



METHODOLOGY FOR THE 2017 PROJECTIONS

Australia's emissions projections incorporate a variety of key data inputs, assumptions and methods. This methodology document provides information on how the Department of the Environment and Energy (the Department) has estimated the 2017 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. The projections include estimates of abatement from policies and measures where appropriate.

Greenhouse gas emission estimates are expressed in terms of carbon dioxide equivalent (CO₂-e) using the 100 year global warming potentials contained 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 residence time, converting emissions into CO₂-e allows the integrated effect of emissions of the various gases to be compared.

Australia's emission projections includes the following elements:

- historical emissions data taken from the *National Inventory Report*, released in June 2017 (DoEE 2017)
- sector specific emissions estimation processes.

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

The 2017 projections have been scaled to the *National Greenhouse Gas Inventory, June Quarter 2017* (DoEE 2017b). Scaling is done as shown below:

Scaled value E_t = Inventory value $E_{(2017)}$ x Modelled value E_t / Modelled value $E_{(2017)}$

Where E_t = emissions in year t from the given subsector (Mt CO₂-e)

$E_{(2017)}$ = emissions in the base year (2017).

The methodology does not reflect all the data and processes involved in producing Australia's emissions projections. Constraints and sensitivities exist so specific inputs, such as facility level information, has not been included due to commercial-in-confidence company data considerations.

Sector specific methodologies are discussed in greater detail below.

Electricity

The *electricity sector* emissions projections have been prepared based on modelling and research commissioned by the Department and undertaken by Jacobs Australia (forthcoming). Abatement from the Emissions Reduction Fund (ERF) has been adjusted separately.

The Department has sourced data from the Australia Energy Market Operator (AEMO 2017; AEMO 2017a) to inform electricity demand projections for the National Electricity Market and Western Australia Wholesale Electricity Market. Data and information from the 2016 electricity emissions projections, the Northern Territory Utilities Commission Power System Review 2015–16 (NT Utilities Commission 2017), AGL and Ergon Energy have been used to inform electricity demand projections for the smaller grids and off-grid.

The electricity emissions projections are prepared using a model that simulates the electricity market. The model 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. The model represents major thermal, hydro and pumped storage resources in the market. Separate models are used for modelling the renewable energy market and uptake of small scale renewable technologies.

In addition the electricity emissions projections include consumption of electricity from electric vehicles consistent with estimates in the *transport sector*. Gas to electricity fuel switching estimates consistent with estimates in the *direct combustion sector* are also included.

Direct combustion

Emissions from the *direct combustion sector* are projected using bottom-up modelling. 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).

Direct combustion models are a combination of facility specific and top down models, depending on the nature of the emission source and the availability of data. The models are maintained and updated within the Department using external inputs including the National Greenhouse and Energy Reporting (NGER) data, Office of the Chief Economist's (OCE) commodity forecasts (OCE 2017; OCE 2017a), Australian Energy Update (DoEE 2017a), AME Group's industry analysis, IBISWorld industry reports and AEMO's National Gas Forecasting Report (NGFR) (AEMO 2016).

For most subsectors (i.e. mining, manufacturing, construction and some energy), emissions are projected to grow in line with an appropriate proxy such as production estimates from the base year emissions (2017). Historical trends are also used to inform growth where projected production data is unavailable (i.e. for agriculture, forestry and fishing and other subsectors).

The production data for Liquefied Natural Gas (LNG) is estimated at the facility-level, taken from the *fugitives sector*, as the facilities have different emissions intensities. For Queensland based facilities, assumptions on the direct gas use requirements for LNG are taken from *the 2016 Projections of Gas and Electricity Used in LNG*, prepared by Lewis Grey Advisory for AEMO (Lewis Grey Advisory 2016). For other projects, where sufficient historical data is available, emissions intensities are calculated based on the NGER data analysis. For new

LNG projects environmental impact statement (EIS) data is used to infer the emissions intensity. The emissions intensities are assumed to be constant across the projections period.

For the coal mining subsector, facility-level production data from the *fugitives sector* is used to inform *direct combustion* emissions. For the other mining subsector, emissions are further broken down into different commodities such as iron ore, gold, copper, nickel ore, zinc, bauxite and manganese. These commodities are projected to grow at different rates over the projections period. The base year emissions are not reported at this granular level in *National Greenhouse Gas Inventory, June Quarter 2017* (DoEE 2017b) and hence need to be broken down into these categories to apply the different growth rates. The proportion of the base year emissions are estimated from the NGER data.

Similar methodology is applied to the manufacturing categories: non-ferrous metals, non-metallic minerals and chemicals. For ceramics (glass and glass products, pulp, paper and print and basis chemicals) a zero growth rate is applied. This is based on the analysis of industry outlook from the IBISWorld industry reports. These industries have experienced limited growth in the past and the short-term forecasts are either expected to decline or remain constant at current levels. Following review of these factors, projections apply a zero growth rate.

For food processing, beverages and the tobacco industry, IBISWorld industry reports indicate modest growth over the next five years through to 2023. This is underpinned by higher domestic consumption and a growing middle class in Asia that demands Australian food products. However, emissions aren't expected to grow at the same rate as activity, due to the decoupling of economic activity from emissions observed over the past few years. Therefore, a 10-year historical average is used to inform this subsector projections.

Emissions from the residential and commercial subsectors are based on the 2016 ClimateWorks Australia report on *Gas-Electricity Substitution Projections to 2050* (ClimateWorks Australia 2016). The results take into account fuel switching from gas to electric hot water systems and heating ventilation and air conditioning (HVAC) appliances and improved energy efficiency of new buildings and appliances.

This analysis looks at demographic factors (such as household income and ownership), cost of installation, energy costs and improved efficiency of electric appliances over time to inform fuel switching. The uptake of technology is based on an S-curve or logistic function, which assumes that in the year in which electrification becomes attractive 50 per cent of eligible households will switch.

The assumptions underpinning the model were updated to account for the latest energy consumption data from Table F of the Australian Energy Update (DoEE 2017a), latest cost assumptions for installing new appliances from the Equipment Energy Efficiency program, electricity prices which are consistent with those used in the *electricity sector*, and gas prices consistent with the neutral scenario of the NGFR (AEMO 2016).

Emissions from the construction subsector are based on the growth rate of activity invested in the construction industry. This data is sourced from the Australian Construction Industry Forum's *Australian Construction Market Report May 2017* (ACIF 2017).

Emissions from the agriculture, forestry and fishing sector are projected to grow in line with increased diesel use in the *agriculture sector*, based on the historical trends. The model determines future diesel use based on the historical diesel use from the *Australian Energy Update* (DoEE 2017a).

Table 1. Summary of sources and formula for each direct combustion subsector

Emissions subsector	Data source	Formula
Energy		
LNG	Production data from the <i>fugitives sector</i> and emissions intensity from NGER, Lewis Grey Advisory 2016 and various EIS	$E_t = \sum ([El_{it} \cdot P_{it}])$ Where: E_t = emissions in year t (Mt CO ₂ -e) El_{it} = facility-specific emissions intensity in year t P_{it} = production at facility i in year t
Other oil and gas extraction	Gas demand from AEMO 2016, AEMO 2016a	$E_t = E_{t-1} \cdot \Delta \text{Production}$ Where: E_t = emissions in year t (Mt CO ₂ -e) E_{t-1} = emissions in the previous year $\Delta \text{Production}$ = percentage change in production between year t and year $t-1$
Manufacture of solid fuels	Iron and steel growth rates from OCE 2017 ¹ , OCE 2017a and AME Group's industry analysis	
Domestic gas production and distribution	Gas demand from AEMO 2016, AEMO 2016a	
Petroleum refining	Total refinery output from OCE 2017a	
Mining		
Coal mining	Production data from the <i>fugitives sector</i>	$E_t = E_{t-1} \cdot \Delta \text{Production}$ Where: E_t = emissions in year t (Mt CO ₂ -e) E_{t-1} = emissions in the previous year $\Delta \text{Production}$ = percentage change in production between year t and year $t-1$
Other mining (iron ore; gold; copper; nickel; zinc; bauxite and manganese)	Production data from OCE 2017, OCE 2017a, AME Group's industry analysis and derived proportion of the base year from NGER data	
Manufacturing		
Non-ferrous metals (alumina; aluminium and refined nickel)	Production data from OCE 2017, OCE 2017a, AME Group's industry analysis and derived proportion of the base year from NGER data	$E_t = E_{t-1} \cdot \Delta \text{Production}$ Where: E_t = emissions in year t (Mt CO ₂ -e) E_{t-1} = emissions in the previous year $\Delta \text{Production}$ = 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	

¹ Production data for most commodities are sourced from the OCE which goes out to 2022 and thereafter growth rates from AME Group's industry analysis have been used.

Emissions subsector	Data source	Formula
Iron and steel	Production data from OCE 2017, OCE 2017a, and AME Group's industry analysis	<i>10 year average of historical emissions</i>
Pulp, paper and print	IBISWorld industry reports analysis	
Chemicals (other petroleum and coal product and basic chemical, chemical and plastic)	IBISWorld industry reports analysis and derived proportion of the base year from NGER data	
Food processing, beverages and tobacco	IBISWorld industry reports analysis	
Other manufacturing	n/a	
Buildings		
Residential and commercial	ClimateWorks Australia 2016, DoEE 2017b, AEMO 2016	$E_t = \sum ([U_{jyt} \cdot EC_j \cdot EF_{j}])$ <p>Where: E_t = emissions in year t (Mt CO₂-e) U_{jyt} = the use of fuel_j in State_y in year t EC_j = the energy content of fuel_j EF_j = the emissions factor of fuel_j</p>
Construction	Activity data from ACIF 2017	$E_t = E_{t-1} \cdot \Delta \text{Activity}$ <p>Where: E_t = emissions in year t (Mt CO₂-e) E_{t-1} = emissions in the previous year $\Delta \text{Activity}$ = percentage change in activity between year t and year t-1</p>
Agriculture, forestry and fishing	DoEE 2017b	<i>Historical diesel use from the agriculture sector is used to inform emissions</i>
Other (military)	n/a	<i>10 year average of historical emissions</i>

Transport

The Department commissioned the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) Energy Business Unit and ABMARC to undertake the modelling of transport emissions for the 2016 projections. For the 2017 projections, a review of major influences in the sector such as electric vehicle forecasts, oil prices and activity forecasts was conducted. The review concluded that it was not necessary to adjust the *transport sector* emissions from those calculated for the 2016 projections.

The transport projections have been developed to reflect current policies and measures. The three key policies impacting the *transport sector* that were included are the Commonwealth fuel excise, the NSW biofuels mandate and the Queensland biofuel policy. Abatement from the ERF was adjusted separately.

Emissions from the *transport sector* are projected using an integrated bottom-up and top-down modelling approach (Reedman, Luke J. and Graham, Paul W. 2016). The economic partial equilibrium model applied is called the Energy Sector Model (ESM), which represents the Australian energy sector. The ESM was developed by CSIRO and ABARES in 2006.

The ESM determines the least cost fuel and vehicle mix to meet given transport activity levels. 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.

In the modelling, the rail, marine and aviation sectors are primarily represented by their current and future fuel demand. The future fuel demand is projected by applying a fuel energy efficiency (MJ/km) improvement rate to the projected growth in non-road transport activity demand (km). These sectors use a top-down approach, which assumes that demand is driven by population and industry activity that is a function of the general level of economic activity and that infrastructure needs will keep pace to meet that demand.

The main components of ESM for the *transport sector* include:

- Coverage of all States and the Northern Territory (Australian Capital Territory is modelled as part of New South Wales).
- Ten road transport modes: motorcycles, small, medium and large passenger cars; small, medium and large commercial vehicles; rigid trucks; articulated trucks and buses. The passenger and light commercial vehicles are represented in three weight categories:
 - light/small: less than 1200 kg
 - medium: 1200 to 1500 kg
 - heavy/large: 1500 to 3000 kg.
- Five 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 per cent ethanol blend (E10); diesel with 20 per cent biodiesel blend (B20); ethanol and biodiesel at high concentrations; gas to liquids diesel (GTL); coal to liquids diesel (CTL) with upstream CO₂ capture; shale to liquids (STL) diesel with upstream CO₂ capture, hydrogen (from renewables) and electricity.

All technologies are assessed on the basis of their relative costs subject to constraints such as the turnover of capital stock, existing policies such as subsidies and taxes. The model aims to mirror real world investment decisions by simultaneously taking into account:

- the requirement to earn a reasonable return on investment over the life of a vehicle
- that consumers react to price signals (price elastic demand)
- the overall cost of transport services, and
- transport market policies and regulations.

The model projects uptake on the basis of cost competitiveness but at the same time takes into account constraints on the operation of transport markets, current excise and mandated fuel mix legislation, existing vehicle stock in each State, and lead times in the availability of new vehicles.

Table 2. Input and data sources for the transport sector model

Input	Data source
Demand for road and non-road transport	Bureau of Infrastructure, Transport and Regional Economics (BITRE)
Fuel consumption	Table F of the Australian Energy Update 2016 (DIIS 2016)
Oil prices	The oil price projections are informed by the Office of the Chief Economist (OCE 2016) and the United States Energy Information Administration (EIA 2016).
Wholesale gas prices	Consistent with the <i>electricity sector</i>
Gross Domestic Product	Department of the Treasury consistent with the Australian Government's 2016-17 Budget (Australian Government 2016)
Fuel efficiency and technology trends	ABMARC 2016

Key output variables from the ESM include:

- demand for transport activity by fuel, engine and vehicle types in vehicle kilometres travelled (VKT)
- fuel consumption by different fuel and vehicles types in PJ
- price of fuels (i.e. capital cost, fuel cost and OpexCost by different vehicle types)
- greenhouse gas and air pollutant emissions (i.e. Mt CO₂-e, Mt CO₂, Mt CH₄ and Mt N₂O).

Understanding the flow from economic growth and transport activity (including modal substitution where relevant) to fuel consumption (via fuel efficiency) and fuel selection is almost all that is required to project emissions. The final step is to apply a fuel emission factor which is sourced from the national greenhouse gas inventory which remain constant over time. *Electricity sector* emissions are accounted for separately in *electricity sector* modelling as are upstream refining sector emissions.

Emissions from other transportation (i.e. off-road recreational vehicles and pipeline transport) are projected based on historical growth rates in these subsectors.

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

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 CO₂-e)

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

EI_i = the emissions intensity of production at mine i , (Mt CO₂-e/kt coal)

ERF_t = abatement from forthcoming ERF projects in year t (Mt CO₂-e)

The emissions intensity of coal mines includes all sources of fugitive emissions from vented methane and carbon dioxide, flaring and post mining. For mines that are operating in 2015 or 2016 the emissions intensity is sourced from the latest national greenhouse gas inventory data which is based on company data reported under the NGER scheme. For prospective coal mines emission intensities are sourced from Environmental Impact Statements or are the average for currently operating mines in the same coal basin.

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 thermal and coking coal production consistent with the New Policies Scenario in the *2017 World Energy Outlook* (IEA 2017). 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.

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

Abandoned coal mines

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.

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

Where:

E_t = emissions from abandoned coal mines in year t (Mt CO₂-e)

ED_i = annual emissions of mine i in the year before decommissioning d (Mt CO₂-e)

EF_{it} = emission factor for the mine at a point in time since decommissioning. It is derived from the Emissions Decay Curves (see DoEE 2017).

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 CO₂-e).

The model requires the emissions at the time of closure, the mine type, mine void size and mine water inflow rates. 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. 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 2017). Mine flooding rates are estimated based on the mine's water production region consistent with the national greenhouse gas inventory.

Oil and gas fugitives

Oil

Oil fugitive emissions are separated into five sub-sectors. Proxy indicators are used to project the growth in emissions as listed below.

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

Where:

E_t = emissions in the year t (Mt CO₂-e)

E_{t-1} = emissions in the year $t-1$ (Mt CO₂-e)

Pr_t = proxy indicator in the projection year

Pr_{t-1} = proxy indicator in the year $t-1$

Table 3. Summary of sources for oil and gas fugitive emissions

Fugitive emissions source	Proxy indicator	Source
Oil refinery	Refinery output	OCE 2017a
Oil - flaring	Crude oil and condensate production	OCE 2017a, BREE 2014
Oil - production	Crude oil and condensate production	OCE 2017a, BREE 2014
Oil - exploration	Historical 10-year average	DOEE 2017
Oil - transport	Crude oil and condensate production	OCE 2017a, BREE 2014

Oil exploration emissions are small (<0.01Mt CO₂-e) and volatile from year-to-year. A consistent link to a proxy indicator was not found. Therefore historical emissions levels have been used to project future emissions from this source.

Fugitive emissions from LNG

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.

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

Where:

E_t = LNG fugitive emissions in year t (Mt CO₂-e)

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

El_{vi} = venting emissions intensity at facility i (Mt CO₂-e/Mt LNG)

El_{fi} = flaring emissions intensity at facility i (Mt CO₂-e/Mt LNG)

El_{oi} = other leaks emissions intensity at facility i (Mt CO₂-e/Mt LNG)

CCS_{ti} = CO₂ captured and stored at facility i in year t (Mt CO₂)

Production projections of each facility are informed by estimates from the OCE (OCE 2017a), Bloomberg New Energy Finance (BNEF 2017), AME Group and Lewis Grey Advisory (Lewis Grey Advisory 2016). The projections consider committed and prospective additions and removals in capacity given the global outlook for LNG.

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.

The projections include abatement from the carbon dioxide injection project at Gorgon.

Other fugitive emissions from gas

Other fugitive emissions from gas include gas exploration, extraction, processing, storage and transport. Emissions are separated into twenty sub-sectors. Proxy indicators are used to project the growth in emissions from the sectors as listed below.

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

Where:

E_t = emissions in the year t (Mt CO₂-e)

E_{t-1} = emissions in the year $t-1$ (Mt CO₂-e)

Pr_t = proxy indicator in the projection year

Pr_{t-1} = proxy indicator in the year $t-1$

Table 4. Summary of sources for gas fugitive emissions

Fugitive emissions source	Proxy indicator	Source
Distribution	Unaccounted for gas losses	AEMO 2016
Exploration - flared	Total gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for LNG, electricity and direct combustion
Exploration - leakage - conventional	Conventional gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for LNG, electricity and direct combustion
Exploration - leakage - unconventional	Unconventional gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for LNG, electricity and direct combustion
Exploration - venting - completions - conventional	Conventional gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for LNG, electricity and direct combustion
Exploration - venting - completions - unconventional	Unconventional gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission

Fugitive emissions source	Proxy indicator	Source
		projections models for LNG, electricity and direct combustion
Exploration - venting - workovers	Unconventional gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for LNG, electricity and direct combustion
Processing	Total gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for LNG, electricity and direct combustion
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 2017a, AEMO 2016, AEMO 2016a, emission projections models for electricity and direct combustion
Production - onshore gathering and boosting - unconventional gas	Unconventional gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for LNG, electricity and direct combustion
Production - onshore wells - conventional gas	Conventional gas production (excluding LNG)	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for electricity and direct combustion
Production - onshore wells - unconventional gas	Unconventional gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for LNG, electricity and direct combustion
Production - onshore wells - water production	Unconventional gas production	OCE 2017a, AEMO 2016, AEMO 2016a, emission projections models for LNG, electricity and direct combustion
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

Fugitive emissions source	Proxy indicator	Source
Transmission and storage - transmission	Total pipeline length	AEC 2017, company reports, Department of the Environment and Energy expert advice
Venting and flaring - flaring - gas	Domestic gas consumption	AEMO 2016, AEMO 2016a, emission projections models for electricity and direct combustion
Venting and flaring - venting - gas	Domestic gas consumption	AEMO 2016, AEMO 2016a, emission projections models for electricity and direct combustion

Industrial Processes and Product Use

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

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* (DoEE 2017). Where sufficient data is not available, a simplified methodology is applied and emissions are projected to grow in line with an appropriate driver, such as population.

For the major chemical industry subsectors the growth in the final demand for these products is used as the driver for production growth, as outlined below.

Ammonia is primarily used in the production of explosives used by the mining industry and in fertilisers. Projections of natural gas use in the manufacture of ammonia are estimated at the facility level and are informed by coal mining estimates prepared for the *fugitives sector* for east coast explosive manufacturers, iron ore mining estimates prepared for the *direct combustion* sector for west coast explosives manufacturers, and fertiliser use estimates prepared for the *agriculture sector* for fertiliser producers.

Nitric acid is primarily used in the production of explosives used by the mining industry. Projections of nitric acid emissions are estimated at the facility level and are informed by coal mining estimates prepared for the *fugitives sector* for east coast explosive manufacturers and iron ore mining estimates prepared for the *direct combustion* sector for west coast explosives manufacturers. Facility-specific capacity constraints are applied to these estimates.

Synthetic rutile is used to produce titanium dioxide. **Titanium dioxide** is a white pigment used in paint manufacture, paper, plastics, rubber, ceramics, fabrics, floor covering, printing ink and other miscellaneous uses. Approximately 75 per cent of Australia's titanium dioxide is exported. Projections of the use of fuels in the production of titanium dioxide and synthetic

rutile are estimated at the facility level and are informed by projections of gross world product, as well as facility-specific capacity constraints.

Table 5. Summary of sources and formula for each IPPU subsector

Emissions subsector	Data source	Formula
Chemical industry		
Ammonia	DoEE estimates based on projected iron ore, coal production and fertiliser use	$E_t = \sum ([U_{ji} \cdot EC_j \cdot EF_j])$ <p>Where: E_t = annual emissions in year t (Mt CO₂-e) U_{ji} = 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</p>
Nitric acid	DoEE estimates based on projected iron ore and coal production	$E_t = \sum ([EF_i \cdot P_{it}])$ <p>Where: E_t = annual emissions in year t (Mt CO₂-e) EF_i = facility-specific emissions factor P_{it} = annual nitric acid production at facility_i in year t</p>
Titanium dioxide	GDP growth from the Australian Government 2017 and Organisation for Economic Co-operation and Development (OECD)	$E_t = \sum ([U_{jit} \cdot EC_j \cdot EF_j])$ <p>Where: E_t = annual emissions in year t (Mt CO₂-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</p>
Synthetic rutile		
Acetylene	ABS 2013 ABS 2017	$E_t = E_{t-1} \cdot \Delta \text{Population}$ <p>Where: E_t = annual emissions in year t (Mt CO₂-e) E_{t-1} = emissions in the previous year $\Delta \text{Population}$ = percentage change in population between year t and year t-1</p>
Petrochemical and carbon black	n/a	$E_t = E_{t-1}$ <p>Where: E_t = annual emissions in year t (Mt CO₂-e) E_{t-1} = emissions in the previous year</p>
Metal Industry		
Aluminium production	Production data from OCE 2017, OCE 2017a, and AME Group's industry analysis	$E_t = \sum ([EF_i \cdot P_{it}])$ <p>Where: E_t = annual emissions in year t (Mt CO₂-e) EF_i = facility-specific emissions factor P_{it} = annual production at facility_i in year t</p>
Iron and steel production		
Ferroalloys production	Company statements	$E_t = \sum ([U_{jit} \cdot EC_j \cdot EF_j])$ <p>Where: E_t = annual emissions in year t (Mt CO₂-e) U_{jit} = the use of fuel j as a reductant at facility_i in year t EC_j = the energy content of fuel j EF_j = the emissions factor of fuel j</p>

Emissions subsector	Data source	Formula
Other metal production (copper, nickel and silicon)	Production data from OCE 2017, OCE 2017a, and AME Group's industry analysis	$E_t = \sum ([U_{jit} \cdot EC_j \cdot EF_j])$ <p>Where: E_t = annual emissions in year t (Mt CO₂-e) U_{jit} = the use of fuel j as a reductant at facility, in year t EC_j = the energy content of fuel j EF_j = the emissions factor of fuel j</p>
Mineral Industry		
Cement Lime	Production from IBISWorld industry report	$E_t = \sum ([EF_i \cdot P_{it}])$ <p>Where: E_t = annual emissions in year t (Mt CO₂-e) EF_i = facility-specific emissions factor P_{it} = annual production at facility, in year t</p>
Limestone and dolomite and other carbonates	DoEE estimates based on projected ceramics, ferroalloy production, glass production, iron and steel production and zinc production	$E_t = E_{t-1} * \Delta \text{ Production}$ <p>Where: E_t = emissions in year t (Mt CO₂-e) E_{t-1} = emissions in the previous year $\Delta \text{ Production}$ = percentage change in production between year t and year t-1</p>
Non-energy products from fuel and solvent use		
Lubricant use	n/a	$E_t = E_{t-1}$ <p>Where: E_t = annual emissions in year t, E_{t-1} = emissions in the previous year</p>
Product uses as a substitute for ozone depleting substances	DoEE 2017	Based on <i>National Inventory Report</i> methodology
Other product manufacture and use		
Electrical equipment		Based on <i>National Inventory Report</i> methodology
SF ₆ and PFCs from other product uses N ₂ O from product uses	ABS 2013 ABS 2017	$E_t = E_{t-1} \cdot \Delta \text{ Population}$ <p>Where: E_t = annual emissions in year t (Mt CO₂-e) E_{t-1} = emissions in the previous year $\Delta \text{ Population}$ = percentage change in population between year t and year t-1</p>
Other production	DoEE estimates based on projected ammonia production and food, beverages & tobacco production	$E_t = E_{t-1} * \Delta \text{ Production}$ <p>Where: E_t = emissions in year t (Mt CO₂-e) E_{t-1} = emissions in the previous year $\Delta \text{ Production}$ = percentage change in production between year t and year t-1</p>

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* (DoEE 2017).

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.

Emissions are projected by calculating the amount of agricultural activity in Australia each year. This is done by drawing on external data sources that contain activity numbers and activity growth rates (Table 6.).

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 is grown broadly 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.

The projections also includes a trend towards grain-fed beef cattle, as some farmers seek a feeding system more resistant to drought. 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 2017).

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 6. 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 Commodities: March quarter 2017, September quarter 2017 OECD-FAO Agricultural Outlook 2017-2026	Heads of animal
Pigs	ABARES Commodities: March quarter 2017, September quarter 2017 OECD-FAO Agricultural Outlook 2017-2026	Heads of animal

Commodity	Data sources	Unit of activity
Crops	ABARES Commodities: March, September quarter 2017 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 Commodities: March, September quarter 2017 CSIRO 2015 (CSIRO LUTO)	Heads of animal
Dairy	ABARES Commodities: March, September quarter 2017 CSIRO 2015 (CSIRO LUTO)	Heads of animal
Grain fed beef	ABARES Commodities: March, September quarter 2017 CSIRO 2015 (CSIRO LUTO)	Heads of animal
Grazing beef	ABARES Commodities: March, September quarter 2017 CSIRO 2015 (CSIRO LUTO)	Heads of animal

Table 7. 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
Dairy	Enteric fermentation Manure management Agricultural soils
Grain fed beef	Enteric fermentation Manure management Agricultural soils
Grazing beef	Enteric fermentation Manure management Agricultural soils

Formula

Emissions in the *agriculture sector* are driven by activity numbers.

Table 8. Symbols used in algorithms

Symbol	Variable	Variable categories
k^2	State	ACT, 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
ρ	Gas source	Enteric fermentation, manure management, rice cultivation, agricultural soils, field burning of agricultural residues, lime and urea application

Emissions from agricultural activity is calculated as:

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

Where E = Emissions in year t (Mt CO₂-e)

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

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

Emissions factors in: (kt/unit of activity/year)

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.

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

The agriculture projections use emissions factors for activity derived from Australia's *National Inventory Report*. For formulas on calculating emissions intensity, please see Australia's *National Inventory Report* (DoEE 2017).

Waste

The *waste sector* emissions are prepared by the Department, modelling three waste subsectors: solid waste, domestic and commercial waste water, and industrial wastewater. The projections calculate emissions based on population forecasts from the ABS population projection for moderate growth (ABS 2013, Series B). The rates of waste generation, diversion methane capture and proportion of wastewater anaerobically treated are taken from Hyder modelling (Hyder Consulting 2014).

The projections of wastewater activity are based on the assumption that the organic content of wastewater, the proportion of wastewater that is treated anaerobically, and the proportion of the population serviced by a sewer will remain at the levels estimated for 2012,⁴ over the projections period.

Over the period 2017 to 2025, per capita waste generation is assumed to grow at the same average rate of increase observed between 2008 and 2011 of 1.7 per cent per year. Growth in waste generation is assumed to peak in 2025 as the impact of state and national waste policies, recycling and increased waste conscious products converges with expected population growth. Waste generation is capped at 2025 levels from 2025 to 2030.

The National Food Waste Strategy is not included in this projection.

Table 9. Summary of sources and formulas for each waste subsector

Emissions subsector	Data sources	Formula
Solid waste	ABS 2013 ABS 2017 DoEE 2017 DoEE 2017b Hyder Consulting 2014	$E_{SW} = i + c + (CH_4^g - CH_4^c)$ <p>Where: E_{SW} = solid waste emissions i = emissions from solid waste incineration c = emissions from composting CH_4^g = solid waste methane generated CH_4^c = solid waste methane captured</p>
Domestic and commercial wastewater	ABS 2013 ABS 2017 DoEE 2017 DoEE 2017b DoEE 2017c ^a Hyder Consulting 2014	$E_{DC} = (CH_4^t - CH_4^r) + (N_2O^t + N_2O^l)$ <p>Where: E_{DC} = domestic and commercial wastewater emissions CH_4^t = total domestic and commercial wastewater methane emissions CH_4^r = domestic and commercial wastewater methane recovered N_2O^t = total domestic and commercial wastewater nitrous oxide emissions N_2O^l = land application nitrous oxide emissions</p>

⁴ The department's estimate of these parameters come from the *Australian National Greenhouse Accounts: National Inventory Report 2012* (DoE 2014), which was used by Hyder Consulting (Hyder Consulting 2014)

Emissions subsector	Data sources	Formula
Industrial wastewater	DoEE 2017 DoEE 2017b	$E_i = (CH_4^t - CH_4^r)$ <p>Where: E_i = industrial wastewater emissions CH_4^t = total industrial wastewater methane emissions CH_4^r = industrial wastewater methane recovered</p>

a Industrial wastewater modelling incorporates annual growth rates from the *agriculture sector* and *direct combustion sector* emissions projections.

Land use, land use change and forestry

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 2017, Appendix 6.B).

Key assumptions include:

- The forecast land clearing rates on forest lands converted to croplands and grasslands are assumed to return to historical levels before following the relationship between land clearing activity and the farmers’ terms of trade, as described in the *National Inventory Report* (DoEE 2017, Appendix 6.A.6 and 6.H).
- 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 utilised the FullCAM modelling framework to estimate emissions, in conjunction with the harvested wood products model as described in section 2.1 of *Australian Land Use, Land Use-Change and Forestry emissions projections to 2035* (DoE 2015).

The projections include abatement from vegetation, soil carbon and savanna burning projects under the ERF.

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

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