Australian Government
Department of the Environment and Energy

METHODOLOGY FOR THE 2019 PROJECTIONS

Australia's emissions projections incorporate a variety of data inputs, assumptions and methods. This methodology document outlines how the Department of the Environment and Energy (the Department) has estimated the 2019 projections of greenhouse gas (GHG) emissions.

The 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 are consistent with Australia's national greenhouse gas inventory.

Greenhouse gas emission estimates are expressed as the carbon dioxide equivalent (CO_2-e) using the 100 year global warming potentials in the Intergovernmental Panel on Climate Change's *Fourth Assessment Report* (IPCC 2007). As greenhouse gases vary in their radiative activity, and in their atmospheric resistance time, converting emissions into CO_2-e allows the integrated effect of emissions of the various gases to be compared.

Australia's emissions projections include:

- historical emissions data taken from the *National Inventory Report*, released in April 2019 (DoEE 2019)
- sector-specific emissions estimation processes.

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.

The 2019 projections have been scaled to the *National Greenhouse Gas Inventory, June Quarter 2019* (DoEE 2019a). Scaling is done as shown below:

Scaled value E_t = Inventory value $E_{(2019)}$ x Modelled value E_t / Modelled value $E_{(2019)}$

Where E_t = emissions in year t from the given subsector (Mt CO_2-e)

$E_{(2019)}$ = emissions in the base year (2019).

Sector specific methodologies are discussed in greater detail below.

The 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.

Electricity

The *electricity sector* emissions projections have been prepared using external modelling by Jacobs Australia 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

Jacobs Australia used Plexos, a market simulation model developed by Energy Exemplar, to project emissions in the NEM, WEM and minor grids to 2030. Plexos is a simulator that emulates the settlements mechanism. This model optimises dispatch using the same techniques that are used by AEMO to clear the NEM and WEM (and other grids) and incorporates Monte-Carlo forced outage modelling. It also uses mixed integer linear programming to determine an optimal long-term generation capacity expansion plan. Plexos is part of an integrated suite of models that include long-term planning for optimisation of generation new builds and market dispatch, supported by Jacobs Australia's proprietary model for Large Generation Certificates (LGCs). Demand is included in the model as an exogenous assumption and presented to the market. Generator portfolios compete against this demand for dispatch.

Plexos accounts for the economic relationships between generating plants in the system. In particular, the model calculates production of each power station given the availability of the station, the availability of other power stations and the relative costs of each generating plant in the system.

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 two 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. The second is a top-down model that is driven by demand growth in the overall subsector and the uptake of renewable technology in the form of solar generation.

For off-grid generation, emissions are calculated by:

$$E_t = \sum([G_{it} \, . \, EI_{ijt}])$$

Where:
E_t = annual emissions in year t (kt CO_2-e)
G_{it} = electricity generation by $fuel_i$, in year t (GWh)
EI_{ij} = the emissions intensity of generation by $fuel_i$ at $grid_j$, in year t (t CO_2-e/MWh coal)

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 2019; AEMO 2019a) to inform electricity demand projections for the NEM and the WEM. The demand scenario that was included in the projections was the ESOO 2019 central scenario.

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 2019) which include demand forecasts by AEMO for the Commission, and trends from the WEM ESOO are used in the minor grids of the DKIS and SWIS, respectively.

Off-grid demand is derived using production estimates of LNG in line with assumptions under the *fugitives sector*, and estimates under the report commissioned by the Department from ABAMRC (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 2019 projections (CER 2019). The pipeline provides renewable uptake to the early 2020s, after which new renewable capacity is induced by the Plexos model.

The Clean Energy Regulator's modelling of rooftop solar is adopted in the projections (CER forthcoming). These projections extend to 2024. After this period, the projections adopt growth rates from AEMO's high DER rooftop solar projections under the ESOO 2019 (AEMO 2019).

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
Small grids: Darwin Katherine interconnected system North West interconnected system	NT Utilities Commission 2019 annual report, AEMO Electricity Statement of Opportunities for the WEM
Off-grid	LNG production consistent with production assumptions in the *fugitives sector*, ABMARC 2019

Direct combustion

Emissions from the *direct combustion sector* are projected using modelling processes developed within the Department. Projections are aggregated from six subsectors: energy, mining, manufacturing, buildings, agriculture, forestry and fishing and other (which is solely fuel used by military vehicles within Australia).

Modelling approach

Direct combustion 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 2.

The production data for LNG is estimated at the facility-level as each facility has a different emissions intensity. Where sufficient historical data is available, emissions intensities are calculated based on emissions reported through the National Greenhouse and Energy Reporting scheme. For new LNG projects, information provided in Environmental Impact Statements are used to calculate the emissions intensity. The emissions intensity is updated yearly for each facility where data is available and is assumed to be constant across the projections period.

Activity data

Activity data used in the direct combustion subsectors is presented in Table 2.

Emissions projections in the *direct combustion sector* are estimated using activity data from a range of sources including, Office of the Chief Economist (OCE) commodity forecasts (OCE 2019; OCE 2019a), Australian Energy Update (DoEE 2019b), AME Group's industry analysis, IBISWorld industry reports, AEMO's Gas Statement of Opportunities (GSOO) (AEMO 2018; AEMO 2019b) and Merchant Research & Consulting Ltd Ammonia production forecast 2019.

Table 2. Summary of activity data and calculation methods for each direct combustion subsector

Emissions subsector	Activity data	Calculation method
Energy		
LNG (facility level model)	Production data from the *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 2018, East Coast gas demand from AEMO 2019b, crude and condensate oil demand from OCE 2019, 2019a.	$E_t = E_{t-1} \, . \, \Delta \, Production$ *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*
Manufacture of solid fuels (top down model)	Iron and steel growth rates from OCE 2019[1], OCE 2019a and AME Group's industry analysis	
Domestic gas production and distribution (top down model)	Western Australia Gas demand from AEMO 2018, East Coast gas demand from AEMO 2019b.	
Petroleum refining (top down model)	Total refinery output from OCE 2019, 2019a.	
Mining		
Coal mining (facility level model)	Production data from the *fugitives sector,* technological improvement including fuel consumption savings and efficiency factors from ABMARC 2019	$E_t = (E_{t-1} \, . \, \Delta \, Production)*(1-Eti_{t})$ *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* *Eti_t= emissions reduction from technological improvement in coal mining/ other mining in year t*

[1] Production data for most commodities are sourced from the OCE which goes out to 2024. Growth rates from AME Group's industry analysis have been used for 2025 and beyond.

Emissions subsector	Activity data	Calculation method
Other mining (iron ore; gold; copper; nickel; zinc; bauxite lithium , and manganese) (top down model)	Production data from OCE 2019, OCE 2019a, 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 and lead/ acid battery)	Production data from OCE 2019, OCE 2019a, AME Group's industry analysis and derived proportion of the base year from NGER data	$E_t = E_{t-1} . \Delta Production$ *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-metallic minerals (cement, lime, plaster and concrete; ceramics; glass and glass products and other)	IBISWorld industry reports analysis and derived proportion of the base year from NGER data	
Iron and steel	Production data from OCE 2019, OCE 2019a, and AME Group's industry analysis	
Pulp, paper and print	DoEE 2019a, final data point held constant.	
Chemicals (other petroleum and coal product and basic chemical, chemical and plastic)	Merchant Research & Consulting Ltd Ammonia: Australia market outlook 2019 and derived proportion of the base year from NGER data	
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	AEMO 2018, 2019b for annual gas consumption, DoEE 2019b for wood and woodwaste fuel use, DoEE 2019 for derived proportion of emissions from wood biomass and others The final numbers have been adjusted to incorporate energy efficiency improvements from the Climate Solutions Package.	$E_{t} = E_{wt} + E_{ot}$ $E_{wt} = E_{wt-1} \cdot \Delta$ *Consumption* $E_{ot} = E_{ot-1} \cdot \Delta$ *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 change in wood consumption between year t and year t-1*
Construction	Activity data from ACIF 2019	$E_t = E_{t-1} \cdot \Delta$ *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 2019 and 2019a. Average rate of change in diesel consumption derived from NGER data.	$E_t = (E_{t-1} \cdot \Delta \text{ Production}) * (1-Dcr)$ *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)	DoEE 2019, 2019b	10 year average of historical emissions

Transport

The Department commissioned the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to undertake modelling of the *transport sector* in 2018.

The transport projections have been developed to reflect current policies and measures. The policies impacting the *transport sector* that were included are:

1. Commonwealth fuel excise,
2. New South Wales and Queensland biofuels mandates, and
3. Commonwealth Emissions Reduction and Climate Solutions Fund.

Modelling approach

Modelling of transport emissions involves three models:

- the Adoption model
- the Demand model
- the Australian-TIMES (Aus-TIMES) model.

The Adoption model

The Adoption model takes vehicle costs together with demographic information to determine the future share of electric, fuel cell and autonomous vehicles. The model assumes that investment decisions are driven by a combination of price and non-price drivers so that adoption will broadly follow the consumer technology adoption curve. The adoption curve is calibrated to appropriate spatial scales (due to differing demographic characteristics and travel needs) and across different customer segments (fleet purchasing behaviour and vehicle utilisation).

The Demand model

The Demand model uses information of Gross Domestic Product, population, mode share and the cost of travel to determine projected activity for passenger and freight transport. Future mode share assumptions are developed based on observation of historical trends and consideration of the future of cities in Australia. This includes specific government programs to extend airports, rail and road infrastructure.

The Aus-TIMES model

The activity and sales of alternative vehicle projections from the Adoption and Demand models are then provided to the Aus-TIMES model which calculates least cost fuel and vehicle fleet changes to meet activity. Aus-TIMES is a partial equilibrium ('bottom-up') model, implemented as a linear program optimisation. The model has a robust economic decision making framework that incorporates the cost of alternative fuels and vehicles, as well as detailed characterisation of fuel and vehicle technical performance, including fuel efficiencies and emission factors by transport mode, vehicle type, engine type and age.

The Aus-TIMES transport model includes:

- coverage of all states and territories
- four broad transport modes: road, rail, aviation and shipping

- ten road transport modes: motorcycles; small, medium and large passenger cars; small, medium and large commercial vehicles; rigid trucks; articulated trucks and buses
- five road engine types: internal combustion; hybrid electric/internal combustion; hybrid plug-in electric/internal combustion; fully electric and fuel cell
- fourteen road transport fuels: petrol; diesel; liquefied petroleum gas (LPG); natural gas (compressed (CNG) or liquefied (LNG)); petrol with 10% ethanol blend; diesel with 20% biodiesel blend; ethanol and biodiesel at high concentrations; gas to liquids diesel; coal to liquids diesel with upstream CO_2 capture; shale to liquids diesel with upstream CO_2 capture, hydrogen (from renewables) and electricity
- all road vehicles are assigned a vintage based on when they were first purchased or installed in annual increments
- time is represented in annual frequency (2015, 2016 etc.).

Table 3. Input and data sources for the transport sector model

Input	Data source
Fuel consumption	Table F of the Australian Energy Update 2018 (DoEE 2018)
Oil prices	The oil price projections are informed by the Office of the Chief Economist and the United States Energy Information Administration (EIA 2018)

Key outputs of the modelling include:

- fuel and engine technology uptake
- fuel consumption
- greenhouse gas emissions
- demand for transport services.

During 2019, separate analysis and modelling was commissioned from Keypath Consulting in alliance with Ndevr on the uptake of electric trucks and buses in Australia.

The investigation was completed via the conduct of three discrete but interconnected stages of work.

- Research and Industry Consultation
- Construction and Validation of Forecasts
- Study Report

The modelling took account of a range of uptake drivers including:

- current and near-term availability of electric trucks and buses;
- Government policy and programmes promoting electric vehicle adoption;
- battery charging infrastructure;
- battery technology development;
- technology competition;
- autonomous and semi-autonomous vehicle operation; and
- fuel price movements.

The modelling forecast high uptake of electric buses in urban operations, moderate uptake of electric rigid trucks in urban operations and low uptake of electric trucks and buses for interstate operations and for all operations of articulated trucks.

The CSIRO results for fuel and technology uptake and greenhouse gas emissions were adjusted to incorporate these results.

Fugitives

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.

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

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)
ERF_t = abatement from forthcoming ERF and CSF projects 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 two 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 emissions intensity is sourced from Environmental Impact Statements or is the average for currently operating mines in the same coal basin.

The Emissions Reduction Fund has contracted abatement from coal mine waste gas capture projects. Abatement from projects are subtracted from the coal fugitives projection.

Activity data

Mine-by-mine production estimates for existing and new mines are informed by the OCE and AME Group estimates. Production is separately calculated for thermal and coking coal production at each mine.

Production from prospective new mines is scaled down so that total Australian production is equal to International Energy Agency (IEA) estimates. The IEA supplies the Department with projections of Australian thermal and coking coal production consistent with the Stated Policies Scenario in the *2019 World Energy Outlook* (IEA 2019). 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.

<u>*Abandoned coal mines*</u>

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)
EDi = annual emissions of mine i in the year before decommissioning d (Mt CO_2-e)
EFi = emission factor for the mine i at a point in time since decommissioning. It is derived from the Emissions Decay Curves (see DoEE 2019).
Fit = fraction of mine i flooded at a point in time since decommissioning.
ERit = quantity of methane emissions avoided by recovery at mine i in year t (Mt CO_2-e).

The model requires the 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* (DoEE 2019). 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 and AME Group and is consistent with the operating coal mines model.

Oil and gas fugitives

<u>*Oil*</u>

Oil fugitive emissions are separated into five subsectors:

- Refining;
- Flaring;
- Production;
- Exploration; and
- Transport.

Modelling approach

Oil fugitive emissions projections are calculated using the following algorithm:

$E_t = E_{t-1} \,.\, Pr_t / Pr_{t-1}$

Where:
E_t = emissions in the year t (Mt CO_2-e)
E_{t-1} = emissions in the year t-1 (Mt CO_2-e)
Pr_t = proxy indicator in the projection year
Pr_{t-1} = proxy indicator in the year t-1

Activity data

Activity data used to estimate emissions from oil and gas fugitives is provided in Table 4.

Table 4. Summary of sources for oil and gas fugitive emissions

Fugitive emissions source	Proxy indicator	Source
Oil refinery	Refinery output	OCE 2019a
Oil - flaring	Crude oil and condensate production	OCE 2019a
Oil - production	Crude oil and condensate production	OCE 2019a
Oil - exploration	Historical 10-year average of emissions from oil exploration	DoEE 2019
Oil - transport	Crude oil and condensate production	OCE 2019a

Oil exploration emissions are small (<0.03 Mt CO_2-e) 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

Modelling approach

The Department maintains a facility-by-facility model of fugitive emissions from LNG. Emissions depend on 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)
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 new facilities emissions intensities are sourced from Environmental Impact Statements or other sources. The projected emissions intensities take account of changes in feed gas source.

Activity data

Production projections of each facility are informed by estimates from the OCE (OCE 2019a), AME Group, Wood Mackenzie and Lewis Grey Advisory (Lewis Grey Advisory 2017). 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, production and processing, transmissions, distribution, venting and flaring. Emissions are separated into twenty subsectors. Proxy indicators are used to project the growth in emissions at the state level from the subsectors as listed below.

$$E_t = E_{t-1} . Pr_t / Pr_{t-1}$$

Where:
E_t *= emissions in the year t (Mt* CO_2*-e)*
E_{t-1} *= emissions in the year t-1 (Mt* CO_2*-e)*
Pr_t *= proxy indicator in the projection year*
Pr_{t-1} *= proxy indicator in the year t-1*

Table 5. Summary of sources for gas fugitive emissions

Fugitive emissions source	Proxy indicator	Source
Distribution	Unaccounted for gas losses	AEMO 2019b
Exploration - flared	Total gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Exploration - leakage - conventional	Conventional gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Exploration - leakage - unconventional	Unconventional gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Exploration - venting - completions - conventional	Conventional gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Exploration - venting - completions - unconventional	Unconventional gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Exploration - venting - workovers	Unconventional gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Processing	Total gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Production - offshore platforms	Number of shallow and deep offshore platforms	AME Group, Company Reports
Production - onshore gathering and boosting - conventional gas	Conventional gas production (excluding LNG)	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Production - onshore gathering and boosting - unconventional gas	Unconventional gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Production - onshore wells - conventional gas	Conventional gas production (excluding LNG)	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity

Fugitive emissions source	Proxy indicator	Source
Production - onshore wells - unconventional gas	Unconventional gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Production - onshore wells - water production	Unconventional gas production	OCE 2019a, AEMO 2019b, AEMO 2018, emission projections models for LNG and electricity
Transmission and storage - LNG terminals	Number of LNG terminals operating	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	AME Group, company reports
Transmission and storage - transmission	Total pipeline length	AEC 2018, company reports, Department of the Environment and Energy expert advice
Venting and flaring - flaring - gas	Domestic gas consumption	AEMO 2019b, AEMO 2018, emission projections models for electricity
Venting and flaring - venting - gas	Domestic gas consumption	AEMO 2019b, AEMO 2018, emission projections models for electricity

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 emissions intensity of production across facilities.

Modelling approach

A summary of data sources and model frameworks applied are provided in Table 6.

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 2017* (DoEE 2019).

Activity Data

Activity data used in the industrial processes and product use subsectors is presented in Table 6. 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 2019; OCE 2019a), AME Group's industry analysis, Merchant Research & Consulting Ltd Ammonia Production Forecast 2019, IBISWorld industry reports and the Organisation for Economic Co-operation and Development's (OECD) real GDP long-term forecast.

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 2017* (DoEE 2019).

Table 6. 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 2019	$E_t = \sum([U_{ji} \,.\, EC_j \,.\, EF_j])$ *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	DoEE estimates based on projected iron ore and coal production	$E_t = \sum([EF_{it} \,.\, P_{it}])$ *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
Titanium dioxide	World GDP growth from the Organisation for Economic Co-operation and Development (OECD 2019)	$E_t = \sum([U_{jit} \,.\, EC_j \,.\, EF_j])$ *Where:* E_t = emissions in year t (Mt CO_2-e) $U_{jit,}$ = the use of fuel j at facility$_i$ in year t EC_j = the energy content of fuel$_j$ EF_j = the emissions factor of fuel$_j$
Synthetic rutile		

Emissions subsector	Data source	Formula
Acetylene	Population data from the Australian Bureau of Statistics 2018	*$E_t = E_{t-1} \, . \, \Delta$ 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 2019, OCE 2019a, and AME Group's industry analysis	*$E_t = \sum([U_{jit} \, . \, EC_j \, . \, EF_j + (PFC_{t-1} * \Delta$ 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 2019, OCE 2019a, and AME Group's industry analysis	*$E_t = \sum([EF_i \, . \, P_{it} - cs_{it}])$* *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} = deduction for carbon content in steel at facility$_i$ in year t*
Ferroalloys production	Company statements	*$E_t = \sum([U_{jit} \, . \, EC_j \, . \, EF_j])$* *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 $_j$*
Other metal production (copper, nickel, silicon and lead)	Production data from OCE 2019, OCE 2019a, 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 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	DoEE estimates based on projected ceramics, ferroalloy production, glass production, and iron and steel production. Zinc production data from OCE 2019a, 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	DoEE 2019	Based on *National Inventory Report* methodology
Other product manufacture and use		
Electrical equipment	DoEE 2019	Based on *National Inventory Report* methodology
SF_6 and PFCs from other product uses N_2O from product uses	Population data from the Australian Bureau of Statistics 2018	$E_t = E_{t-1} \,.\, \Delta\ Population$ *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*
Other production	DoEE 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 7. Symbols used in algorithms

Symbol	Variable	Variable categories
***K*[2]**	State	Australian Capital Territory, Northern Territory, Queensland, Tasmania, South Australia, NSW, Victoria, Tasmania
***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* (DoEE 2019).

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 8.

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, 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 (e.g. 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* (DoEE 2019).

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 8. Summary of principle data source for Agriculture

Commodity	Data sources	Unit of activity
Lime and urea	DoEE estimate based on historical trends	Kilotonnes
Fertilisers	DoEE estimate based on historical trends	Kilotonnes
Other animals	Activity held constant at final year of inventory	Heads of animal
Other animals - poultry	ABARES 2019, ABARES 2019a OECD-FAO Agricultural Outlook 2019-2028	Heads of animal
Pigs	ABARES Commodities: March quarter 2019, September quarter 2019 OECD-FAO 2019	Heads of animal

Commodity	Data sources	Unit of activity
Crops	ABARES 2019, ABARES 2019a CSIRO 2015 (CSIRO Land Use Trade-Offs (LUTO))	Non-rice crops: Kilotonnes of crop Rice: Kilotonnes of rice, Hectares of area under cultivation
Sheep	ABARES 2019, ABARES 2019a CSIRO 2015 (CSIRO LUTO)	Heads of animal
Dairy	ABARES 2019, ABARES 2019a CSIRO 2015 (CSIRO LUTO)	Heads of animal
Grain-fed beef	ABARES 2019, ABARES 2019a CSIRO 2015 (CSIRO LUTO)	Heads of animal
Grazing (grass-fed) beef	ABARES 2019, ABARES 2019a CSIRO 2015 (CSIRO LUTO)	Heads of animal

Table 9. 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 Agricultural soils
Crops	Agricultural soils Field burning of agricultural residues Rice cultivation
Sheep	Enteric fermentation Manure management Agricultural soils

Commodity	Emissions subsectors
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 five waste subsectors:

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

Modelling approach

During 2019, Blue Environment, supported by AECOM, were commissioned by the Department to update the *waste sector* projections models. The modelling replicated the methods for historical emissions applied in Australia's *National Inventory Report 2017* (DoEE 2019). For the solid waste sector the modelling was 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 per cent reduction in food waste per capita by 2030), which changes the mix of waste in the MSW and C&I waste streams. The projections also take account of commitments made by state and territory governments to reduce waste generation and increase recovery as outlined in Table 10 below. South Australia's target for 2020 was adjusted to avoid a rise from the recorded 2016-17 rates, as shown in the table.

Table 10. State and territory resource recovery targets

	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
Qld	2030		60%	60%	80%	Queensland Government, 2019
SA[1]	2020		70%	80%	90%	Green Industries South Australia, 2015
			62%	90%	87%	Adjusted target used in the modelling
WA	2025	70%	65%	70%	75%	WA Waste Authority, 2018
	2030	75%	70%	75%	80%	

1 Based on the National Waste Report 2018, SA's 2016-17 resource recovery rates were 59% for MSW, 90% for C&I and 84% for C&D

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.

A new waste-to-energy facility based in Kwinana, Western Australia is scheduled to open in 2022. The facility is expected to incinerate approximately 400,000 tonnes of waste each year, reducing the amount of waste deposited at landfills. Note the combustion emissions from this facility 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 2017-18 for each State and Territory.

Methane recovery rates were projected to increase by 0.25 per cent per year from 48 per cent in 2018 to 50 per cent in 2030. 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.

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.

Food waste was projected based on the National Food Waste Strategy target to reduce food waste landfilled by 50 per cent per capita by 2030. The model assumed reductions in food waste landfilled are diverted to biological treatment through improved collection services and processing facilities. The solid waste emission projections were used to calculate a national average of food organics landfilled per person (tonnes per capita).

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 per cent).

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.

Climate Solutions Fund

The solid waste and wastewater projections were adjusted to include additional abatement (e.g. 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* (DoEE 2019, Appendix 6.B).

Activity data

Key activity data include:

- The projected rates of primary clearing of forest lands and their conversion to croplands and grasslands are derived by performing a lagged regression using the farmers' terms of trade, as described in the *National Inventory Report* (DoEE 2019, Appendix 6.A.7). Projected rates of clearing of regrowth on previously cleared land - for example, management of bush encroachment on grazing land - are based on historical averages.
- 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). Projected changes in total forest cover, including regrowth on previously cleared land, are based on a gradual return to historical levels.

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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