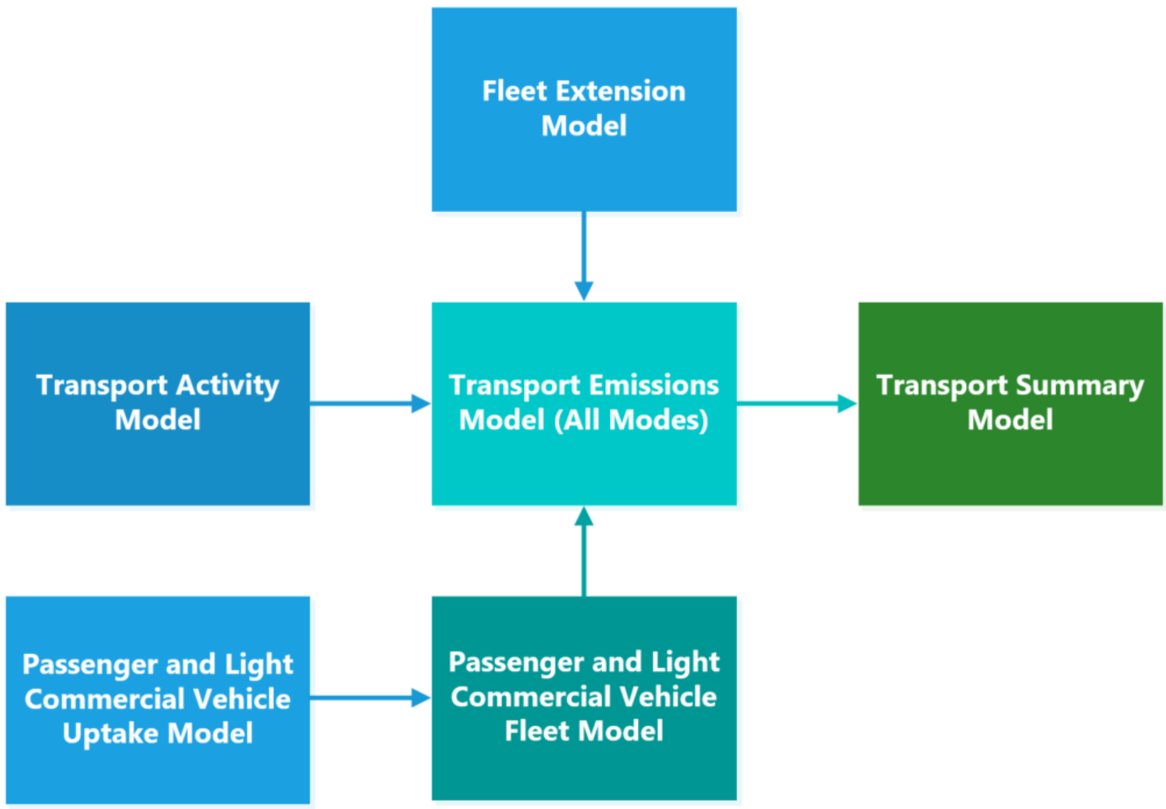
Transport

DCCEEW maintains an internal transport model to project emissions. The light duty vehicle subsector is modelled based on a detailed fleet model that tracks changes in the vehicle fleet over time. Other transport subsectors are modelled based on projected activity, changes in fleet efficiency and technology uptake. The exception to this modelling approach is for pipeline transport, because projected pipeline emissions were based on projections of state-level natural gas consumption and production (AEMO 2022e and Departmental analysis). For the remainder of the transport modelling, DCCEEW draws on inputs from various sources, which are detailed in the following sections.

Modelling approach

The transport sector emissions projections are modelled using several submodels outlined in Figure 1. The passenger and light commercial vehicle uptake model is an input into the passenger and light commercial vehicle fleet model. This fleet model then acts as an input along with the transport activity and fleet extension models into the final recalculation model. The output of the final recalculation model is then used as a final input into the transport summary model.

Figure 1 Simplified flowsheet of the transport sector emissions model



The transport sector model is based on projections of vehicle activity and vehicle fleet technology. The activity and fleet technology projections are segmented by state, mode/vehicle type, and fuel/engine type. Table 3 summarises the different modes and vehicle types included in the transport model and Table 4 lists the fuel and technology types used in the transport model.

Table 3 Modes and vehicle types in the transport emissions projections model

Mode	Vehicle Types
Road	Passenger vehicles
	Light commercial vehicles
	Articulated trucks
	Rigid trucks
	Buses
	Motorcycles
Marine	Passenger
	Freight
Aviation	Passenger
	Freight
Rail	Passenger
	Freight

Table 4 Fuel and technology types in the transport emissions projections model

Fuel Types	Technology Types
Diesel	Battery Electric Vehicle (BEV)
Gasoline	Hybrid Electric Vehicle (HEV)
Liquefied Natural Gas (LNG)	Plug-In Hybrid Electric Vehicle (PHEV)
Liquefied Petroleum Gas (LPG)	Fuel Cell Electric Vehicle (FCEV)

Projected emissions for transport models and vehicle types other than light duty vehicles are the product of projected activity and emissions intensity for each transport sector segment (by region, by mode/vehicle, by fuel/engine type). The emissions intensity of each segment is assumed to improve by 0.5% per year. In 2022, DCCEEW commissioned Transport Energy/Emission Research (TER) to undertake research and modelling relevant to the light-duty vehicle category. This research, along with available data from other sources, enabled a review of key inputs into the light-duty transport fleet model. Modelling capability was also built to enable the development of new uptake forecasts, with a focus on road vehicles. Revisions were also made for the transport activity model with the use of freight data provided by the Bureau of Infrastructure and Transport Research Economics (BITRE).

Compared to the transport modelling underpinning the 2021 projections, the transport model structure has remained broadly the same. However, various model inputs were updated including latest data, trends, and research.

Activity Projections

The production of the transport activity projections involves a hybrid approach in which vehicle kilometres travelled (VKT) is produced based on projected net-tonne-kilometres (NTK) for freight, and projected passenger kilometres travelled (PKT) for passenger activity.

To produce total projected passenger activity, DCCEEW recalculated state-level activity projections that were based on multiple linear regression-based forecasts using gross state product (GSP) and population projections. For the 2022 activity projections, updated inputs were used.

The input GSP series was informed by the Australian Bureau of Statistics (ABS) (ABS 2021a), Centre for Population (2022), and the Department of the Treasury (2021) publications, as well as the

Ministerial Statement on the Economy (Chalmers 2022). The population projections were similarly based on multiple sources, including publications by the ABS (ABS 2018, 2022), Centre for Population (2022), and the Department of the Treasury (2021). These updated population and GSP series were then used to recalculate passenger activity projections using regression functions originally produced by Energeia (2020). For these revised activity projections, a small long-term impact in activity was assumed to reflect changes in behaviour resulting from the pandemic, such as increased working from home and virtual meetings. This reduction in passenger activity was applied as an annual adjustment to projected transport activity, with the impacts estimated to be 1.6% for aviation, 0.8% for private road transport, and 1.4% for public road transport and the rail and marine sectors.

Freight activity forecasts were based on new analysis from the BITRE. This included state-level freight activity projections for the road sector, and national-level freight projections for other modes (aviation, marine, rail). The series produced for both projected NTK and PKT were then used as inputs in calculating a final series for VKT.

Technology uptake

Technology uptake series for road vehicles were produced based on the analysis of multiple data sources, both historical and forecast. Historical sales data was sourced from VFACTS and used as an input to ensure the model was calibrated up to the 2022 financial year. This historical data was also analysed to inform the projected uptake series in terms of trends in the absolute sales of passenger and light commercial vehicles, along with trends in fuel type sales. Forecast data available for analysis included data produced by S&P Global for the Federal Chamber of Automotive Industries (FCAI), BITRE, and Bloomberg New Energy Finance. Forecast light-duty vehicle uptake was based on modelling completed for the Government by Energeia in 2020 and was used for both analysis and input. Energeia's modelling included vehicle sales technology projections based on a technology adoption function dependent on projected model availability and the projected first-year return on investment.

The final technology uptake series of use for the 2022 transport fleet model was developed through analysis of the data sources mentioned above. Trends in fuel type uptake were analysed and projected individually. Ratios in fuel type preference (e.g. gasoline to diesel, PHEV to BEV) were also analysed and factored into calculating the final technology uptake series.

The composition of the technology uptake series for passenger vehicles was developed separately to the light commercial series. The total number of passenger vehicles and light commercial vehicles projected to be sold was developed through analysis of both VFACTS historical data and the projected sales estimates. The technology uptake series compositions were then applied to the sales of passenger and light commercial vehicles respectively to arrive at projected uptake by fuel type and vehicle type.

Table 5 summarises the projected new light-duty vehicle sales by fuel type as a proportion of total sales.

Table 5 Projected new light-duty vehicle sales by fuel type in the baseline scenario (%)

Financial Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Light Commercial Vehicles														
BEV	0.0	0.3	0.7	1.3	2.0	2.5	4.2	7.0	10.0	12.1	15.6	19.9	24.9	30.1
Diesel	91.8	91.9	91.6	91.0	89.9	88.9	87.1	84.3	81.3	79.3	76.2	72.4	68.1	63.6
Gasoline	8.1	7.8	7.8	7.7	7.6	7.5	7.4	7.1	6.9	6.7	6.5	6.1	5.8	5.4
HEV	0.0	0.0	0.0	0.0	0.5	1.1	1.3	1.5	1.9	1.9	1.7	1.5	1.2	0.9
PHEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Passenger Vehicles														
BEV	2.5	3.2	4.4	6.2	8.0	9.8	14.5	17.2	21.8	26.3	31.2	36.2	41.5	46.9
Diesel	16.0	12.3	11.4	11.1	10.6	10.1	9.1	8.6	8.1	7.2	6.6	6.1	5.8	5.6
Gasoline	70.6	73.6	71.5	68.2	64.6	61.4	56.1	52.8	48.4	45.1	42.7	40.5	39.4	38.2
HEV	10.2	10.1	11.4	12.6	14.1	15.3	16.1	16.6	16.4	16.3	15.0	13.5	10.8	8.0
PHEV	0.7	0.8	1.3	1.9	2.7	3.4	4.2	4.8	5.2	5.2	4.6	3.7	2.5	1.3

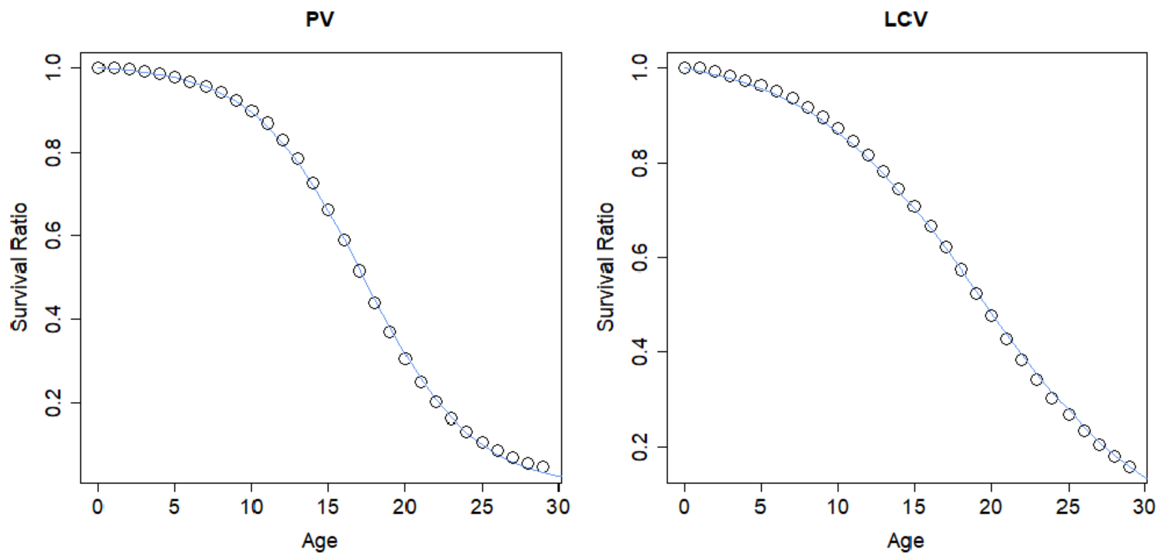
Note: Data is projected for financial years. For example, '2030' refers to the financial year 2029–30. These projections do not take account of new policies under the National Electric Vehicle Strategy. For example, if the Government introduced mandatory national vehicle fuel efficiency standards, this would increase the projected uptake of EVs and hybrid EVs in Australia.

Vehicle fleet real-world emissions intensities and survival curves

In 2022, DCCEEW made changes to the estimated emissions intensities and survival curves in relation to the light-duty vehicle fleet. These survival curves display the mathematical relationship between vehicle age and the proportion of the vehicle fleet that is retired. To support these updates, DCCEEW commissioned advice from TER.

TER provided updated survival curves for passenger cars and light commercial vehicles, which were incorporated into DCCEEW's fleet model (Figure 2).

Figure 2 Survival curves developed for passenger vehicles and light commercial vehicles



LCV = light commercial vehicles; PV = passenger vehicles
Source: TER 2022.

Light-duty vehicles sold in Australia have their emissions intensity measured based on the New European Driving Cycle test method. The Australian Government's Green Vehicle Guide publishes these intensities. Real-world emission intensities are generally higher than the test method, but the magnitude of difference is uncertain in the Australian context. DCCEEW commissioned TER to advise on historic and future emission intensities of vehicles. TER used the latest version of COPERT Australia (computer program to calculate emissions from road transport) as a basis for the development of energy intensities for fossil-fuelled vehicles by year of manufacture. Where required, information was extracted from the latest European COPERT version after making appropriate adjustments to more accurately represent Australian fleet characteristics.

DCCEEW compared the TER results with other public and internal sources including BITRE, the ABS Survey of Motor Vehicle Use (SMVU) (ABS 2020) and the National Transport Commission's Carbon Dioxide Emissions Intensity for new Australian Light Vehicles 2021 (NTC 2022). For petrol and diesel vehicles, DCCEEW considered that the TER estimates were at the upper range of probable estimates. To construct the baseline projection, DCCEEW calibrated historical emissions intensities to the ABS SMVU. This survey collects data from respondents based on information provided by selected vehicle owners. Year-to-year variations were informed by data from TER 2022, NTC 2022 and BITRE. The TER intensities were used as a sensitivity to the baseline sensitivity (TER 2022). For Plug-in Hybrid Electric Vehicles (PHEVs) and Hybrid Electric Vehicles (HEVs) the emissions intensity ratio with petrol vehicles was taken from the TER results and applied to the baseline time series. Efficiency of internal combustion vehicles was assumed to improve at a rate of 0.9% per year. For the electricity efficiency of Battery Electric Vehicles (BEVs) and PHEVs, the data was taken directly from the TER report.

The emissions intensity of light-duty vehicles remains an area of uncertainty, given the relative lack of real-world testing data. The Australian Government is providing $14 million to the Australian Automobile Association over the next 4 years to test the real-world fuel usage of a range of popular cars, SUVs, and utes sold in Australia. Future emissions projections will consider the outputs from this work.

The TER report also investigated the deterioration of vehicle emission performance over time. The research concluded that there was not enough useful data or information available regarding CO_2 emission deterioration with age. It recommended that developing degradation factors could be worth further consideration in the future, for both internal combustion engine, EV and fuel cell vehicles (TER 2022).

The series used for the emission intensity of new passenger and light commercial vehicles over the period of 2000 to 2035 can be found in Table 13 and Table 14 in the Appendix.

Fugitive emissions from fuels

Emissions from the fugitive emissions sector are projected using emission estimation models maintained and updated by DCCEEW using external inputs. The models are a combination of facility-specific and top-down models, depending on the nature of the emission source and the availability of data.

Coal fugitives

Operating coal mines

Modelling approach

DCCEEW maintains a mine-by-mine model of fugitive emissions from operating coal mines. A mine-by-mine model takes account of the emissions intensity of each mine. These depend on the operational and geological characteristics of the mine.

$$E_t = \sum_i (P_{it} \cdot EI_i) - \text{Measures}_t$$

Where:

E_t = annual emissions from operating coal mines in year t (Mt CO_2-e)

P_{it} = coal production at mine i in year t (kt)

EI_i = the emissions intensity of production at mine i, (Mt CO_2-e/kt coal)

Measures_t = abatement from policies and measures (e.g. forthcoming projects under the Powering the Regions Fund) in year t (Mt CO_2-e).

Activity data

The emissions intensity of coal mines includes all sources of fugitive emissions from vented CH_4 and CO_2, flaring and post mining. For operating mines, the emissions intensity is sourced from the most recent 5 years of National Greenhouse Gas Inventory data, which are based on company data reported under the NGER scheme. For some mines, expert judgment is applied to exclude years impacted by operational problems and to take into account trends in the emissions intensity of the mine that could be due to mining different parts of the coal resource or updated gas management practices. For prospective coal mines, the emissions intensity is sourced from environmental impact statements or is the average for currently operating mines in the same coal basin.

Mine-by-mine production estimates for existing and new mines are informed by OCE (2022a,b) for 2022–2027 and Wood Mackenzie for 2028 onwards. Coal production is separately estimated for thermal and coking coal production at each mine.

Production estimates from prospective new mines is scaled so that total Australian production of thermal and coking coal is consistent with an estimate of total demand for Australian coal. Total demand is consistent with the OCE for 2022–2027 and then utilises growth rates from Wood Mackenzie adjusted for domestic demand for Australian coal sourced from the electricity sector model and any announced closures not included in the Wood Mackenzie data. All prospective coal mines are scaled at an equivalent rate for thermal and coking coal mines; the projections do not make decisions on which prospective mines would and would not proceed. Scaling is undertaken for thermal and coking coal separately.

Production from brown coal mines is sourced from the electricity sector model.

Abandoned coal mines

Modelling approach

CH_4 emissions occur under certain conditions following the closure of underground coal mines. Emissions are estimated using a mine-by-mine model developed for the National Greenhouse Gas Inventory. The model is extended to include projected closures of underground coal mines to 2035.

$$E_t = \sum_i (ED_i \cdot EF_i \cdot (1 - F_{it})) - ER_{it}$$

Where:

E_t = emissions from abandoned coal mines in year *t* (Mt CO_2-e)

ED_i = annual emissions of mine *i* in the year before decommissioning (Mt CO_2-e)

EF_i = emission factor for mine *i* at a point in time since decommissioning. It is derived from the Emissions Decay Curves (DCCEEW 2022c)

F_{it} = fraction of mine *i* flooded at a point in time since decommissioning

ER_{it} = quantity of CH_4 emissions avoided by recovery at mine *i* in year *t* (Mt CO_2-e).

The model requires the CH_4 emissions at the time of closure, the mine type, mine void size and mine water inflow rates. Emissions at the time of closure and mine void volume are sourced from the operating coal mines model. Emission decay curves are calculated from the formulas published in the *National Inventory Report* (DCCEEW 2022c). Mine flooding rates are estimated based on the mine's water production region consistent with the National Greenhouse Gas Inventory.

Activity data

Closure dates are sourced from mine-by-mine forecasts provided by the OCE (OCE 2022a,b) and Wood Mackenzie and are consistent with the operating coal mines model.

Oil and gas fugitives

Oil

Oil fugitive emissions are separated into 5 subsectors:

- crude oil production
- crude oil transport
- exploration
- other – abandoned wells
- refining/storage
- flaring.

Modelling approach

Oil fugitive emissions projections for the crude oil production, crude oil transport, refining/storage and flaring are calculated using the following algorithm:

$$E_t = \sum_i \left(Pr_t \cdot \left(El_{cp} + El_{ct} + El_{rs} + El_f\right)\right)$$

Where:

E_t = oil fugitive emissions in the year t (Mt CO_2-e)

Pr_t = proxy indicator in year t

EI_{cp} = average emissions intensity for crude oil production (Mt CO_2-e / ML of crude oil and condensate production)

EI_{ct} = average emissions intensity for crude oil transport (Mt CO_2-e / ML of crude oil and condensate production)

EI_{rs} = average emissions intensity for refining/storage (Mt CO_2-e/ ML of refinery output)

EI_f = average emissions intensity for oil flaring (Mt CO_2-e / ML of crude oil and condensate production).

Projected emissions for oil exploration are calculated as a 10-year average of historical fugitive emission from oil exploration.

Projected emissions from abandoned wells is calculated based on historical rates of fugitive emissions growth from abandoned wells. For the 2022 projections, the assumed growth is 3%.

$$E_t = 1.03E_{t-1}$$

Where:

E_t = emissions in year t

E_{t-1}= emissions in the year t – 1.

Activity data

Activity data used to estimate emissions from oil and gas fugitives is provided in Table 6.

Table 6 Summary of data sources for preparing oil fugitive emissions

Fugitive emissions source	Proxy indicator	Source
Oil - production	Crude oil and condensate production	OCE 2022a; OCE 2022b
Oil - transport	Crude oil and condensate production	OCE 2022a; OCE 2022b
Oil - exploration	Historical 10-year average of emissions from oil exploration	DCCEEW 2022c
Oil - abandoned wells	3% growth in emissions derived from historical growth in emissions	DCCEEW 2022c
Oil refinery	Refinery output	OCE 2022a; OCE 2022b
Oil - flaring	Crude oil and condensate production	OCE 2022a; OCE 2022b

Fugitive emissions from oil exploration and abandoned wells is small (0.002 Mt CO_2-e in total) and volatile from year to year. Historical emissions levels have been used to project future emissions from this source, in lieu of a more appropriate proxy indicator.

LNG facilities

Modelling approach

DCCEEW maintains a facility-by-facility model of fugitive emissions from LNG. Factors influencing the emissions from an LNG facility are the operation of the plant, the CO_2 concentration and source of the feed gas, abatement actions and annual production.

$$E_t = \sum_i \left(P_{ti} \cdot \left(El_{vi} + El_{fi} + El_{oi}\right) - CCS_{ti}\right)$$

Where:

E_t = LNG fugitive emissions in year t (Mt CO_2-e)

P_{ti} = production at facility i in year t (Mt LNG)

EI_{vi} = venting emissions intensity at facility i (Mt CO_2-e/Mt LNG)

EI_{fi} = flaring emissions intensity at facility i (Mt CO_2-e/Mt LNG)

EI_{oi} = other leaks emissions intensity at facility i (Mt CO_2-e/Mt LNG)

CCS_{ti} = CO_2 captured and stored at facility i in year t (Mt CO_2).

Emissions intensities for venting, flaring and other fugitive leaks at operating facilities are based on NGER data. For newer facilities or new feed gas sources, emissions intensities are sourced from environmental impact statements or other sources if available.

Activity data

LNG production projections for each facility are informed by estimates from the OCE (OCE 2022a,b) and Wood Mackenzie. The projections consider committed and prospective additions and removals in capacity, given the global outlook for LNG.

Domestic natural gas

Modelling approach

Domestic natural gas is natural gas consumed in Australia. It is distinguished from LNG, which is predominantly produced for export. The small amount of LNG produced for domestic consumption is treated as domestic gas in the projections.

The sources of fugitive emissions from domestic natural gas in the projections are gas exploration, other post-meter emissions, other abandoned wells, production, processing, transmission, distribution, venting and flaring. Proxy indicators are used to project the growth in emissions at the state level from the subsectors as listed below.

$$E_t = \sum_i \left(P_{ti} \cdot El_i\right) - CCS_{ti}$$

Where:

E_t = annual emissions in year t (Mt CO_2-e)

P_{it} = gas production at basin *i* in year *t* (PJ)

EI_i = the emissions intensity of processing/processing/flaring/venting at basin *i* (Mt CO_2-e/PJ gas produced)

CCS_{ti} = CO_2 captured and stored at facility *i* in year *t* (Mt CO_2-e).

The emissions intensities of processing, production, flaring and venting at basins across Australia were calculated from emissions estimates in the National Greenhouse Gas Inventory and historical gas production.

Activity data

Estimates of gas production for domestic consumption are informed by estimates from the OCE (OCE 2022a,b) and AEMO (2021, 2022e). For new gas developments, production estimates are informed by production estimates from Rystad Energy. Emissions intensities for new gas developments are derived from environmental impact statements if available, state average emission intensities from the National Greenhouse Gas Inventory (DCCEEW 2022d) and the CSIRO study of whole-of-life GHG emissions from the Surat Basin for the GISERA project (Schandl et al. 2019).

Table 7 Summary of data sources for gas fugitive emissions

Fugitive emissions source	Proxy indicator	Source
Distribution	Unaccounted for gas losses	AEMO 2022e
Exploration - flared	Total gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e
Exploration - leakage - conventional	Conventional gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e
Exploration - leakage - unconventional	Unconventional gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e
Exploration - venting - completions - conventional	Conventional gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e
Exploration - venting - completions - unconventional	Unconventional gas production	OCE 2022a; OCE 2022b; AEMO 2021 AEMO 2022e
Exploration - venting - workovers	Unconventional gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e
Other – abandoned wells	Historical growth rate of emissions abandoned gas wells	DCCEEW 2022c
Other – Post meter emissions	Derived total appliance in the commercial and residential sector, Vehicle stock projections, Industrial natural gas consumption	ABS 2021b; Energy Consult 2015
Processing	Domestic gas production (conventional and unconventional)	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e; emission projections models for LNG
Production - offshore platforms	Number of shallow and deep offshore platforms	AME Group; Company Reports

Fugitive emissions source	Proxy indicator	Source
Production - onshore gathering and boosting - conventional gas	Conventional gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e; emission projections models for LNG
Production - onshore gathering and boosting - unconventional gas	Unconventional gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e; emission projections models for LNG
Production - onshore wells - conventional gas	Conventional gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e; emission projections models for LNG
Production - onshore wells - unconventional gas	Unconventional gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e; emission projections models for LNG
Production - onshore wells - water production	Unconventional gas production	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e; emission projections models for LNG
Transmission and storage - LNG terminals	Number of LNG terminals operating	AEMO 2022e; AME Group; company reports
Transmission and storage - storage - LNG	Number of LNG storage stations operating	AME Group; company reports
Transmission and storage - storage - natural gas	Number of gas storage stations operating	AEMO 2022e; AME Group; company reports
Transmission and storage - transmission	Total pipeline length	APGA 2020; company reports
Venting and flaring - flaring - gas	Domestic gas production (conventional and unconventional)	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e
Venting and flaring - venting - gas	Domestic gas production (conventional and unconventional)	OCE 2022a; OCE 2022b; AEMO 2021; AEMO 2022e

Industrial processes and product use

Emissions from the industrial processes and product use (IPPU) sector are projected using bottom-up models developed within DCCEEW. Where possible, emissions are projected by estimating fuel use at the facility level, to account for different fuel types, and the emissions intensity of production across facilities.

Modelling approach

A summary of data sources and model frameworks applied is provided in Table 8.

Unless otherwise specified, the emissions intensity of production is assumed to be constant across the entire projections period and is based on the emissions reported in Australia's *National Inventory Report 2020* (DCCEEW 2022c).

Activity data

Emissions projections in the IPPU sector are estimated using activity data from various sources including OCE commodity forecasts (OCE 2022a,b), Wood Mackenzie long-term outlook reports, ammonia production forecasts (MRC 2021), IBISWorld industry reports, and the Organisation for Economic Co-operation and Development (OECD 2022).

Emissions from the 'product uses as substitutes for ozone depleting substances' and 'other product manufacture and use' subsectors are estimated by extrapolating models used in the preparation of the National Inventory Report. A detailed methodology for these subsectors is available in the National Inventory Report 2020 (DCCEEW 2022c).

Table 8 Summary of sources and formula for each IPPU subsector

Emissions subsector	Data source	Formula
Chemical industry		
Ammonia	Production data from *Ammonia: Australia market outlook 2021* (MRC 2021)	$E_t = \sum_i (U_{it} \cdot EC_j \cdot EF_j)$ *Where:* E_t = emissions in year *t* (Mt CO_2-e) U_{it} = natural gas consumption at facility *i* in year *t* EC_j = the energy content of natural gas EF_j = the emissions factor of natural gas
Nitric acid	DCCEEW estimates based on projected iron ore and coal production	$E_t = \sum_i (EF_{it} \cdot P_{it})$ Where: E_t = emissions in year *t* (Mt CO_2-e) EF_{it} = facility-specific emissions factor in year *t*

Emissions subsector	Data source	Formula
		P_{it} = nitric acid production at facility *i* in year *t*
Titanium dioxide Synthetic rutile	World GDP growth from the Organisation for Economic Co-operation and Development (OECD 2022)	$E_t = \sum_{i,j}(U_{jit} \cdot EC_j \cdot EF_j)$ Where: E_t = emissions in year *t* (Mt CO_2-e) U_{jit} = the use of fuel *j* at facility *i* in year *t* EC_j = the energy content of fuel *j* EF_j = the emissions factor of fuel *j*
Acetylene	Population forecasts from ABS (2018, 2022) and Department of the Treasury (2021)	$E_t = E_{t-1} \cdot \Delta\text{Population}$ Where: E_t = emissions in year *t* (Mt CO_2-e) E_{t-1} = emissions in the previous year ΔPopulation = change in population between year *t* and year *t* – 1
Petrochemical and carbon black	n/a	$E_t = E_{t-1}$ Where: E_t = emissions in year *t* (Mt CO_2-e) E_{t-1} = emissions in the previous year
Metal industry		
Aluminium production	Production data from OCE (2022a,b) and Wood Mackenzie	$E_t = \sum_{i,j}(U_{jit} \cdot EC_j \cdot EF_j) + (PFC_{t-1} \cdot \Delta\text{Production})$ Where: E_t = emissions in year *t* (Mt CO_2-e) U_{jit} = the use of fuel *j* as a reductant at facility *i* in year *t* EC_j = the energy content of fuel *j* EF_j = the emissions factor of fuel *j* PFC_{t-1} = perfluorocarbon emissions in the previous year ΔProduction = change in production between year *t* and year *t* – 1
Iron and steel production	Production data from OCE (2022a,b) and Wood Mackenzie; fuel savings from Advisian (2020)	$E_t = \sum_{i}(EF_i \cdot P_{it} - cs_{it})$ Where: E_t = emissions in year *t* (Mt CO_2-e)

Emissions subsector	Data source	Formula
		EF_i = facility-specific emissions factor P_{it} = production at facility *i* in year *t* cs_{it} = carbon content in steel at facility *i* in year *t* Emissions are adjusted to account for switching from coke
Ferroalloys production	Company statements	$E_t = \sum_{i,j} (U_{jit} \cdot EC_j \cdot EF_j)$ Where: E_t = emissions in year *t* (Mt CO2-e) U_{jit} = the use of fuel *j* as a reductant at facility *i* in year *t* EC_j = the energy content of fuel *j* EF_j = the emissions factor of fuel *j*
Other metal production (copper, nickel, silicon and lead)	Production data from OCE (2022a,b) and Wood Mackenzie	$E_t = \sum_{i,j} (U_{jit} \cdot EC_j \cdot EF_j)$ Where: E_t = emissions in year *t* (Mt CO_2-e) U_{jit} = the use of fuel *j* as a reductant at facility *i* in year *t* EC_j = the energy content of fuel *j* EF_j = the emissions factor of fuel *j*
Mineral industry		
Cement	Contextual production forecast from Cement Industry Federation and IBISWorld industry report	$E_t = \sum_{i} (EF_i \cdot P_{it})$ Where: E_t = emissions in year *t* (Mt CO_2-e) EF_i = facility-specific emissions factor P_{it} = production at facility *i* in year *t*
Lime		
Limestone and dolomite and other carbonates	DCCEEW estimates based on projected ceramics, ferroalloy production, glass production, and iron and steel production. Zinc production data from OCE (2022a,b) and Wood Mackenzie	$E_t = E_{t-1} \cdot \Delta\text{Production}$ Where: E_t = emissions in year *t* (Mt CO_2-e) E_{t-1} = emissions in the previous year ΔProduction = change in production between year *t* and year *t* − 1

Emissions subsector	Data source	Formula
Non-energy products from fuel and solvent use		
Lubricant use	n/a	$E_t = E_{t-1}$ Where: E_t = annual emissions in year t E_{t-1} = emissions in the previous year
Product uses as a substitute for ozone depleting substances	DCCEEW (2022c)	Based on National Inventory Report methodology
Other product manufacture and use		
Electrical equipment	DCCEEW 2022c	Based on National Inventory Report methodology
SF_6 and PFCs from other product uses N_2O from product uses	Population forecasts from ABS (2018, 2022) and Department of the Treasury (2021)	$E_t = E_{t-1} \cdot \Delta\text{Population}$ Where: E_t = emissions in year t (Mt CO_2-e) E_{t-1} = emissions in the previous year ΔPopulation = change in population between year t and year $t-1$
Other production	DCCEEW estimates based on projected ammonia production and food, beverages and tobacco production	$E_t = E_{t-1} \cdot \Delta\text{Production}$ Where: E_t = emissions in year t (Mt CO_2-e) E_{t-1} = emissions in the previous year ΔProduction = change in production between year t and year $t-1$

Agriculture

Emissions from the agriculture sector are projected using bottom-up modelling developed by DCCEEW. The model is maintained and updated within DCCEEW using external inputs.

Modelling approach

Emissions from agricultural activity are calculated as

$$E_t = \sum_j \sum_l \sum_k \sum_i (N_{ki} \cdot EF_{kjil}) \times 10^{-3}$$

Where:

E_t = emissions in year t (Mt CO_2-e)

N_{ki} = quantity of activity type in each state, in relevant unit quantity (number of heads, kilotonnes, hectares, etc.)

EF_{kjil} = emissions factors of gas types, by gas source.

Emissions factors are in:

- kt/unit of activity/year
- Gg (gigagram)/unit of activity/year for rice cultivation.

Table 9 Symbols used in algorithms

Symbol	Variable	Variable categories
$\boldsymbol{k}$[a]	State	Australian Capital Territory, New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria, Western Australia
$\boldsymbol{i}$[b]	Activity type	Grazing beef cattle, grain-fed beef cattle, dairy cattle, sheep, wheat, rice, etc.
$\boldsymbol{j}$[a]	Gas type	CO_2, CH_4, N_2O
$\boldsymbol{l}$[a]	Gas source	Enteric fermentation, manure management, rice cultivation, agricultural soils, field burning of agricultural residues, lime and urea application

a Not all states, gas types and gas sources are relevant to all activity types.
b Activity types may contribute to several different gas sources

The agriculture projections use emissions factors for activity derived from the *National Greenhouse Gas Inventory Quarterly Update: June 2022* (DCCEEW 2022d).

The projections include abatement from agriculture projects such as beef cattle herd management and destruction of CH_4 generated from manure in piggeries under the Australia's carbon crediting scheme. They also include abatement from the introduction of low emissions feed supplements such as asparagopsis and the compound 3-NOP.

Activity data

Emissions are projected by calculating the amount of agricultural activity in Australia each year. This is done by drawing on external data sources that contain activity numbers and activity growth rates (Table 10).

ABARES is a key data source informing the agricultural emissions projections. Where activity data are not available for particular commodities, an appropriate proxy such as production (quantity of end product), or a relevant driver such as growth in another connected commodity (as informed by historical comparisons) is used. For example, nitrogen fertiliser use increases in line with crop production. The assumption is that greater crop activity requires more nitrogen from fertilisers to support additional plant growth. Historical trends are also used to inform growth if projected activity data are unavailable.

Determining the impacts of climate change on agricultural commodities across Australia is particularly difficult due to locational variation and uncertainty around market responses. As a result of the complicated nature of climate change impacts on agricultural rates of productivity, activity data have not been adjusted for future climate change conditions, with the exception of the climate variability built into the ABARES forecast.

The projections also include a trend towards grain-fed beef cattle, as some farmers seek a more drought-resistant feed system. This trend has an impact on the overall emissions intensity of beef cattle production. The diets of grain-fed beef cattle are more energy intensive than those of grass-fed cattle. Animals convert a portion of this additional energy to emissions in the gut. However, as low-emissions feed supplements are introduced into the diets of ruminant livestock the emissions intensity of cattle and sheep are expected to decrease. This is expected to have the greatest effect on grain-fed cattle because the supplements can be delivered most effectively in feedlots.

Units of agricultural activity (e.g. head of cattle) are multiplied by relevant emissions intensities to arrive at an emissions estimate. The emissions intensities of activities are assumed to be constant across the projections period and are derived from the *National Greenhouse Gas Inventory Quarterly Update: June 2022* (DCCEEW 2022d).

As emissions within agriculture relate to biological processes, as well as manure and residue management, individual commodities can contribute several types of gases to multiple IPCC subsectors.

Table 10 Summary of principle data sources for Agriculture

Commodity	Emissions subsectors	Data sources	Unit of activity
Lime and urea	Liming and urea application	DCCEEW estimate based on historical trends	Kilotonnes
Fertilisers	Agricultural soils	DCCEEW estimate based on historical trends	Kilotonnes
Other animals	Enteric fermentation Manure management Agricultural soils	Activity held constant at final year of inventory	Heads of animal
Other animals – poultry	Manure management Agricultural soils	ABARES (ABARES 2022a,b) OECD-FAO Agricultural Outlook (OECD-FAO 2022) DCCEEW estimate based on historical trends	Heads of animal
Pigs	Enteric fermentation Manure management Agricultural soils	ABARES (ABARES 2022a,b) OECD-FAO Agricultural Outlook (OECD-FAO 2022) DCCEEW estimate based on historical trends	Heads of animal
Crops	Agricultural soils Field burning of agricultural residues Rice cultivation	ABARES (ABARES 2022a,b,c) DCCEEW estimate based on historical trends	Non-rice crops: kilotonnes of crop Rice: kilotonnes of rice Hectares of area under cultivation
Sheep	Enteric fermentation Manure management Agricultural soils	ABARES (ABARES 2022a,b) DISER estimate based on historical trends	Heads of animal
Dairy	Enteric fermentation Manure management Agricultural soils	ABARES (ABARES 2022a,b) DCCEEW estimate based on historical trends	Heads of animal
Grain-fed beef	Enteric fermentation Manure management Agricultural soils	ABARES (ABARES 2022a,b) DCCEEW estimate based on historical trends	Heads of animal
Grazing (grass-fed) beef	Enteric fermentation Manure management Agricultural soils	ABARES (ABARES 2022a,b) DCCEEW estimate based on historical trends	Heads of animal

Waste

The waste sector emissions projections are prepared by DCCEEW, and include 5 waste subsectors:

- solid waste to landfill
- biological treatment of solid waste (composting)
- incineration
- domestic and commercial wastewater
- industrial wastewater.

Modelling approach

The waste sector models largely replicate the methods used to calculate historical waste emissions. The solid waste sector modelling is completed on a site-specific basis to take account of the emission characteristics of individual landfills.

Solid waste deposited at landfills

A mix of increases and some decreases in the volume of waste disposed to landfill has been observed in Australia's states and territories since 1990. This reflects, in part, differences in population growth and the impacts of state government policies on waste management. A decline in waste disposed to landfill is expected to occur to 2035 as waste-reduction policies are implemented.

Waste quantities are recorded and reported in 3 source streams, which are:

- municipal solid waste (MSW)
- commercial and industrial (C&I) waste

construction and demolition (C&D) waste.

The projections take account of current policies and measures at various levels of government. These include targets from the:

- National Food Waste Strategy (DoEE 2017): halve food waste generation by 2030
- National Waste Policy Action Plan (Australian Government 2019): 80% average resource recovery rate by 2030, reduce total waste generated by 10% per capita by 2030, halve the amount of organic waste sent to landfill for disposal by 2030

Food Waste for Healthy Soils Fund (DCCEEW 2022f): supports the National Waste Policy target to halve the amount of organic waste sent to landfill for disposal by 2030.

Projects funded through the Recycling Modernisation Fund are also included, as are approved Energy from Waste projects, based on expected completion dates. These projects contribute to meeting the noted government targets, and therefore abatement was not generally considered to be additional. Projected resource recovery from these projects was calculated and would be included in the projections if it exceeded the government targets.

The projections also take account of commitments made by state and territory governments to reduce waste generation and increase recovery, as outlined in Table 11 and Table 12.

Table 11 State and territory resource recovery targets

Jurisdiction	Stream	2025	2030	2040	2050	Strategy document
Australian Capital Territory	Overall	90%				Australian Capital Territory Government (2011)
New South Wales	Overall		80%			New South Wales Government (2021)
Queensland	Overall	65%	80%	85%	90%	Queensland Government (2021)
	MSW	55%	70%	90%	95%	
	C&I	65%	80%	90%	95%	
	C&D	75%	85%	85%	85%	
Victoria	Overall	72%	80%			Victoria State Government (2020)
Western Australia	Overall	70%	75%			Waste Authority (2019)

Table 12 State and territory waste generation reduction targets (% reduction per capita)

Jurisdiction	Stream	2025	2030	2040	2050	Baseline year	Strategy document
Australian Capital Territory	Overall	No increase				2011	Australian Capital Territory Government (2011)
New South Wales	Overall		10%			2017	New South Wales Government (2021)
Queensland	MSW	10%	15%	20%	25%	2018	Queensland Government (2021)
South Australia	Overall	5%				2020	Government of South Australia (2020)
Victoria	Overall		15%			2020	Victoria State Government (2020)
Western Australia	Overall	10%	20%			2015	Waste Authority (2019)

Resource recovery rates were projected to change by the same amount each year to meet targets. Where no targets were applied, resource recovery rates were projected based on underlying growth rates from the *National Waste Report 2020* (Blue Environment 2020). The calculated waste recovery rates were then applied to waste generation estimates to calculate waste sent to landfill.

Waste generation rates per capita were projected to change by the same amount each year to meet targets. Where no targets were applied, waste generation rates were projected based on underlying growth rates from the *National Waste Report 2020*.

The projections consider upcoming approved Energy from Waste facilities. Once operational, these projects will reduce the amount of waste deposited to landfill. The combustion emissions from these facilities are counted in the electricity sector. These facilities are:

- Kwinana facility in Western Australia, which is expected to incinerate approximately 400 kilotonnes of waste annually

- East Rockingham facility in Western Australia, which is expected to process 300 kilotonnes of waste annually
- Renergi demonstration project in Western Australia, which is expected to divert up to 4 kilotonnes of organic waste and 8 kilotonnes of forestry and agricultural waste annually
- Laverton North waste gasification project in Victoria, which is expected to divert up to 200 kilotonnes of municipal solid waste annually
- Maryvale facility in Victoria, which is expected to process 325 kilotonnes of municipal solid waste annually.

Waste generation and recovery were projected by calculating the amount of waste deposited at landfills. Growth rates for the resource recovery of individual waste types were projected using data from the *National Waste Report 2020*, as well as policies aimed at certain waste types. The waste stream growth rates were then applied to the waste recovered in each state and territory.

Recovery rates for CH_4 were projected to increase by 0.25% per year. This rate of increase was based on a logarithmic trend of historical increases, which is expected to continue.

Historical waste is modelled on a facility-by-facility basis to reflect the characteristics of each landfill, including weather conditions. Future waste deposited is estimated on separate state and territory bases, reflecting the average conditions of landfills in each jurisdiction.

Biological treatment of solid waste

Policies at various levels of government in Australia are diverting organics from landfill to reduce landfill emissions and create market opportunities for organic waste products. Organic waste is treated through composting or anaerobic digestion.

The quantity of organic waste is projected from the amount of organic waste diverted from landfill. Policies aimed at diverting organic waste from landfill, such as the Food Waste for Healthy Soils Fund, are included in this projection.

Incineration

In Australia, incineration emissions are generated from thermal oxidation of clinical waste and solvents. The model assumes that clinical waste increases proportionately to population and the volume of solvents incinerated remains constant over the projection period.

At the time of publishing, several energy-from-waste projects had been approved. They will generate energy from the incineration of combustible waste. Under IPCC guidelines, emissions generated through the combustion of waste for energy are accounted for within the electricity sector.

Domestic and commercial wastewater

Emissions are estimated separately for unsewered and sewered populations, which have different assumed chemical oxygen demands (CODs).

The unsewered COD per capita ratio is applied to a projection of the unsewered population in each state and territory. Emissions are calculated based on the inventory CH_4 emissions factor and the percentage of wastewater anaerobically treated (50%).

The sewered COD per capita is applied to a projection of the sewered population in each state and territory. COD flows are used to estimate emissions from domestic and commercial wastewater facilities. COD influent refers to COD entering the wastewater facility in wastewater. COD outflow refers to:

- COD removed as sludge within the facility
- COD discharged from a facility as effluent, such as into rivers or the ocean
- COD in sludge removed to landfill or other land-based sites.

COD outflows are projected using ratios to COD influent. The ratios are a national average based on the latest inventory data. COD outflows are projected for each state and territory using the calculated ratio and the COD influent for the relevant year. This approach assumes that the proportion of COD outflow to COD influent remains constant over the projection timeframe.

The total CH_4 generated is the sum of CH_4 generated from wastewater and from sludge. These are calculated using the following formulas:

$$\text{Methane generated from wastewater} = (\text{COD influent} - \text{COD removed as sludge} - \text{COD discharged as effluent}) \times \text{methane correction factor} \times \text{methane emissions factor}$$

$$\text{Methane generated from sludge} = (\text{COD removed as sludge} - \text{COD removed to landfill or other land site}) \times \text{methane correction factor} \times \text{methane emissions factor}$$

The proportion of CH_4 recovered is held fixed from the latest inventory year.

N_2O emissions are calculated by replicating the same assumptions and calculations used to project CH_4 from the sewered population. However, N_2O emissions did not include any GHG recovery and are applied to the entire Australian population rather than only the sewered population.

Industrial wastewater

Industrial wastewater emissions are projected for the following subsectors: dairy production, pulp and paper production, meat and poultry processing, organic chemicals production, sugar production, beer production, wine production, fruit processing, and vegetable processing.

Projections are based on changes to commodity production levels. Growth rates are based on long-term forecasts using sector-specific metrics.

Inclusion of projects funded through Australia's carbon crediting scheme

The solid waste projection includes existing CH_4 recovery projects funded through Australia's carbon crediting scheme. The solid waste and wastewater projections include additional abatement, for example, capture of biogas at wastewater treatment facilities, incentivized by the carbon crediting scheme that are additional to the modelled business-as-usual scenario.

Land use, land use change and forestry

Modelling approach

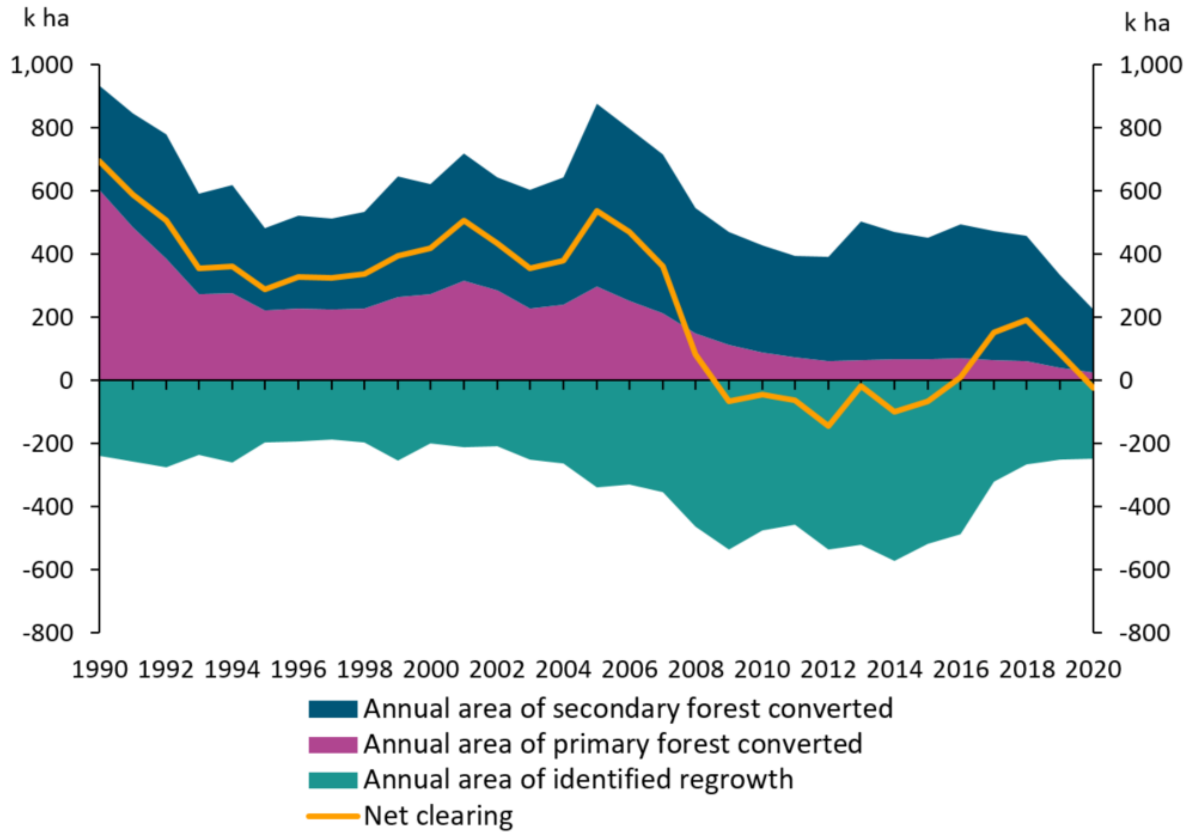
The Full Carbon Accounting Model (FullCAM) provides the modelling framework for estimating land sector emissions in the National Greenhouse Gas Inventory and the emissions projections. FullCAM models the exchange of carbon between the terrestrial biological system and the atmosphere in a full/closed-cycle mass-balance model, which includes all biomass, litter/debris and soil pools. The model uses data on climate, soils, and management practices, as well as land-use changes observed from satellite imagery, to produce estimates of emissions and removals across the Australian landscape. A detailed description of the model is provided in the National Inventory Report (DCCEEW 2022c, Appendix 6.B).

Activity data

Most forest conversion activity in Australia is to maintain pastures for grazing activities. Some forest conversion occurs to support cropping. Smaller quantities occur for settlements, infrastructure, and reservoirs.

Most clearing activity in Australia is associated with the re-clearing of regrown forest vegetation. Land clearing restrictions have seen primary forest conversion stabilise at record low levels over the past decade (Figure 3).

Figure 3. Historical land clearing activity, 1990 to 2020, k ha



For the 2022 projection, it was assumed that primary forest conversion would remain at historic low levels and that regrowth and re-clearing activity responds to changes in the number of livestock included in the projection for the agriculture sector. The projection also includes the assumption that a 10-year cycle of regrowth and re-clearing applies, which involves land managers re-clearing regrowth vegetation to maintain production.

For projections of net emissions from forest lands, log harvest forecasts were adopted from the business-as-usual scenario published in *Outlook scenarios for Australia's forestry sector: key drivers and opportunities* (Burns et al. 2015).

For cropland and grassland emissions projections, management practices are assumed to remain unchanged over the projection period, and emissions assumed to gradually return to long-run average levels.

The projections include state policies around declining native forest logging as well as abatement from vegetation, soil carbon, and savanna burning projects under the Australia's carbon crediting scheme.

With additional measures scenario

The ‘with additional measures’ scenario is intended to provide insights into the emissions impacts of announced policies that are still subject to ongoing consultation and design.

Electricity sector - national renewable electricity target of 82% by 2030

In the electricity sector, it is assumed that the share of renewable energy is increased to 82% of electricity generated in Australia’s electricity grids (NEM, WEM, NWIS, DKIS) by 2030. Off-grid electricity and minor-grids such as Mt Isa are unchanged from the baseline in this scenario.

Each grid is assumed to reach 82% renewable generation (as generated) by 2030 with the 82% renewable portion being maintained post-2030. This assumption has been made for modelling purposes and should not be interpreted as a policy decision.

The NEM scenario is modelled using PLEXOS to project emissions to 2035. The NWIS uses a top-down model that changes the fuel mix, in particular the uptake of solar generation. Both the WEM and the DKIS use a simple method of multiplying the projected grid emissions in 2030 by the difference in the proportion of fossil fuels.

Other Sectors - Reforms to the Safeguard Mechanism

Broadly consistent with the approach outlined in the Safeguard Consultation paper released in August 2022, it is assumed that facilities covered by the safeguard contribute their proportional share to achieving Australia’s 2030 target. That is, aggregate safeguard baselines fall to 100 Mt CO_2-e in 2030 which is 46 Mt CO_2-e lower than their projected emissions under the baseline scenario. Beyond 2030 aggregate safeguard baselines decline consistent with reaching net zero by 2050.

Abatement is assumed to be achieved through a combination of on-site abatement and the surrender of Australian Carbon Credit Units (ACCUs). The baseline scenario includes ACCUs generated from existing offset projects and new projects supported by future auctions under the Powering the Regions Fund. In 2030, 9 million tonnes of the Safeguard Mechanism abatement task is assumed to be met through ACCUs that are already included in the baseline projection. To avoid double counting, the ‘with additional measures’ scenario only includes abatement from the reforms to the safeguard mechanism that is not already included in the baseline. Abatement has not been attributed to individual facilities, sectors or GHG.

Assumptions have been made about design aspects of the reforms to the safeguard mechanism for modelling purposes. These should not be interpreted as policy decisions.

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Australian Government

Department of Climate Change, Energy, the Environment and Water

Appendix

Table 13 Emission Intensities by vehicle and fuel type for new vehicles, 2000-2020 (g CO_2/km)

Vehicle Type	Fuel Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Light Commercial	Diesel	375	369	362	356	349	343	336	330	330	329	329	329	329	328	328	327	326	325	324	323	323
	Gasoline	323	323	323	323	323	322	320	319	318	317	316	315	313	312	311	310	308	305	302	299	299
	HEV	232	232	232	232	236	237	237	237	236	235	235	234	233	232	231	231	229	231	230	228	228
Passenger	Diesel	352	347	341	336	330	320	310	300	300	299	299	298	298	297	297	297	296	296	295	295	295
	Gasoline	277	275	273	272	272	273	264	261	262	260	258	258	250	246	242	243	242	242	238	238	238
	HEV	148	146	147	156	146	161	164	163	163	166	181	175	164	162	163	167	161	153	146	152	161
	PHEV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	115	115	111	109	148	141	131	134	130	138	139

Table 14 Emission Intensities by vehicle and fuel type for new vehicles, 2021-2035 (g CO_2/km)

Vehicle Type	Fuel Type	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Light Commercial	Diesel	320	317	314	312	309	306	303	300	298	295	292	290	287	285	282
	Gasoline	296	294	291	288	286	283	281	278	276	273	271	268	266	263	261
	HEV	226	224	222	220	218	216	214	212	210	208	206	205	203	201	199
Passenger	Diesel	292	290	287	285	282	279	277	274	272	269	267	265	262	260	258
	Gasoline	236	234	232	230	228	226	224	222	220	218	216	214	212	210	208
	HEV	160	158	157	155	154	153	151	150	149	147	146	145	143	142	141
	PHEV	137	136	135	134	132	131	130	129	128	127	125	124	123	122	121