Australian Government
Department of Industry, Science, Energy and Resources

Methodology for the 2021 projections

Australia's emissions projections incorporate a variety of data inputs, assumptions and methods. This methodology document outlines how the Department of Industry, Science, Energy and Resources (the department) has estimated the 2021 projections of greenhouse gas (GHG) emissions.

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.

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.

Paris agreement update to global warming potential for emissions estimation

The emissions projections have been prepared with the 100-year time horizon global warming potential (GWP) values from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) to estimate emissions, consistent with rules adopted under the UN Framework Convention on Climate Change (UNFCCC) Paris Agreement (Decision 18/CMA.1 Annex 2.D Paragraph 37) for the estimation and reporting of national greenhouse gas emissions.

As greenhouse gases vary in their radiative efficiency, and in their atmospheric residence time, converting emissions into CO_2-e provides a standard unit of measurement of the quantity of greenhouse gases in terms of their impact on climate change.

Prior to the 2021 emissions projections report, the emissions projections were prepared with 100-year time horizon GWP values from the IPCC fourth assessment report in accordance with previous UNFCCC decisions. The table below compares the 100-year GWPs from the IPCC fifth (IPCC 2013) and fourth assessment reports (IPCC 2007).

Table 1: Comparison of the IPCC Fifth and Fourth Assessment Reports' 100-year GWPs

Major greenhouse gases	4th Assessment Report GWP	5th Assessment Report GWP
Carbon dioxide (CO_2)	1	1
Methane (CH_4)	25	28
Nitrous oxide (N_2O)	298	265
Perfluorocarbon - CF_4	7,390	6,630
Perfluorocarbon – C_2F_6	12,200	11,100
HFC-23	14,800	12,400
HFC-32	675	677
HFC-41	92	116
HFC-43-10mee	1,640	1,650
HFC-125	3,500	3,170
HFC-134	1,100	1,120
HFC-134a	1,430	1,300
HFC-143	353	328
HFC-143a	4,470	4,800
HFC-152	53	16
HFC-152a	124	138
HFC-161	12	4
HFC-227ea	3,220	3,350
HFC-236cb	1,340	1,210
HFC-236ea	1,370	1,330
HFC-236fa	9,810	8,060
HFC-245ca	693	716
HFC-245fa	1,030	858
HFC-365mfc	794	804
Sulphur hexafluoride (SF_6)	22,800	23,500

Electricity

The *electricity sector* emissions projections have been prepared using external modelling by ACIL Allen for the National Electricity Market (NEM), Wholesale Electricity Market (WEM) and minor grids, and the department's internal modelling for off-grid electricity generation.

Modelling approach

NEM, WEM and minor grids

ACIL Allen used PowerMark, ACIL Allen's proprietary market simulation model to project emissions from Australia's electricity grids to 2030. PowerMark is a simulator that emulates the settlements mechanism of the NEM and WEM. PowerMark uses a linear program to settle the market, as does AEMO's Dispatch Engine in its real time settlement process. ACIL Allen's own, simpler internal models, were used to model the minor grids. PowerMark constructs a set of offer curves that match bidding behaviour to match demand and determine dispatch through the market clearing rules. Bidding behaviour for generators accounts for optimising portfolios' positions in the market.

Demand is included as an exogenous assumption and presented to the market. Generator portfolios compete against this demand for dispatch. PowerMark resolves to match this demand at hourly resolutions across the entire projections period.

PowerMark is part of an integrated suite of modelling software that also induces new entrant generators under market and policy settings, including renewable energy targets. The modelling suite takes account of numerous parameters and constraints in the electricity markets, including weather, unplanned outage events and network utilisation and generation capacity constraints.

New large interconnector projects in the NEM are exogenous inputs into the model, in line with the central development pathway under AEMO's Integrated System Plan (AEMO 2020a), 2021-21 Inputs, Assumptions and Scenarios (AEMO 2021a) and advice from the department.

Off-grid

The department undertook modelling of emissions from Australia's off-grid electricity networks. Off-grid refers to all other locations where small electricity networks operate, this can include 'microgrids'. Off-grid electricity demand is predominantly from industrial users from mining and liquefied natural gas (LNG) production.

Off-grid electricity emissions are calculated with 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 *fugitives sector* modelling and electricity use assumptions based on information reported by facilities under the National Greenhouse 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 renewable technology in the form of solar generation.

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

$E_t = \sum ([EF_{it} \cdot EC_{it} \cdot P_{it}])$

Where:
E_t *= 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)*

$$E_t = \sum ([\ Ef_i \cdot Fc_i \cdot G_{it}\ ])$$

Where:
E_t *= annual emissions in year t (Mt* CO_2*-e)*
Ef = 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)*

Electricity demand

NEM and WEM

Forecasts of electricity demand are a key input into the *electricity sector* emissions projections. The department has sourced data from the AEMO's Electricity Statement of Opportunities (ESOO) reports (AEMO 2020b; AEMO 2021b) to inform electricity demand projections for the NEM and the WEM. The demand scenario that was included in the projections was the ESOO 2020 central scenario. This includes AEMO's forecasts for energy efficiency. The projections further include savings from energy efficiency measures announced under the Climate Solutions Package and measures announced in the 2020–21 and 2021–22 Budget.

The electricity emissions projections include consumption of electricity from electric vehicles consistent with estimates in the *transport sector*.

Small grids and off-grid

Data and information from the Utilities Commission of the Northern Territory (NT Utilities Commission 2020) which include demand forecasts by AEMO for the commission, and trends from ACIL Allen's analysis are used in the minor grids of the DKIS and NWIS, respectively.

Off-grid demand is derived using production estimates of LNG in line with assumptions in the *fugitives sector*, and estimates under the report commissioned by the department from ABMARC (ABMARC 2019) on electrification opportunities in Australian mining.

Renewable capacity

The Clean Energy Regulator's pipeline of large-scale renewable projects has been adopted in the 2021 projections (CER 2021a), consistent with the CER's pipeline at July 2021. The pipeline provides renewable uptake to the early 2020s, after which new renewable capacity is induced by ACIL Allen's model.

The Clean Energy Regulator's modelling of rooftop solar is adopted in the projections (CER 2021b). These projections extend to 2026. After this period, the projections adopt growth rates from AEMO's

2021 Inputs, Assumptions and Scenarios workbook (central scenario) (AEMO 2021a), based on advice from the CER.

Table 2. 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
Small grids: **Darwin Katherine interconnected system** **North West interconnected system**	NT Utilities Commission Northern Territory Electricity Outlook Report, ACIL Allen analysis
Off-grid	LNG production consistent with production assumptions in the *fugitives sector*, ABMARC 2019.

Stationary energy

Emissions from the *stationary energy sector* are projected using modelling processes developed within the department. 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 the department. The structure of these models is provided in Table 3.

The production data for LNG is estimated at the facility-level as each facility has a different emissions intensities. Emissions intensities are calculated based on emissions reported through the National Greenhouse and Energy Reporting (NGER) scheme. The emissions intensity is updated yearly for each facility where new data is available.

Activity data

Activity data used in the stationary energy subsectors is presented in Table 3.

Emissions projections in the *stationary energy sector* are estimated using activity data from a range of sources including, Office of the Chief Economist (OCE) commodity forecasts (OCE 2021a; OCE 2021b), Australian Energy Update (DISER 2021c), AME Group's industry analysis, IBISWorld industry reports, AEMO's Gas Statement of Opportunities (GSOO) (AEMO 2020c; AEMO 2021c) and Merchant Research & Consulting Ltd Ammonia production forecast 2021. The emissions reductions from policies and measures announced in the 2020–21 and 2021–22 Budgets, Climate Solution package and the Emissions Reduction Fund (ERF) have been included.

Table 3. 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 National Greenhouse Energy Reporting scheme (NGER), various environmental impact studies	$E_t = \sum ([EF_{it} . P_{it}])$ *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 2020c, East Coast gas demand from AEMO 2021c, crude and condensate oil demand from OCE 2021a and OCE 2021b.	$E_t = E_{t-1} . \Delta$ Production *Where:* *E_t = emissions in year t (Mt CO_2-e)* *E_{t-1} = emissions in the previous year* *Δ Production = percentage change*

Emissions subsector	Activity data	Calculation method
Manufacture of solid fuels **(top down model)**	Iron and steel growth rates from OCE 2021a[1], OCE 2021b and AME Group's industry analysis	*in production between year t and year t-1*
Domestic gas production and distribution **(top down model)**	Western Australia gas demand from AEMO 2020c, east coast gas demand from AEMO 2021c.	
Petroleum refining **(top down model)**	Total refinery output from OCE 2021a, OCE 2021b. The announced closure of the Kwinana and Altona petroleum refineries is also accounted for in the model.	
Mining		
Coal mining **(top down model)**	Production data from the *coal fugitives sector,* technological improvement including fuel consumption savings and efficiency factors from ABMARC 2019	$E_t = (Fc_{t-1}. Ec. Ef. \Delta P)*(1- Eti_t)$ *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* *Δ P = percentage change in production between year t and year t-1* *Eti_t= emissions reduction (%) 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 2021a, OCE 2021b, AME Group's industry analysis and derived proportion of the base year from NGER data, technological improvement including fuel consumption savings and efficiency factors from ABMARC 2019.	
Manufacturing **(top down model)**		
Non-ferrous metals (alumina; aluminium; refined nickel, copper, zinc, lithium, lead/ acid battery, battery recycling, recycled metal, and e-waste)	Production data from OCE 2021a, OCE 2021b, AME Group's industry analysis and derived proportion of the base year from NGER data, fuel savings and efficiency factors from Advisian 2020.	$E_t = Fc_{t-1}. Ec. Ef. Fs_t. \Delta P$ *Where:* *E_t = emissions in year t (Mt CO_2-e)* *Fc_{t-1} = fuel consumption in the previous year* *Ec= energy content of the fuel* *Ef= emissions factor of the fuel*

[1] Production data for most commodities are sourced from the OCE which is provided to 2026. Growth rates from AME Group's industry analysis have been used for 2027 and beyond.

Emissions subsector	Activity data	Calculation method
Non-metallic minerals (cement, lime, plaster and concrete; ceramics; glass and glass products and other)	IBISWorld industry reports analysis and Cement Industry Federation 2020; derived proportion of the base year from NGER data, fuel savings and efficiency factors from Advisian 2020.	*Fs=fuel saving estimates (due to fuel switching, technology and efficiency opportunities)* *ΔP = percentage change in production between year t and year t-1*
Iron and steel	Production data from OCE 2021a, OCE 2021b, and AME Group's industry analysis, fuel savings and efficiency factors from Advisian 2020.	
Pulp, paper and print	DISER 2021a, final data point (2021) held constant.	
Chemicals (other petroleum and coal product and basic chemical, chemical and plastic)	Merchant Research & Consulting Ltd Ammonia: Australia market outlook 2021 and derived proportion of the base year from NGER data, fuel savings and efficiency factors from Advisian 2020.	
Food processing, beverages and tobacco	n/a	10 year historical average emissions growth
Other manufacturing	n/a	
Buildings (top down model)		
Residential and commercial	AEMO 2020c, 2021c for annual gas consumption, DISER 2021c for wood and wood waste fuel use, DISER 2021b for derived proportion of emissions from wood biomass and others The share of the residential and commercial buildings emissions for the year 2021 and 2022 have been adjusted to consider the impacts of COVID-19.	$E_{t=} E_{wt+} E_{ot}$ $E_{wt} = E_{wt-1} . \Delta$ Consumption $E_{ot} = E_{ot-1} . \Delta$ 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* *Eo/w_{t-1} = emissions in the previous year from consumption of wood or other fuels* *Δ Demand = percentage change in gas consumption in commercial /residential buildings between year t and year t-1* *Δ Consumption = percentage*

Emissions subsector	Activity data	Calculation method
		change in wood consumption between year t and year t-1
Construction	Activity data from Australian Construction Industry Forum (ACIF) 2021.	$E_t = E_{t-1} \cdot \Delta$ Activity *Where:* E_t *= emissions in year t (Mt* CO_2*-e)* E_{t-1} *= emissions in the previous year* *Δ Activity = percentage change in activity between year t and year t-1*
Agriculture, forestry and fishing **(top down model)**	Farm production data from ABARES 2021a and 2021b. Average rate of change in diesel consumption derived from NGER data.	$E_t = (E_{t-1} \cdot \Delta$ Production) * (1-Dcr) *Where:* E_t *= emissions in year t (Mt* CO_2*-e)* E_{t-1} *= emissions in the previous year* *Δ Production = percentage change in production between year t and year t-1* *Dcr=average rate of change in diesel consumption per unit of production* Emissions held constant at 2024 level.
Other (military) **(top down model)**	DISER 2021b	10 year average of historical emissions

Transport

The department commissioned Energeia Pty Ltd (Energeia) to undertake modelling of the transport sector in 2020 (Energeia 2020). The model outputs and methods used by Energeia formed the basis for the transport emissions trends in Australia's emissions projections 2021, with the exception of pipeline transport, which were based on projections of state-level natural gas consumption (AEMO 2021c) and production (OCE 2021a; OCE 2021b ; and Departmental analysis).

Energeia modelling

The transport sector emissions modelled by Energeia were based on interrelated projections of vehicle activity and vehicle fleet technology. These activity and fleet technology projections were segmented by state, mode/vehicle type, and fuel/engine type. Emissions were derived from the projections as the product of projected activity and projected emissions intensity for each of the transport sector segments. In 2021, the department made adjustments to these activity and technology projections, and in some cases made modifications to the original methodologies and assumptions to improve the way these variables are projected and to account for new projections in the key exogenous inputs (population and economic activity) for this modelling approach.

Activity projections

Projections of state-level passenger and freight activity formed the basis of activity projected at the mode and fuel/engine type level. These state-level activity projections were based on multiple linear regression-based forecasts using gross state product (GSP) and population projections provided by the department. Mode-level projections of transport activity were derived by applying the 10-year average trend in historic passenger and freight mode-shares to these regression-based projections of state-level passenger and freight activity. Mode-level activity was then subsequently allocated to fuel/engine type segments based on projections of the relative fuel/engine type population share of the relevant mode-level fleet segment. In 2021, the department recalculated these state-level passenger and freight activity projections using the relevant regression functions provided by Energeia. In lieu of the previously used population and GSP inputs the department used a series based on the more recent projections of population and GDP trends published by the department of the Treasury in the 2021 Intergenerational Report (Department of the Treasury 2021).

COVID-19 impact on transport activity

To account for the direct impact of COVID-19 on transport activity, mode-level activity projections were scaled by separately estimated annual activity impacts (estimated as a percentage of projected annual mode-level activity). These 'COVID impact' activity adjustments included an estimate to account for changes in the tendency of passengers to use certain transport modes (preference mechanism), and an estimate to account for the pandemic's impact on the economic structure of demand for transport services (economic mechanism).

The preference mechanism was originally calibrated using data on variables considered to be good proxies for passenger activity during the period of initial lockdowns and border closures in the first half of the 2020 calendar year. The economic mechanism was based off an analysis of reported revenue impacts on the various economic sectors in Australia and the input–output distribution of supply of transport services to these sectors. In 2021, the department updated the preference mechanism impacts to account for more recent proxy data.

Vehicle fleet technology projections

In 2020, Energeia provided the department with technology projections of vehicle sales and vehicle fleets, with the projections of sales acting as the primary input for the fleet projections. The vehicle sales technology projections were based on a technology adoption function, where technology shares would be proportional to projected model availability and the projected first year return-on-investment. A lagged version of projected model availability in the United States was adopted for Australia's model availability projection and return on investment was projected based on projections of changes in upfront price premiums, fuel prices, and vehicle registration and stamp duty concessions.

In 2021, the department took the detailed vehicle sales projections provided by Energeia in 2020 and used these as inputs for 2 fleet models, separately modelling fleet technology for light duty vehicles (passenger cars and light commercial vehicles) and all other vehicle types. The department removed the forecasts for uptake of fuel cell vehicles in the light duty segment based on announcements from vehicle manufacturers who are prioritising the development of new battery electric rather than fuel cell vehicles.

The fleet model for non-light duty vehicle types was structurally the same as that used by Energeia in 2020, where fleet segments were assumed to have a constant attrition rate, and retired vehicles were replaced by the new uptake projected in the sales forecasts. Fleet-level emissions intensity was assumed to improve at a fixed rate (Table 4). The department modified this model to update the originally assumed fleet attrition rates, and the assumed, top-down emissions intensity improvement rates.

The fleet model adopted for light duty vehicles took a vehicle vintage approach, where individual vehicle vintages could be modelled separately, allowing for a more realistic simulation of vehicle attrition and the consequent effect on fleet technology composition and average emissions intensity. The department calibrated the light duty vehicle vintage model based on advice provided by BITRE, and data reported in the ABS motor vehicle census (ABS 2021) and by the National Transport Commission (NTC 2020). The department assumed that the emissions intensity of new internal combustion engine vehicle segments would decline into the future at a rate of 0.9% per year in the baseline scenario (Table 5), based on forecasts published by Bloomberg New Energy Finance (BNEF 2021a).

Table 4. Assumed YoY fleet segment level emissions intensity (g CO2-e/km) and/or fuel intensity (Mj/km) reduction rates

Model type	Technology typeType	Baseline	High tech scenario
Motorcycles	ICE	1.2%	1.5%
Motorcycles	BEV, FCEV	2%	2.4%
Aviation, marine, articulated trucks, rigid trucks, buses	ICE	0.5%	0.6%
Aviation, marine, articulated trucks, rigid trucks, buses	BEV, FCEV	1%	1.2%

Table 5. Assumed YoY new segment-level light duty vehicle emissions intensity (g CO2-e/km) and/or fuel intensity (Mj/km) improvement rates

Technology Type	Baseline	High Tech Scenario
ICE	0.9%	1.1%
HEV, PHEV, BEV	1.4%	1.7%

Fugitive emissions from fuels

Emissions from the *fugitives sector* are projected using emission estimation models maintained and updated by the department 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

The department 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 which is dependent on the operational and geological characteristics of the mine.

$E_t = \sum ([P_{it} \cdot EI_i]) - Measures_t$

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 (for example forthcoming projects under the ERF and CSF) in year t (Mt CO_2-e)

The emissions intensity of coal mines includes all sources of fugitive emissions from vented methane and carbon dioxide, flaring and post mining. For operating mines the emissions intensity is sourced from the latest 4 years of national greenhouse gas inventory data which is based on company data reported under the National Greenhouse Energy Reporting (NGER) scheme. 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.

Activity data

Mine-by-mine production estimates for existing and new mines are informed by OCE for 2021-2026 (OCE 2021a; OCE 2021b) and AME Group estimates for 2027 onwards. Coal production is separately estimated for thermal and coking coal production at each mine.

Production from prospective new mines is scaled down so that total Australian production of thermal and coking coal is consistent with an estimate of total demand for Australian coal. This estimate utilises inputs from the IEA World Energy Outlook (IEA 2020), Bloomberg New Energy Finance's New Energy Outlook (BNEF 2021b) and departmental analysis. All prospective coal mines are scaled back at an equivalent rate, 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

Methane 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 2030.

$E_t = \sum ((ED_i \, . \, EF_i \, . \, (1 - F_{it})) - ER_{it})$

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 the mine i at a point in time since decommissioning. It is derived from the Emissions Decay Curves (see DISER 2021b).
F_{it} = fraction of mine i flooded at a point in time since decommissioning.
ER_{it} = quantity of methane emissions avoided by recovery at mine i in year t (Mt CO_2-e).

The model requires the methane 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* (DISER 2021b). Mine flooding rates are estimated based on the mine's water production region consistent with the national greenhouse gas inventory.

Activity data

Closure timing is informed by mine-by-mine projections provided by the OCE (2021a; OCE 2021b) and AME Group and is 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:

$E_t = \sum (Pr_t \, .(EI_{cp} + EI_{ct} + EI_{rs} + EI_f))$

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 2021 projections, the assumed growth is 3%.

$E_t = E_{t-1} . (1.03)$

Where:
Et= 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 sources for oil and gas fugitive emissions

Fugitive emissions source	Proxy indicator	Source
Oil - production	Crude oil and condensate production	OCE 2021a; OCE 2021b
Oil - transport	Crude oil and condensate production	OCE 2021a; OCE 2021b
Oil - exploration	Historical 10-year average of emissions from oil exploration	DISER 2021b
Oil - abandoned wells	3% growth in emission derived from historical growth in emissions	DISER 2021b
Oil refinery	Refinery output	OCE 2021a; OCE 2021b
Oil - flaring	Crude oil and condensate production	OCE 2021a; OCE 2021b

Oil exploration and abandoned wells fugitives emissions are 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.

Fugitive emissions from LNG facilities

Modelling approach

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

$E_t = \sum (P_{ti} . (EI_{vi} + EI_{fi} + EI_{oi})) - CCS_{ti}$

Where:
E_t = LNG fugitive emissions in year t (Mt CO_2-e)
P_{ti} = production at facility i in year t (Mt LNG)

$EIvi$ = venting emissions intensity at facility i (Mt CO_2-e/Mt LNG)
$EIfi$ = 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 where available.

Activity data

LNG Production projections for each facility are informed by estimates from the OCE (OCE 2021a; OCE 2021ba), AME Group, Wood Mackenzie and Bloomberg New Energy Finance. The projections consider committed and prospective additions and removals in capacity given the global outlook for LNG.

Fugitive emissions from domestic natural gas

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, 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.

$E_t = \sum([P_{it} \cdot EI_i]) - ERF_t$

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)
ERF_t = abatement from forthcoming ERF and CSF projects in year t (Mt CO_2-e)

The emissions intensities of processing, production, flaring and venting at basins across Australia have been 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 2021a; OCE 2021b) and AEMO (2021c; AEMO 2020c). For new gas developments, for example Beetaloo, production estimates are informed by production estimates from Rystad Energy. Emissions intensities for new gas developments are derived from environmental impact statements where available, state average emission intensities from the National Greenhouse Gas Inventory (DISER 2021b) and the CSIRO study of whole of life greenhouse gas emissions from the Surat Basin for the GISERA project (Heinz Schandl et al 2019).

Table 7. Summary of sources for gas fugitive emissions

Fugitive emissions source	Proxy indicator	Source
Distribution	Unaccounted for gas losses	AEMO 2021c
Exploration - flared	Total gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c,
Exploration - leakage - conventional	Conventional gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c,
Exploration - leakage - unconventional	Unconventional gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c,
Exploration - venting - completions - conventional	Conventional gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c,
Exploration - venting - completions - unconventional	Unconventional gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c,
Exploration - venting - workovers	Unconventional gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c,
Other – abandoned wells	Historical growth rate of emissions abandoned gas wells	DISER 2021b
Other – Post meter emissions	Derived total appliance in the commercial and residential sector, Vehicle stock projections, Industrial natural gas consumption	ABS 2021, Energy Consult 2015, 2020 electricity modelling outputs
Processing	Domestic gas production (conventional and unconventional)	OCE 2021a OCE 2021b, AEMO 2020c, AEMO 2021c, emission projections models for LNG
Production - offshore platforms	Number of shallow and deep offshore platforms	AME Group, Company Reports
Production - onshore gathering and boosting - conventional gas	Conventional gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c, emission projections models for LNG
Production - onshore gathering and boosting - unconventional gas	Unconventional gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c, emission projections models for LNG
Production - onshore wells - conventional gas	Conventional gas production	OCE 2021ab, OCE 2021b, AEMO 2020c, AEMO 2021c, emission projections models for LNG

Fugitive emissions source	Proxy indicator	Source
Production - onshore wells - unconventional gas	Unconventional gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c, emission projections models for LNG
Production - onshore wells - water production	Unconventional gas production	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c, emission projections models for LNG
Transmission and storage - LNG terminals	Number of LNG terminals operating	AEMO 2021c, 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 2021c, 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 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c,
Venting and flaring - venting - gas	Domestic gas production (conventional and unconventional)	OCE 2021a, OCE 2021b, AEMO 2020c, AEMO 2021c,

Industrial processes and product use

Emissions from the *industrial processes and product use sector* (IPPU) are projected using bottom-up models developed within the department. 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 are 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 2019* (DISER 2021b).

Activity data

Activity data used in the *industrial processes and product use* subsectors is presented in Table 8. Emissions projections in the *industrial processes and product use sector* are estimated using activity data from a range of sources including: Office of the Chief Economist's (OCE) commodity forecasts (OCE 2021a; OCE 2021b), AME Group's industry analysis, Merchant Research & Consulting Ltd Ammonia Production Forecast 2021, IBISWorld industry reports, and the Organisation for Economic Co-operation and Development's (OECD 2021). The emissions reductions from policies and measures announced in the 2021–22 Budget, and the Emissions Reduction Fund (ERF) have been included.

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 2019* (DISER 2021b).

Table 8. Summary of sources and formula for each IPPU subsector

Emissions subsector	Data source	Formula
Chemical industry		
Ammonia	Production data from Merchant Research & Consulting Ltd Ammonia: Australia Market Outlook 2021	$E_t = \sum([U_{ji} \cdot EC_j \cdot EF_j])$ *Where:* *E_t = emissions in year t (Mt CO_2-e)* *$U_{j,i}$ = 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	DISER estimates based on projected iron ore and coal production	$E_t = \sum([EF_{it} \cdot P_{it}])$ *Where:* *E_t = emissions in year t (Mt CO_2-e)* *EF_i = facility-specific emissions factor in year t* *P_{it} = nitric acid production at facility$_i$ in year t*

Emissions subsector	Data source	Formula
Titanium dioxide		$E_t = \sum([U_{jit} . EC_j . EF_j])$
Synthetic rutile	World GDP growth from the Organisation for Economic Co-operation and Development (OECD 2021)	*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 and Department of the Treasury 2021	$E_t = E_{t-1} . \Delta$ Population *Where:* *E_t = emissions in year t (Mt CO_2-e)* *$E_{,t-1}$ = emissions in the previous year* *Δ Population = percentage 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 2021a, OCE 2021b, and AME Group's industry analysis	$E_t = \sum([U_{jit} . EC_j . EF_j + (PFC_{t-1} . \Delta \text{Production})])$ *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* *Δ Production = percentage change in production between year t and year t-1*
Iron and steel production	Production data from OCE 2021a, OCE 2021b, and AME Group's industry analysis, fuel savings from Advisian 2020.	$E_t = \sum([EF_i . P_{it} - cs_{it}])$ *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* *cs_{it} = carbon content in steel at facility$_i$ in year t* Emissions are adjusted to account for switching from coke.

Emissions subsector	Data source	Formula
Ferroalloys production	Company statements	$E_t = \sum ([U_{jit} . EC_j . EF_j])$ *Where:* *Et = emissions in year t (Mt CO2-e)* *Ujit, = the use of fuel j as a reductant at facilityi in year t* *ECj = the energy content of fuel j* *EFj = the emissions factor of fuel j*
Other metal production (copper, nickel, silicon and lead)	Production data from OCE 2021a, OCE 2021b, and AME Group's industry analysis	$E_t = \sum ([U_{jit} . EC_j . EF_j])$ *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 **Lime**	Contextual production forecast from Cement Industry Federation and IBISWorld industry report	$E_t = \sum ([EF_i . P_{it}])$ *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*
Limestone and dolomite and other carbonates	DISER estimates based on projected ceramics, ferroalloy production, glass production, and iron and steel production. Zinc production data from OCE 2021a and 2021b, and AME Group's industry analysis	$E_t = E_{t-1} \; . \; \Delta$ Production *Where:* E_t *= emissions in year t (Mt* CO_2*-e)* E_{t-1} *= emissions in the previous year* *Δ Production = percentage change in production between year t and year t-1*
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	DISER 2021b	Based on National Inventory Report methodology

Emissions subsector	Data source	Formula
Other product manufacture and use		
Electrical equipment	DISER 2021b	Based on National Inventory Report methodology
SF_6 and PFCs from other product uses	Population forecasts from ABS 2018 and Department of the Treasury 2021	$E_t = E_{t-1} . \Delta$ Population *Where:* *E_t = emissions in year t (Mt CO_2-e)* *E_{t-1} = emissions in the previous year* *Δ Population = percentage change in population between year t and year t-1*
N_2O from product uses		
Other production	DISER estimates based on projected ammonia production and food, beverages & tobacco production	$E_t = E_{t-1} . \Delta$ Production *Where:* *E_t = emissions in year t (Mt CO_2-e)* *E_{t-1} = emissions in the previous year* *Δ Production = percentage change in production between year t and year t-1*

Agriculture

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

Modelling approach

Emissions from agricultural activity is calculated as:

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

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 in:

(kt/unit of activity/year)

(Gg/unit of activity/year for rice cultivation)

Table 9. Symbols used in algorithms

Symbol	Variable	Variable categories
K[2]	State	Australian Capital Territory, Northern Territory, Queensland, Tasmania, South Australia, New South Wales, Victoria, Tasmania, Western Australia
i[3]	Activity type	Grazing beef cattle, grain fed beef cattle, dairy cattle, sheep, wheat, rice, etc.
j[2]	Gas type	Methane, nitrous oxide, carbon dioxide
l[2]	Gas source	Enteric fermentation, manure management, rice cultivation, agricultural soils, field burning of agricultural residues, lime and urea application

[2] Different states, gas types and gas sources are not relevant to all activity types
[3] Activity types may contribute a number of different gas sources

The agriculture projections use emissions factors for activity consistent with the *National Inventory Report*. For formulas on calculating emissions intensity, please see the *National Inventory Report* (DISER 2021b).

The projections include abatement from agriculture projects such as beef cattle herd management and destruction of methane generated from manure in piggeries under the Emissions Reduction Fund and the Climate Solutions Fund.

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 as summarised in Table 10.

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) is a key data source to inform agricultural emissions projections. Where activity data is 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 has increased 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 where projected activity data is 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, with the exception of the climate variability built into the ABARES forecast, activity data has not been adjusted for future climate change conditions.

The projections also include a trend towards grain-fed beef cattle, as some farmers seek a more drought resistant feeding system. This trend affects the emissions intensity of beef cattle production. Grain-fed is more emissions intensive than grass-fed, as diets of grain-fed beef cattle are more energy intensive. Animals convert a portion of this additional energy to emissions in the gut.

Units of agricultural activity (for example, heads of cattle) are multiplied by relevant emissions intensities. Emissions intensity of activities are assumed to be constant across the projections period and equal to that reported in the final year of the *National Inventory Report* (DISER 2021b).

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

Table 10. Summary of principle data source for Agriculture

Commodity	Data sources	Unit of activity
Lime and urea	DISER estimate based on historical trends	Kilotonnes
Fertilisers	DISER estimate based on historical trends	Kilotonnes
Other animals	Activity held constant at final year of inventory	Heads of animal
Other animals - poultry	Australian Bureau of Agricultural and Resource Economics (ABARES) 2021a, ABARES 2021b OECD-FAO Agricultural Outlook 2021 DISER estimate based on historical trends	Heads of animal
Pigs	ABARES 2021a, ABARES 2021b Organisation for Economic Co-operation and Development - Food and Agriculture Organization	Heads of animal

Commodity	Data sources	Unit of activity
	(OECD-FAO) 2021 DISER estimate based on historical trends	
Crops	ABARES 2021a, ABARES 2021b, ABARES 2021c DISER estimate based on historical trends	Non-rice crops: Kilotonnes of crop Rice: Kilotonnes of rice, Hectares of area under cultivation
Sheep	ABARES 2021a, ABARES 2021b DISER estimate based on historical trends	Heads of animal
Dairy	ABARES 2021a, ABARES 2021b DISER estimate based on historical trends	Heads of animal
Grain-fed beef	ABARES 2021a, ABARES 2021b DISER estimate based on historical trends	Heads of animal
Grazing (grass-fed) beef	ABARES 2021a, ABARES 2021b DISER estimate based on historical trends	Heads of animal

Table 11. Summary of emission subsectors for each agricultural commodity

Commodity	Emissions subsectors
Lime and urea	Liming and urea application
Fertilisers	Agricultural soils
Other animals	Enteric fermentation Manure management Agricultural soils
Other animals - poultry	Manure management Agricultural soils
Pigs	Enteric fermentation Manure management

Commodity	Emissions subsectors
	Agricultural soils
Crops	Agricultural soils Field burning of agricultural residues Rice cultivation
Sheep	Enteric fermentation Manure management Agricultural soils
Dairy	Enteric fermentation Manure management Agricultural soils
Grain fed beef	Enteric fermentation Manure management Agricultural soils
Grazing beef	Enteric fermentation Manure management Agricultural soils

Waste

The *waste sector* emissions projections are prepared by the department, 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 department commissioned Blue Environment, supported by AECOM, to update the *waste sector* projections models in 2019. The model replicates the methods for historical emissions and was updated this year to apply Australia's *National Inventory Report 2019* (DISER 2021b). For the solid waste sector the modelling is completed on a site-specific basis to take account of the emission characteristics for individual landfills.

Solid waste deposited at landfills

For landfills, despite strong population growth, total disposal quantities have fallen over the last decade due to declining per capita rates. This trend is projected to continue to 2030.

Waste quantities are recorded and reported by source stream which consists of:

- municipal solid waste (MSW)
- commercial and industrial (C&I) waste
- construction and demolition (C&D) waste.

The projections take account of policies and measures at various levels of government including the National Food Waste Strategy (50% reduction in food waste per capita by 2030), which changes the mix of waste in the MSW and C&I waste streams. The Recycling Modernisation Fund (RMF) was also included to account for the $190 million in government funding to generate investment in recycling. The RMF aims at generating $600 million in private investment as part of the national resource recovery target of 80% by 2030. The fund is expected to divert over 10 million tonnes of waste from landfill.

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

Table 12. State and territory resource recovery targets[4]

	Year	All	MSW	C&I	C&D	Source
ACT	2025	80%	85%	90%	95%	ACT Government, 2011
NSW	2022		70%	70%	80%	NSW Environment Protection Authority, 2014

	Year	All	MSW	C&I	C&D	Source
Qld	2030		60%	60%	80%	Queensland Government, 2019
WA	2025	70%	65%	70%	75%	WA Waste Authority, 2018
	2030	75%	70%	75%	80%	

[4] Based on the National Waste Report 2020. Tasmania's recovery rate targets will be included in future projections after the *Draft Waste Action Plan (2019)* is finalised.

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 National Waste Policy modelling. The calculated waste recovery rates were then applied to waste generation estimates to calculate waste landfilled.

The projections include upcoming waste-to-energy facilities including 3 projects in Western Australia and one project in Victoria. In Western Australia, the Kwinana facility is expected to incinerate approximately 400,000 tonnes of waste each year and the East Rockingham facility is expected to process up to 330,000 tonnes of residual waste each year, reducing the amount of waste deposited at landfills. A smaller Renegi waste-to-energy demonstration project in Western Australia is expected to divert up to 4,000 tonnes of organic waste and 8,000 tonnes of forestry and agricultural waste annually from 2024. The Laverton North waste gasification to energy project in Victoria is expected to divert up to 210,000 tonnes of municipal solid waste annually from 2020. The combustion emissions from these facilities are counted in the *electricity sector*.

Waste generation and recovery were projected to calculate the amount of waste deposited at landfills. Growth rates for nation-wide waste generation and recovery were extracted from modelling undertaken in support of the National Waste Policy. The waste stream growth rates were applied to waste generated in for each state and territory.

Methane recovery rates 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 reflecting the characteristics of the landfill, including weather conditions. Future waste deposited is estimated on a state and territory basis 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 processed is projected for different sub-streams. The quantities of organic materials were assumed to change in proportion to changes in population or gross domestic product (GDP). Population growth rates were used to project quantities for organic materials generated mainly by people. These materials are garden organics, biosolids, oils, straw and others miscellaneous organics. GDP growth rates were used to project quantities for organic materials driven mainly by industry activity. These materials are commercial wood, sawdust, paunch and animal mortalities waste quantities.

Incineration

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

Domestic and commercial wastewater

Emissions are estimated separately for sewered and unsewered population which have different assumed Chemical Oxygen Demand (COD).

The unsewered COD per capita ratio was applied to a projection of the unsewered population in each state and territory. Emissions were calculated based on the inventory methane emissions factor and the percentage of wastewater anaerobically treated (5%).

The sewered COD per capita was applied to the population in each state and territory. COD flows were used to estimate emissions from domestic and commercial wastewater facilities. COD influent refers to COD entering the wastewater facility in wastewater. COD outflows 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 were projected using ratios to COD influent. The ratios are a national average and based on the latest inventory data. COD outflows were 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 outflows to COD influent remains constant over the projection timeframe.

The methane generated was calculated using the following formulas:

methane generated from wastewater = (COD influent – COD removed as sludge – COD discharged as effluent) x methane correction factor x methane emissions factor

methane generated from sludge = (COD removed as sludge – COD removed to landfill or other landsite) x methane correction factor x methane emissions factor.

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

Nitrous oxide emissions were calculated by replicating the same assumptions and calculations used to project methane from the sewered population. However, nitrous oxide emissions did not include any greenhouse gas recovery and are applied to the entire Australian population rather than to the sewered proportion.

Industrial wastewater

Industrial wastewater emissions are projected for the following sub-sectors: 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 were based on changes to commodity production levels. Growth rates were based on long-term forecasts using sector-specific metrics.

Inclusion of Emissions Reduction Fund and Climate Solutions Fund waste projects

The solid waste projection includes all existing methane recovery projects under the Emissions Reduction Fund. The solid waste and wastewater projections include additional abatement (for example, capture of methane at landfills) induced by the Climate Solutions Fund that are additional to the business as usual scenario that was modelled.

Land use, land use change and forestry

Modelling approach

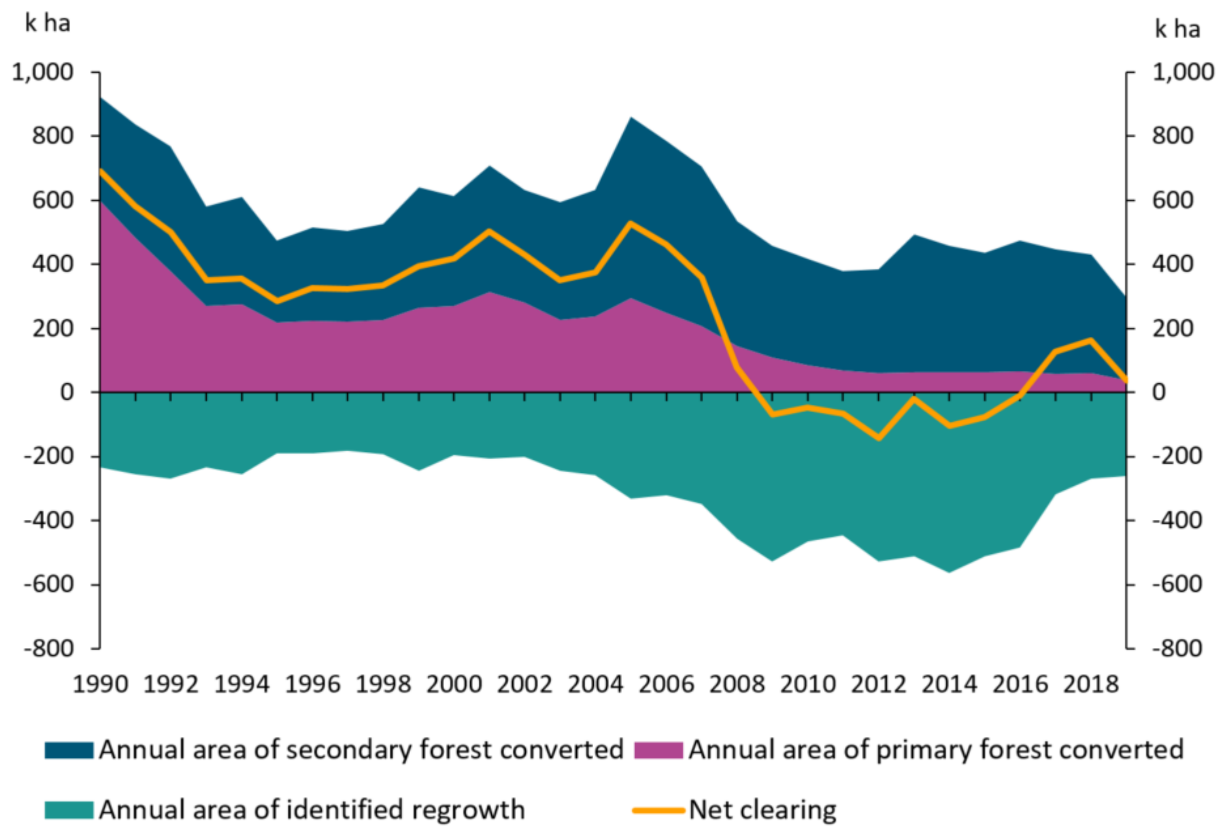
The Full Carbon Accounting Model (FullCAM) provides the modelling framework for estimating land sector emissions in the national greenhouse gas inventory and the emissions projections. FullCAM models the exchange of carbon between the terrestrial biological system and the atmosphere in a full/closed 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. For more information, a detailed description of the model is provided in the *National Inventory Report* (DISER 2021b, Appendix 6.B).

Activity data

Most forest conversion activity in Australia is for the purpose of maintaining pastures for grazing activities. Some forest conversion does occur to support cropping as well as smaller quantities for settlements, infrastructure and reservoirs.

Most clearing activity in Australia is associated 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 1).

Figure 1: Historical land clearing activity, 1990 to 2019, k ha



For the 2021 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 the *Outlook Scenarios for Australia's Forestry Sector: Key Drivers and Opportunities* (ABARES 2015).

The projections include abatement from vegetation, soil carbon and savanna burning projects under the Emissions Reduction Fund and the Climate Solutions Fund.

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.

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