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Australian National Greenhouse Accounts

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Introduction

The *National Greenhouse Accounts (NGA) Factors* has been prepared by the Department of the Environment and Energy and is designed for use by companies and individuals to estimate greenhouse gas emissions. The *NGA Factors* is not published for the purposes of reporting under the *National Greenhouse and Energy Reporting Act 2007 (the NGER Act).* While drawing on the *National Greenhouse and Energy Reporting (Measurement) Determination 2008,* the methods described in the *NGA Factors* have a general application to the estimation of a broader range of greenhouse emissions inventories.

Unless otherwise stated, the methods for calculating emissions listed in this document are "Method 1" from the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* incorporating the *National Greenhouse and Energy Reporting (Measurement) Amendment (Energy) Determination 2017.*

The default emission factors listed have been estimated by the Department of the Environment and Energy using the Australian Greenhouse Emissions Information System (AGEIS) and are determined simultaneously with the production of Australia's National Greenhouse Accounts. This promotes consistency between inventories at company or facility level and the emission estimates presented in the National Greenhouse Accounts. The emission factors are referred to in this document as NGA default emission factors.

More information on the estimation methods employed in the National Greenhouse Accounts is available in the *National Inventory Report 2015*. The methods used at the national level, and reflected in the factors reported here, are consistent with international guidelines and are subject to international expert review each year.

Revisions to the previous issue

The emission factors reported in this publication replace those listed in the *NGA Factors Workbook* released in August 2016. The *NGA Factors Workbook July 2017* has been updated to include the latest amendments to Method 1 methodologies within the *National Greenhouse and Energy Reporting (Measurement) Amendment (Energy) Determination 2017.* Updates in this workbook include:

- Electricity – an explanation of how scope 2 factors are calculated has been added in section 2.3.
- Electricity – most recent scope 2 and scope 3 emission factors have been included (Tables 5, 6 and 41);
- Composting factor for biological treatment of solid waste at the landfill has changed (section 5.2).

Further information about revised factors can be found at Appendix 5.

1 Key definitions and terms

1.1 Direct and indirect emissions

Direct emissions are produced from sources within the boundary of an organisation and as a result of that organisation's activities. These emissions mainly arise from the following activities:

- generation of energy, heat, steam and electricity, including carbon dioxide and products of incomplete combustion (methane and nitrous oxide);
- manufacturing processes which produce emissions (for example, 1cement, aluminium and ammonia production);
- transportation of materials, products, waste and people; for example, use of vehicles owned and operated by the reporting organisation;
- fugitive emissions: intentional or unintentional GHG releases (such as methane emissions from coal mines, natural gas leaks from joints and seals); and
- on-site waste management, such as emissions from landfill sites.

For example, a company with a car fleet would report greenhouse gas emissions from the combustion of petrol in those motor vehicles as direct emissions. Similarly, a mining company would report methane escaping from a coal seam during mining (fugitive emissions) as direct emissions and a cement manufacturer would report carbon dioxide released during cement clinker production as direct emissions.

Emission factors for calculating direct emissions are generally expressed in the form of a quantity of a given GHG emitted per unit of energy (kg CO_2-e /GJ), fuel (t CH_4/t coal) or a similar measure. Emission factors are used to calculate GHG emissions by multiplying the factor (e.g. kg CO_2/GJ energy in petrol) with activity data (e.g. kilolitres x energy density of petrol used). In this workbook, emission factors are provided as applicable, for each of the following greenhouse gases:

- carbon dioxide
- methane
- nitrous dioxide
- synthetic gases
    - HFCs, SF_6, CF_4, C_2F_6

All factors are standardised by being expressed as a carbon dioxide equivalent (CO_2-e). This is achieved by multiplying the individual gas emission factor by the respective gas global warming potential (GWP). The GWPs for each gas are listed in Table 26, Appendix 1.

Indirect emissions are emissions generated in the wider economy as a consequence of an organisation's activities (particularly from its demand for goods and services), but which are physically produced by the activities of another organisation. The most important category of indirect emissions is from the consumption of electricity. Other examples of indirect emissions from an organisation's activities include upstream emissions generated in the extraction and production of fossil fuels, downstream emissions from transport of an organisation's product to customers, and emissions from contracted/outsourced activities. The appropriate emission

factor for these activities depends on the parts of upstream production and downstream use considered in calculating emissions associated with the activity.

1.2 Types of emission factors

The world of emission factors can become confusing—the following is provided to clarify the purpose of the types of emissions factors in this workbook.

Firstly, it is important to note that an emission factor is activity-specific. The activity determines the emission factor used. The scope that emissions are reported under is determined by whether the activity is within the organisation's boundary (direct—scope 1) or outside it (indirect—scope 2 and scope 3).

- **Direct (or point-source) emission factors** give the kilograms of carbon dioxide equivalent (CO_2-e) emitted per unit of activity at the point of emission release (i.e. fuel use, energy use, manufacturing process activity, mining activity, on-site waste disposal, etc.). These factors are used to calculate **scope 1 emissions**.

- **Indirect emission factors** are used to calculate **scope 2 emissions** from the generation of the electricity **purchased and consumed** by an organisation as kilograms of CO_2-e per unit of electricity consumed. Scope 2 emissions are physically produced by the burning of fuels (coal, natural gas, etc.) at the power station.

- **Various emission factors** can be used to calculate **scope 3 emissions**. For ease of use, this workbook reports **specific 'scope 3' emission factors** for organisations that:

(a) burn fossil fuels: to estimate their indirect emissions attributable to the extraction, production and transport of those fuels; or

(b) consume purchased electricity: to estimate their indirect emissions from the extraction, production and transport of fuel burned at generation and the indirect emissions attributable to the electricity lost in delivery in the transmission and distribution network.

The definition, methodologies and application of scope 3 factors are currently subject to international discussions. Available scope 3 emission factors are listed in Appendix 4. Scope 3 factors and methods are also provided for companies wishing to estimate their scope 3 emissions from disposal of waste generated (e.g. if the waste is transported outside the organisation and disposed of).

1.3 Information sources

The principle sources of information used in developing this workbook include:

American Petroleum Institute (2009) *Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009*.

Australian Greenhouse Office (2006), *AGO Generator Efficiency Standards - Technical Guidelines*, December 2006, Commonwealth of Australia, Canberra.

Energy Supply Association of Australia (2015), *Electricity, Gas Australia 2015*.

Department of the Environment and Energy (2017), *National Inventory Report2015*, Commonwealth of Australia, Canberra.

Intergovernmental Panel on Climate Change (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*; Japan.

International Aluminium Institute (2006), *The Aluminium Sector Greenhouse Gas Protocol, Addendum to the WRI/WBCSD GHG Protocol*.

International Energy Agency (2005), *Energy Statistics Manual*, 2005, Paris.

National Greenhouse and Energy Reporting (Measurement) Determination 2008. (Cwlth), ComLaw, https://www.legislation.gov.au/Series/F2008L02309.

US EPA, International Aluminium Institute (2003), *Protocol for Measurement of Tetrafluoromethane (CF_4) and Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production*.

World Business Council for Sustainable Development / World Resources Institute, *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard*, Revised edition.

World Business Council for Sustainable Development, (2005), *CO_2 Accounting and Reporting Standard for the Cement Industry- The Cement CO_2 Protocol*, June 2005.

Wilkenfeld, George, and Associates Pty Ltd (2007), *Australia's National Greenhouse Gas Inventory,1990, 1995, 2000 and 2005 End Use Allocation of Energy Emissions*, report to the Department of Climate Change, Commonwealth of Australia, Canberra.

Wilkenfeld, George and Associates (2012), *Updated Scope 3 Emission Factors for Natural Gas and Ethane Consumed in Australia*., report to the Department of Climate Change and Energy Efficiency.

1.4 Additional information and web sites

Australian National Greenhouse Gas Accounts and related topics
http://www.environment.gov.au/climate-change

Intergovernmental Panel on Climate Change (IPCC) National Greenhouse Gas Inventories Program
www.ipcc-nggip.iges.or.jp

National Greenhouse and Energy Reporting

http://www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme

The Emissions and Energy Reporting System (EERS)

http://www.cleanenergyregulator.gov.au/OSR/EERS/The-Emissions-and-Energy-Reporting-System

United Nations Framework Convention on Climate Change and related topics including the Kyoto Protocol and Paris Agreement
www.unfccc.int

The Greenhouse Gas Protocol Initiative (convened by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI))
www.ghgprotocol.org

1.5 Contacts

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National Greenhouse Accounts (NGA) Factors

2 Energy

This section addresses the estimation of emissions in the energy sector and includes emission factors for:

- the stationary combustion of solid, gaseous and liquid fuels (section 2.1);
- the combustion of liquid and gaseous fuels for transport (section 2.2);
- the consumption of purchased electricity (section 2.3); and
- the extraction of fossil fuels (section 2.4).

The principal greenhouse gas generated by the combustion of fossil fuels for energy is carbon dioxide. The quantity of gas produced depends on the carbon content of the fuel and the degree to which the fuel is fully combusted (i.e. the oxidation factor, which usually ranges between 98% and 99.5%). Small quantities of methane and nitrous oxide are also produced, depending on the actual combustion conditions. Methane may be generated when fuel is heated, but only partially burnt, and depends on combustion temperatures and the level of oxygen present. Nitrous oxide results from the reaction between nitrogen and oxygen in the combustion air.

2.1 Stationary energy emissions (non-transport)

Estimates of emissions from the combustion of individual fuel types are made by multiplying a (physical) quantity of fuel combusted by a fuel-specific energy content factor and a fuel-specific emission factor. This is performed for each relevant greenhouse gas (in this case, carbon dioxide, methane and nitrous oxide). Separate calculations should be carried out for each fuel type.

Total greenhouse emissions are calculated by summing the emissions of each fuel type and each greenhouse gas.

2.1.1 Fuel combustion emissions – solid fuels

The following formula can be used to estimate greenhouse gas emissions from the combustion of each type of fuel listed in Table 1.

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1\,000}$$

where:

$\boldsymbol{E_{ij}}$ is the emissions of gas type (j), (carbon dioxide, methane or nitrous oxide), from fuel type (i) (CO_2-e tonnes).

$\boldsymbol{Q_i}$ is the quantity of fuel type (i) (tonnes).

EC_i is the energy content factor of the fuel (gigajoules per tonne) according to each fuel in Table 1.

If Q_i is measured in gigajoules, then EC_i is 1.

EF_{ijoxec} is the emission factor for each gas type (j) (which includes the effect of an oxidation factor) for fuel type (i) (kilograms of CO_2-e per gigajoule) according to each fuel in Table 1.

Table 1: Fuel combustion emission factors - solid fuels and certain coal based products

Fuel combusted	Energy content factor GJ/t	Emission factor kg CO_2-e/GJ (relevant oxidation factors incorporated)		
		CO_2	CH_4	N_2O
Bituminous coal	27.0	90	0.03	0.2
Sub-bituminous coal	21.0	90	0.03	0.2
Anthracite	29.0	90	0.03	0.2
Brown coal	10.2	93.5	0.02	0.4
Coking coal	30.0	91.8	0.02	0.2
Coal briquettes	22.1	95	0.07	0.3
Coal coke	27.0	107	0.04	0.2
Coal tar	37.5	81.8	0.03	0.2
Solid fossil fuels other than those mentioned in the items above	22.1	95	0.07	0.3
Industrial materials and tyres that are derived from fossil fuels, if recycled and combusted to produce heat or electricity	26.3	81.6	0.02	0.2
Non-biomass municipal materials, if recycled and combusted to produce heat or electricity	10.5	87.1	0.7	1.1
Dry wood	16.2	0	0.1	1.2
Green and air dried wood	10.4	0	0.1	1.2
Sulphite lyes	12.4	0	0.07	0.6
Bagasse	9.6	0	0.2	1.2
Biomass municipal and industrial materials, if recycled and combusted to produce heat or electricity	12.2	0	0.7	1.1
Charcoal	31.1	0	4.8	1.1
Primary solid biomass fuels other than those mentioned in the items above	12.2	0	0.7	1.1

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 1)

Notes: All emission factors incorporate relevant oxidation factors (sourced from the Department of the Environment and Energy National Inventory Report).

Note Energy content and emission factors for coal products are measured on an as combusted basis. The energy content for black coal types and coking coal (metallurgical coal) is on a washed basis.

Example: calculation of emissions from black coal consumption

A facility consumes 20,000 tonnes of bituminous coal for a purpose other than for the production of electricity or to produce coke.

Emissions of greenhouse gases (carbon dioxide, methane and nitrous oxide) in tonnes of CO_2-e are estimated as follows:

Emissions of carbon dioxide:

= (20,000 x 27.0 x 90)/1,000

= 48,600 t CO_2-e

Emissions of methane:

= (20,000 x 27.0 x 0.03)/1,000

= 16 t CO_2-e

Emissions of nitrous oxide:

= (20,000 x 27.0 x 0.2)/1,000

= 108 t CO_2-e

Total scope 1 GHG emissions = 48,600 + 16 + 108

= 48,724 t CO_2-e

2.1.2 Fuel combustion emissions – gaseous fuels

The following formula can be used to estimate greenhouse gas emissions from the combustion of each type of fuel listed in Table 2.

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1\,000}$$

where:

$\boldsymbol{E_{ij}}$ is the emissions of gas type (j), (carbon dioxide, methane or nitrous oxide), from gaseous fuel type (i) (CO_2-e tonnes).

$\boldsymbol{Q_i}$ is the quantity of fuel type (i) (cubic metres)

$\boldsymbol{EC_i}$ is the energy content factor of fuel type (i) (gigajoules per cubic metre according to Table 2).

If $\boldsymbol{Q_i}$ is measured in gigajoules, then $\boldsymbol{EC_i}$ is 1.

$\boldsymbol{EF_{ijoxec}}$ is the emission factor for each gas type (j) (which includes the effect of an oxidation factor) for fuel type (i) (kilograms CO_2-e per gigajoule of fuel type (i) according to Table 2).

Table 2: Emission factors for the consumption of natural gas

Fuel combusted	Energy content factor (GJ/m^3 unless otherwise indicated)	Emission factor kg CO_2-e/GJ (relevant oxidation factors incorporated)		
		CO_2	CH_4	N_2O
Natural gas distributed in a pipeline	39.3×10^{-3}	51.4	0.1	0.03
Coal seam methane that is captured for combustion	37.7×10^{-3}	51.4	0.2	0.03
Coal mine waste gas that is captured for combustion	37.7×10^{-3}	51.9	4.1	0.03
Compressed natural gas (reverting to standard conditions)	39.3×10^{-3}	51.4	0.1	0.03
Unprocessed natural gas	39.3×10^{-3}	51.4	0.1	0.03
Ethane	62.9×10^{-3}	56.5	0.03	0.03
Coke oven gas	18.1×10^{-3}	37.0	0.03	0.05
Blast furnace gas	4.0×10^{-3}	234.0	0.0	0.03
Town gas	39.0×10^{-3}	60.2	0.0	0.03
Liquefied natural gas	25.3 GJ/kL	51.4	0.1	0.03
Gaseous fossil fuels other than those mentioned in the items above	39.3×10^{-3}	51.4	0.1	0.03
Landfill biogas that is captured for combustion (methane only)	37.7×10^{-3}	0.0	4.8	0.03
Sludge biogas that is captured for combustion (methane only)	37.7×10^{-3}	0.0	4.8	0.03
A biogas that is captured for combustion, other than those mentioned in the items above	37.7×10^{-3}	0.0	4.8	0.03

Sources: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 1)
Notes: All emission factors incorporate relevant oxidation factors (sourced from the Department of the Environment and Energy National Inventory Report).

Example: calculation of emissions from natural gas consumption

A facility consumes 100,000 gigajoules of natural gas.

Emissions of greenhouse gases (carbon dioxide, methane and nitrous oxide) in tonnes of CO_2-e are estimated as follows:

Emissions of carbon dioxide:

= (100,000 x 1 x 51.4)/1,000

= 5,140 t CO_2-e

Emissions of methane:

= (100,000 x 1 x 0.1)/1,000

= 10 t CO_2-e

Emissions of nitrous oxide:

= (100,000 x 1 x 0.03)/1,000

= 3 t CO_2-e

Total scope 1 GHG emissions = 5,140 + 10 + 3

= 5,153 t CO_2-e

2.1.3 Fuel combustion emissions – liquid fuels

The following formula can be used to estimate greenhouse gas emissions from the stationary combustion of each type of liquid fuel listed in Table 3.

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1\,000}$$

where:

$\boldsymbol{E_{ij}}$ is the emissions of gas type (j), (carbon dioxide, methane or nitrous oxide, from fuel type (i) (CO_2-e tonnes).

$\boldsymbol{Q_i}$ is the quantity of fuel type (i) (kilolitres) combusted for stationary energy purposes

$\boldsymbol{EC_i}$ is the energy content factor of fuel type (i) (gigajoules per kilolitre) for stationary energy purposes, according to Table 3.

If $\boldsymbol{Q_i}$ is measured in gigajoules, then $\boldsymbol{EC_i}$ is 1.

$\boldsymbol{EF_{ijoxec}}$ is the emission factor for each gas type (j) (which includes the effect of an oxidation factor) for fuel type (i) (kilograms CO_2-e per gigajoule) according to Table 3.

Table 3: Fuel combustion emission factors - liquid fuels and certain petroleum based products for stationary energy purposes

Fuel combusted	Energy content factor (GJ/kL unless otherwise indicated)	Emission factor kg CO_2-e/GJ (relevant oxidation factors incorporated)		
		CO_2	CH_4	N_2O
Petroleum based oils (other than petroleum based oil used as fuel, eg lubricants)	38.8	13.9	0.0	0.0
Petroleum based greases	38.8	3.5	0.0	0.0
Crude oil including crude oil condensates	45.3 GJ/t	69.6	0.1	0.2
Other natural gas liquids	46.5 GJ/t	61.0	0.1	0.2
Gasoline (other than for use as fuel in an aircraft)	34.2	67.4	0.2	0.2
Gasoline for use as fuel in an aircraft (avgas)	33.1	67	0.2	0.2
Kerosene (other than for use as fuel in an aircraft)	37.5	68.9	0.0	0.2
Kerosene for use as fuel in an aircraft (avtur)	36.8	69.6	0.02	0.2
Heating oil	37.3	69.5	0.03	0.2
Diesel oil	38.6	69.9	0.1	0.2
Fuel oil	39.7	73.6	0.04	0.2
Liquefied aromatic hydrocarbons	34.4	69.7	0.02	0.2
Solvents if mineral turpentine or white spirits	34.4	69.7	0.02	0.2
Liquefied petroleum gas	25.7	60.2	0.2	0.2
Naphtha	31.4	69.8	0.00	0.01
Petroleum coke	34.2 GJ/t	92.6	0.07	0.2
Refinery gas and liquids	42.9 GJ/t	54.7	0.02	0.0
Refinery coke	34.2 GJ/t	92.6	0.07	0.2
Petroleum based products other than mentioned in the items above	34.4	69.8	0.0	0.2
Biodiesel	34.6	0.0	0.07	0.2
Ethanol for use as a fuel in an internal combustion engine	23.4	0.0	0.07	0.2
Biofuels other than those mentioned in the items above	23.4	0.0	0.07	0.2

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 1).

Notes: All emission factors incorporate relevant oxidation factors (sourced from the Department of the Environment and Energy National Inventory Report).

2.2 Transport fuel emissions

Fuels used for transport purposes produce slightly different methane and nitrous oxide emissions than if the same fuels were used for stationary energy purposes. Therefore, separate emission factors are provided in Table 4, to apply where fuels are used for general transport purposes. In additional, a range of optional emission factors are provided in Table 4 for use with post-2004 vehicles and heavy vehicles conforming to Euro design standards.

Transport includes purposes for which fuel is combusted that consist of any of the following:

- transport by vehicles registered for road use;
- rail transport;
- marine navigation;
- air transport.

No transport factors are provided for vehicles not registered for road use. Stationary energy factors for individual fuel types should be used in these cases.

Estimates of emissions from the combustion of individual fuel types are made by multiplying a (physical) quantity of fuel combusted by a fuel-specific energy content factor and a fuel-specific emission factor. This is performed for each relevant greenhouse gas (in this case, carbon dioxide, methane and nitrous oxide). Separate calculations should be carried out for each fuel type.

Total greenhouse emissions are calculated by summing the emissions of each fuel type and each greenhouse gas.

The following formula can be used to estimate greenhouse gas emissions from the combustion of each type of fuel listed in Table 4 used for transport energy purposes.

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1\,000}$$

where:

$\boldsymbol{E_{ij}}$ is the emissions of gas type (j), carbon dioxide, methane or nitrous oxide, from fuel type (i) (CO_2-e tonnes).

$\boldsymbol{Q_i}$ is the quantity of fuel type (i) (kilolitres or gigajoules) combusted for transport energy purposes

$\boldsymbol{EC_i}$ is the energy content factor of fuel type (i) (gigajoules per kilolitre or per cubic metre) used for transport energy purposes — see Table 4.

If $\boldsymbol{Q_i}$ is measured in gigajoules, then $\boldsymbol{EC_i}$ is 1.

$\boldsymbol{EF_{ijoxec}}$ is the emission factor for each gas type (j) (which includes the effect of an oxidation factor) for fuel type (i) (kilograms CO_2-e per gigajoule) used for transport energy purposes — see Table 4.

Table 4: Fuel combustion emission factors - fuels used for transport energy purposes

Transport equipment type	Fuel combusted	Energy content factor (GJ/kL unless otherwise indicated)	Emission factor kg CO_2-e/GJ (relevant oxidation factors incorporated)		
			CO_2	CH_4	N_2O
General transport					
	Gasoline (other than for use as fuel in an aircraft)	34.2	67.4	0.5	1.8
	Diesel oil	38.6	69.9	0.1	0.5
	Gasoline for use as fuel in an aircraft	33.1	67.0	0.05	0.7
	Kerosene for use as fuel in an aircraft	36.8	69.6	0.01	0.6
	Fuel oil	39.7	73.6	0.07	0.6
	Liquefied petroleum gas	26.2	60.2	0.6	0.7
	Biodiesel	34.6	0.0	0.7	1.9
	Ethanol for use as fuel in an internal combustion engine	23.4	0.0	0.7	1.9
	Biofuels other than those mentioned in items above	23.4	0.0	0.7	1.9
	Compressed natural gas that has converted to standard conditions (light duty vehicles)	39.3×10^{-3} GJ/m^3	51.4	6.5	0.3
	Compressed natural gas that has converted to standard conditions (heavy duty vehicles)	39.3×10^{-3} GJ/m^3	51.4	2.5	0.3
	Liquefied natural gas (light duty vehicles)	25.3	51.4	6.5	0.3
	Liquefied natural gas (heavy duty vehicles)	25.3	51.4	2.5	0.3
Post-2004 vehicles					
	Gasoline (other than for use as fuel in an aircraft)	34.2	67.4	0.02	0.2
	Diesel oil	38.6	69.9	0.01	0.6
	Liquefied petroleum gas	26.2	60.2	0.4	0.3
	Ethanol for use as fuel in an internal combustion engine	23.4	0	0.2	0.2
Heavy vehicles conforming to Euro design standards					
Euro iv or higher	Diesel oil	38.6	69.9	0.06	0.5
Euro iii	Diesel oil	38.6	69.9	0.1	0.5
Euro i	Diesel oil	38.6	69.9	0.2	0.5

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 1).
Notes: All emission factors incorporate relevant oxidation factors (sourced from the Department of the Environment and Energy National Inventory Report).

Example: calculation of emissions from transport fuels consumed

A freight company consumes 10000 kL of automotive diesel for transport purposes. Emissions of greenhouse gases (carbon dioxide, methane and nitrous oxide) in tonnes of CO_2-e are estimated as follows;

Emissions of carbon dioxide:

= (10,000 x 38.6 x 69.9)/1,000

= 26,981 t CO_2-e

Emissions of methane:

= (10,000 x 38.6 x 0.1)/1,000

= 39 t CO_2-e

Emissions of nitrous oxide:

= (10,000 x 38.6 x 0.5)/1,000

= 193 t CO_2-e

Total scope 1 GHG emissions = 26981 + 39 + 193

= 27,213 t CO_2-e

2.3 Indirect emissions from electricity (Scope 2 emission factors)

2.3.1 How scope 2 factors are calculated

The scope 2 emission factors are state-based emission factors from on-grid electricity generation calculated systematically from the physical characteristics of the electricity grid. The state-based emission factor calculates an average emission factor for all electricity consumed from the grid in a given state, territory or electricity grid. All emissions attributable to a state territory or grid's electricity consumption are allocated amongst individual consumers in proportion to their relative level of consumption. In effect, the likelihood of a particular generator supplying a particular consumer is assumed to reflect each generator's relative level of supply to that State's component of the grid.

This approach minimises information requirements for the system and produces factors that are relatively easy to interpret and apply. Consistent adoption of these 'physical' state-based emission factors ensures the emissions generated in each state are fully accounted for by the end-users of the purchased electricity and double counting is avoided. It is recognised that this approach does not serve all possible policy purposes and that alternative, more data-intensive approaches are possible.

The scope 2 emission factors reflect data that are based on:

- on-grid activity only;
- state-based activity;
- annual financial year averages;

- physical characteristics of the electricity supply and demand.

The estimated electricity emission factors have been aligned with the definitions used in *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard of the World Resources Institute/World Business Council for Sustainable Development* (the GHG Protocol). The emission factor for scope 2 is defined in terms of energy sent out on the grid rather than energy delivered because this effectively ensures that end users of electricity are allocated only the scope 2 emissions attributable to the electricity they consume and not the scope 2 emissions attributable to electricity lost in transmission and distribution. The latter are allocated to the transmission and distribution network. This follows the GHG Protocol guidance that scope 2 emissions be reported by the organisation owning or controlling the plant or equipment where the electricity is consumed. Companies that own or control transmission and distribution networks report their transmission and distribution loss emissions under scope 2.

Electricity generation that is not supplied to the grid, for example remote generators is not included in the scope 2 calculation.

The emission factors are calculated as financial year averages based on electricity generation within each state and territory and take into account interstate electricity flows and the emissions attributable to those flows. To reduce volatility scope 2 emission factors are calculated as a three-year moving average.

Scope 2 emissions result from the generation of purchased electricity from each state's electricity grid.

$$scope\ 2 = \frac{Combustion\ emissions\ from\ electricity\ \ in\ the\ state}{Electricity\ sent\ out\ in\ the\ state}$$

The estimated 'Scope 2' emission factors use Scope 1 data obtained under the *National Greenhouse and Energy Reporting Act 2007*, supplemented with data from the Australian Energy Market Operator and the Clean Energy Regulator. Emission estimates are taken from the National Greenhouse Accounts. Further detail on the approach to calculating electricity emission estimates is available in the *National Inventory Report 2015*.

It should be noted that Renewable Energy Certificates and other emissions reduction programs are not used in the calculation of scope 2 emission factors. These programs may impact the emissions intensity of electricity generation but are not directly related to the calculation of scope 2 emission factors.

2.3.2 General calculations for indirect emissions from consumption of purchased electricity or loss of electricity

This section describes the method of determining scope 2 emissions from:

- the consumption of purchased electricity from the main grid, or
- loss of electricity from a facility, the operation of which is constituted by an electricity transmission network or distribution network that is, or is part of, the main grid (hereinafter "or loss of electricity").

These are not the relevant grid emissions factors for methodology determinations under the *Carbon Credits (Carbon Farming Initiative) Act 2011* which can be found at 2.3.3.

Indirect emission factors for the consumption of purchased electricity or loss of electricity are provided in Table 5. The factors estimate emissions of CO_2, CH_4 and N_2O expressed

together as carbon dioxide equivalent (CO_2-e). The greenhouse gas emissions in tonnes of CO_2-e attributable to the quantity of electricity used may be calculated with the following equation.

$$Y = Q \times \frac{EF}{1\,000}$$

where:

Y is the scope 2 emissions measured in CO_2-e tonnes.

Q is the quantity of electricity purchased (kilowatt hours).

For a company operating an electricity transmission network or distribution network, ***Q*** is the quantity of electricity losses for that transmission network or distribution network during the year.

For ***Q***, if the electricity purchased is measured in gigajoules, the quantity of kilowatt hours must be calculated by dividing the amount of gigajoules by 0.0036.

EF is the scope 2 emission factor, for the State, Territory or electricity grid in which the consumption occurs (kg CO_2-e per kilowatt hour). If the electricity is not sourced from a listed electricity grid the emission factor can be either provided by the supplier of the electricity or, if that factor is not available, the emission factor for the Northern Territory may be used.

Table 5 : Indirect (scope 2) emission factors for consumption of purchased electricity or loss of electricity from the grid

State or Territory	Emission factor kg CO_2-e/kWh
New South Wales and Australian Capital Territory	0.83
Victoria	1.08
Queensland	0.79
South Australia	0.49
South West Interconnected System (SWIS) in Western Australia	0.70
North Western Interconnected System (NWIS) in Western Australia	0.62
Darwin Katherine Interconnected System (DKIS) in the Northern Territory	0.59
Tasmania	0.14
Northern Territory	0.64

Sources: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 1) and Department of the Environment and Energy.

Example: calculation of emissions from electricity consumption

A company in New South Wales consumes 100,000 kWh of purchased electricity from the grid.

Emissions of greenhouse gases (scope 2) in tonnes of CO_2-e are estimated as follows:

= 100,000 x (0.83 /1000)

= 83 tonnes.

Total scope 2 GHG emissions = 83 tonnes CO_2-e

2.3.3 Emissions factors for the *Carbon Credits (Carbon Farming Initiative) Act 2011*

This section contains emissions factors for electricity grids to be used for calculating a carbon dioxide equivalent net abatement amount in accordance with a methodology determination under the *Carbon Credits (Carbon Farming Initiative) Act 2011*.

Table 6 : Indirect (scope 2) emissions factors for electricity grids

Electricity grid	Emissions factor kg CO_2-e/kWh
National Electricity Market (NEM)	0.82
South West Interconnected System (SWIS) in Western Australia	0.70
North Western Interconnected System (NWIS) in Western Australia	0.62
Darwin Katherine Interconnected System (DKIS) in the Northern Territory	0.59
Off-grid	0.64

Note: The method for calculating Scope 2 emission factors is described in detail in Chapter 7 of the *National Greenhouse and Energy Reporting System Management Technical Guidelines for the estimation of greenhouse gas emissions by facilities in Australia.*

Sources: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 1) and Department of the Environment and Energy.

2.4 Fugitive emissions from fuels

2.4.1 Coal Mining

2.4.1.1 Underground mines

Fugitive emissions from underground mines involve the release of methane and carbon dioxide during the mining process due to the fracturing of coal seams, overburden and underburden strata. Emissions also arise from post mining activities such as transportation and stockpiling of coal from the release of residual gases not released during the mining process. Emissions will also occur when coal mine waste gas is flared.

Where the estimation of fugitive emissions from underground mining activities is for the purposes of NGER reporting, then direct measurement (method 4) under section 3.6 of Chapter 3 in the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* must be used. As method 1 is no longer available for NGER reporting, it is also not reflected here in the NGA Factors publication. However a summary of the fugitive gas emission profile of Australian underground coal 2015 production by coalfield is provided for reference in section 3.8.2 of the National Inventory Report 2015 Volume 1.

Fugitive emissions from post-mining activities (gassy underground mines only)

Emissions from post-mining activities (associated with gassy underground mines only) can be estimated using the method described below

$$E_j = Q \times EF_j$$

Q is the quantity of run-of-mine coal extracted (tonnes).

EF$_j$ is taken to be 0.017, which is the emission factor for methane (j), measured in CO_2-e tonnes per tonne of run-of-mine coal extracted from the mine.

Table 7: Post-mining activities—emission factors

Post-mining activities	Emission factor (tonnes CO_2-e/ tonne raw coal)
	CH_4
Post mining activities associated with gassy underground mines	0.017

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.17).

2.4.1.2 Open cut mines

The method for estimating emissions from open cut mining operations is described below.

$$E_j = Q \times EF_j$$

where:

E$_j$ is the fugitive emissions of methane (j) that result from the extraction of coal from the mine during the year measured in CO_2-e tonnes.

Q is the quantity of run-of-mine coal extracted from the mine during the year measured in tonnes.

EF$_j$ is the emission factor for methane (j), measured in CO_2-e tonnes per tonne of run-of-mine coal extracted from the mine, taken to be the following:

Table 8: Emission factors for the production of coal (fugitive) - Open cut

Activities related to extraction of coal (fugitive)	Emission factor (tonnes CO_2-e/ tonne raw coal)
	CH_4
Open cut mines—NSW	0.054
Open cut mines—Queensland	0.020
Open cut mines—Tasmania	0.017
Open cut mines—Victoria	0.00027
Open cut mines—South Australia	0.00027
Open cut mines—Western Australia	0.020

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.20).

Example: calculation of emissions from open cut mining

An open cut coal mine in NSW extracts 2,554,000 tonnes of run-of-mine coal during the year. Emissions of greenhouse gas (methane) in tonnes of CO_2-e are estimated as follows:

$$E_j = Q \times EF_j$$

where:

$\mathbf{E}_j$ is the emissions of methane in CO_2-e tonnes.
Q is the quantity of run-of-mine coal extracted = 2,554,000 tonnes of raw coal.
$\mathbf{EF_j}$ is the emission factor for methane in CO_2 e tonnes per tonne of raw coal extracted from the mine. In this case, for an open cut mine in NSW the emission factor is 0.054 tonnes CO_2-e per tonne of raw coal extracted.
Therefore, the estimate of methane emissions in CO_2-e tonnes:

= (2,554,000 x 0.054)

Total scope 1 GHG emissions = 137,917t CO_2-e

2.4.1.3 Fugitive emissions from coal mine waste flared

Greenhouse gas emissions from flaring coal mine waste gas can be estimated by multiplying the quantity of gas flared by the energy content and emission factor for each gas type.

$$E_{(fl)ij} = \frac{Q_{i,flared} \times EC_i \times EF_{ij}}{1000} \times OF_{if}$$

where:

$\boldsymbol{E_{(fl)ij}}$ is the emissions of gas type (j) released from coal mine waste gas (i) flared from the mine (CO_2-e tonnes).

$\boldsymbol{Q_{i,flared}}$ is the quantity of coal mine waste gas (i) (cubic metres).

$\boldsymbol{EC_i}$ is the energy content factor of coal mine waste gas (i), in Table 2 (gigajoules per cubic metre).

$\boldsymbol{EF_{ij}}$ is the emission factor for gas type (j) and coal mine waste gas (i) in Table 2 (kilograms CO_2-e per gigajoule).

$\boldsymbol{OF_{if}}$ is 0.98 which is the destruction efficiency of coal mine waste gas (i) flared.

2.4.1.4 Decommissioned underground mines

Fugitive emissions can be estimated from decommissioned underground mines that have been closed for a continuous period of at least 1 year but less than 20 years. A detailed description of the methodology is found in Division 3.2.4 of Chapter 3 in the *National Greenhouse and Energy Reporting (Measurement) Determination 2008.*

2.4.2 Oil and natural gas fugitive emissions

This section includes fugitive emissions from exploration, production, transport, storage, processing and refining of oil and natural gas. Other sources of emissions arising from the production processes, such as from the combustion of fuels for energy, are not described in this chapter and must be estimated using the Methods described in other chapters.

In this section, natural gas includes coal seam methane that is captured for combustion where the production of coal is not intended to occur.

2.4.2.1 Oil and gas exploration-flared emissions

$$E_{ij} = Q_i \times EF_{ij}$$

where:

E_{ij} is the fugitive emissions of gas type (j) from a fuel type (i) flared in oil and gas exploration (CO_2-e tonnes).

Q_i is the quantity of fuel type (i) flared (tonnes).

EF_{ij} is the emission factor for gas type (j) of fuel type (i) flared (tonnes of CO_2-e per tonne flared)

Table 9: Oil and gas exploration-flared emission factors

Fuel type (*i*)	Emission factor (EF_{ij}) (tonnes CO_2-e/tonnes flared)		
	CO_2	CH_4	N_2O
Gas flared	2.8	0.8	0.03
Liquid flared	3.2	0.008	0.07

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.44).

2.4.2.2 Oil and gas exploration-vented emissions

Emissions may occur during exploration as a result of venting and accidental releases such as blowouts. The American Petroleum Institute's Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009 (API Compendium) should be consulted in accordance with the list below for methodologies to estimate vented emissions for the respective emission processes:

Emission process	API Compendium section
Gas treatment processes	Section 5.1
Cold process vents	Section 5.3
Natural gas blanketed tank emissions	Section 5.4.4
Other venting sources — gas driven pneumatic devices	Section 5.6.1
Other venting sources — gas driven chemical injection pumps	Section 5.6.2
Other venting sources — coal seam exploratory drilling, well testing and mud degasssing	Section 5.6.3 or 5.6.6
Non-routine activities — production related non-routine emissions	Sections 5.7.1 or 5.7.2
Non-routine activities — gas processing related non-routine emissions	Sections 5.7.1 or 5.7.3

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2.4.2.3 Crude oil production

Crude oil production consists of emissions from non-flared sources (eg, gas leakage, accidental releases, vents and storage losses) and from flaring. Separate methods for estimating emissions from non-flared (leaks and vents) and flared sources are detailed below

Crude oil production (non-flared) – fugitive leaks emissions of methane

Fugitive leakage emissions of methane may occur in crude oil production from sources such as the unintentional equipment leaks from valves, flanges, pump seals, compressor seals, relief valves, sampling connections, process drains, open-ended lines, casing, tanks and other leakage sources from pressurised equipment not

classed as a vent.

$$E_{ij} = \Sigma_k (Q_{ik} \times EF_{ijk}) + Q_i \times EF_{(l)\,ij}$$

where:

E_{ij} is the fugitive emissions of methane (j) (CO_2-e tonnes).

Σ_k is the total emissions of methane (j), by summing up the emissions released from each equipment type (k) specified in Table 9 (CO_2-e tonnes).

Q_{ik} is the quantities of crude oil that pass through each equipment type (k) (tonnes).

EF_{ijk} is the emission factor for methane (j) (CO_2-e tonnes per tonne of crude oil that passes through each equipment type (k)) listed in Table 9.

Q_i is the total quantity of crude oil production throughput (i) measured in tonnes.

$EF_{(l)\,ij}$ is 1.4×10^{-3}, which is the emission factor for methane (j) from general leaks in crude oil production, (CO_2-e tonnes per tonne of crude oil throughput). General leaks in the crude oil production comprises the emissions (other than vent emissions) from equipment listed in sections 5.4.3, 5.6.4, 5.6.5 and 6.1.2 of the API Compendium,

Table 10: Oil production (other than venting and flaring) emission factors

Equipment type *(k)*	**Emission factor (EF_{ij}) (tonnes CO_2-e/tonnes throughput)**
	CH_4
Internal floating tank	1.0×10^{-6}
Fixed roof tank	5.0×10^{-6}
Floating tank	4.0×10^{-6}

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.49).

Crude oil production (non-flared) – fugitive vent emissions of methane and carbon dioxide

The API Compendium should be consulted in accordance with the list below for methodologies to estimate vented emissions for the respective emission processes:

Emission process	API Compendium section
Gas treatment processes	Section 5.1
Cold process vents	Section 5.3
Natural gas blanketed tank emissions	Section 5.4.4
Other venting sources — gas driven pneumatic devices	Section 5.6.1
Other venting sources — gas driven chemical injection pumps	Section 5.6.2
Other venting sources — coal seam exploratory drilling, well testing and mud degassing	Section 5.6.3 or 5.6.6
Non-routine activities — production related non-routine emissions	Sections 5.7.1 or 5.7.2
Non-routine activities — gas processing related non-routine emissions	Sections 5.7.1 or 5.7.3

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Crude oil production (flared emissions)

$$E_{ij} = Q_i \times EF_{ij}$$

where:

E_{ij} is the fugitive emissions of gas type (j) from a fuel type (i) flared in the crude oil production (CO_2-e tonnes).

Q_i is the quantity of fuel type (i) flared (tonnes).

EF_{ij} is the emission factor for gas type (j) of fuel type (i) flared (tonnes of CO_2-e per tonne flared)

Table 11: Crude oil production (flared emissions) emission factors

Fuel type (*i*)	Emission factor (EF_{ij}) (tonnes CO_2-e/tonnes of fuel flared)		
	CO_2	CH_4	N_2O
Gas flared	2.8	0.8	0.03
Liquid flared	3.2	0.008	0.07

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.52).

Example: calculation of emissions from crude oil production

A crude oil production platform has a throughput of 710,400 tonnes of crude oil during the year. It has an equipment type constituting a floating tank in which 685,000 tonnes of crude oil throughput occurred during the year. 400 tonnes of crude oil were flared during the year.

Emissions are estimated as follows:

Part A: Crude oil production (non flared-leakage component)

$$E_{ij} = \Sigma_k (Q_{ik} \times EF_{ijk}) + Q_i \times EF_{(l)\,ij}$$

where:

E_{ij} is the emissions measured in CO_2-e tonnes of methane

Σ_k is the sum of emissions of methane (tonnes of CO_2-e) arising from relevant equipment types listed in Table 9

Q_{ik} is the quantity of crude oil (tonnes) passing through each equipment of type in Table 9. **In this case 685,000 tonnes of crude oil passes through floating tanks equipment**

EF_{ijk} is the methane emission factor specific to equipment types listed in Table 9 (tonnes of CO_2-e per tonne of crude oil throughput) . **In this case it is the emission factor for the floating tank 4.0 x 10^{-6} tonnes CO_2-e/tonnes fuel throughput.**

Q_i is the total quantity of crude oil production (tonnes). **In this case the total crude oil production is 710,400 tonnes**.

$EF_{(l)\,ij}$ **1.4 x 10^{-3}**, is the emission factor for methane from general leaks in crude oil production (CO_2 e tonnes per tonne of crude oil throughput).

Therefore, emissions of greenhouse gas (methane) in tonnes CO_2-e:

$$= (685{,}000 \times 4.0 \times 10^{-6}) + (710{,}400 \times 1.4 \times 10^{-3})$$

Total scope 1 GHG emissions from crude oil production (non flared component) = 997 t CO_2-e

Part B: Crude oil production (flared component)

where:

$$E_{ij} = Q_i \times EF_{ij}$$

E_{ij} is the emissions of greenhouse gases (carbon dioxide, methane and nitrous oxide) from fuel flared (CO_2-e tonnes)

Q_i is the quantity of fuel type flared (tonnes). **In this case the quantity of crude oil flared is 400 tonnes**.

EF_{ij} is the emission factor for the fuel type flared (tonnes of CO_2-e emissions per tonne of fuel type flared) (Table 10).

Therefore, emissions of greenhouse gases (carbon dioxide, methane and nitrous oxide) in tonnes of CO_2 e are estimated as follows:

Emissions of carbon dioxide:

= 400 x 3.2

= 1,280 t CO_2-e

Emissions of methane:

= 400 x 0.008

= 3 t CO_2-e

Emissions of nitrous oxide:

= 400 x 0.07

= 28 t CO_2-e

Total scope 1 GHG emissions from crude oil production (flared component)

= 1280 + 3 + 28

= 1,311 t CO_2-e

Part C: Crude oil production (vented emissions component)

Refer to section 3.84 which specifies the applicable sections of the American Petroleum Institute's Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry *2004 (API Compendium).* The reporter estimates their vented emissions in accordance with those methods detailed in the API Compendium, producing the following results:

Total emissions of carbon dioxide = 380 t CO2-e

Total emissions of methane = 980 t CO2-e

Part D: Total Crude oil production emissions

= non-flared-leakage component + vented component + flared component

= 997 + 380 + 1,167 + 1311

Total scope 1 GHG emissions from Crude oil production = 3,855 t CO_2-e

2.4.2.4 Crude oil transport

The crude oil transport subsector includes methane emissions associated with the marine, road and rail transport of crude oil. Emissions result largely from three types of activities: loading, transit, and ballasting

$$E_{ij} = Q_i \times EF_{ij}$$

where:

E_{ij} is the fugitive emissions of methane from crude oil transport (CO_2-e tonnes).

Q_i is the quantity of crude oil transported (tonnes).

EF_{ij} is the emission factor for methane (j), (tonnes CO_2-e per tonnes of crude oil transported).

Table 12: Oil transport emission factors

Operation or process source	Emission factor (EF_{ij}) (tonnes CO_2-e/tonne of oil transported)
	CH_4
Crude oil transport (domestic)	8.7×10^{-4}

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.59).

2.4.2.5 Crude oil refining

Crude oil refining consists of emissions from:

- Fugitive emissions from crude oil refining and storage
- process vents, system upsets and accidents (burning of catalyst coke for non-energy purposes)
- flaring.

Fugitive emissions from crude oil refining and storage

$$E_j = \Sigma_i \ (Q_i \times EF_{ij})$$

where:

E_j is the fugitive emissions of methane (j) from crude oil refined and stored in tanks (i) (CO_2-e tonnes).

$\sum_i$ is the sum of emissions of methane (j) released during refining and from storage tanks.

Q_i is the quantity of crude oil (i) refined or stored in tanks (tonnes).

EF_{ij} is the emission factor for tonnes of methane (j) (tonnes CO_2-e per tonne of crude oil refined and crude oil stored in tanks).

Table 13: Oil refining and storage emission factors

Operation or process source	Emission factor (EF_{ij}) (tonnes CO_2-e/tonne of oil refined or stored)
	CH_4
Crude oil refining	8.5×10^{-4}
Crude oil storage	1.5×10^{-4}

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.63).

Crude oil refining (combustion of catalyst coke for non-energy purposes)

$$E_i = Q_i \times CCF_i \times 3.664$$

where:

E_i is the fugitive emissions during the year from deliberate releases from process vents, system upsets and accidents in the crude oil refining measured in CO_2 e tonnes.

Q_i is the quantity of refinery coke (i) burnt to restore the activity of the catalyst of the crude oil refinery (and not used for energy) during the year measured in tonnes.

CCF_i is the carbon content factor for refinery coke (i). See Appendix 3.

3.664 is the conversion factor to convert an amount of carbon in tonnes to an amount of carbon dioxide in tonnes.

Crude oil refining (flared emissions)

$$E_{ij} = Q_i \times EF_{ij}$$

where:

E_{ij} is the fugitive emissions of gas type (j) from a fuel type (i) flared in crude oil refining (CO_2-e tonnes).

Q_i is the quantity of fuel type (i) flared (tonnes).

EF_{ij} is the emission factor for gas type (j) of fuel type (i) flared (tonnes of CO_2-e per tonne flared)

Table 14: Refinery gas flaring emission factors

Fuel type (*i*)	Emission factor (EF_{ij}) (tonnes CO_2-e/tonnes flared)		
	CO_2	CH_4	N_2O
Gas flared	2.7	0.1	0.03

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.67).

2.4.2.6 Natural gas production and processing (other than emissions that are vented or flared)

Fugitive leakage emissions of methane may occur in natural gas production from sources such as the unintentional equipment leaks from valves, flanges, pump seals, compressor seals, relief valves, sampling connections, process drains, open-ended lines, casing, tanks and other leakage sources from pressurised equipment not classed as a vent.

The venting of carbon dioxide and methane extracted from raw gas and flaring of unusable gas produced at various stages of processing should be separately accounted for under venting and flaring.

Other sources of emissions arising from natural gas production and processing, such as from the combustion of fuels for energy, are not described in this chapter and must be estimated using the Methods described in other chapters.

$$E_{ij} = \Sigma_k \ (Q_{ik} \times EF_{ijk}) + Q_i \times EF_{(l)\,ij}$$

where:

E_{ij} is the fugitive emissions of methane (j) (CO_2-e tonnes).

Σ_k is the total emissions of methane (j), by summing up the emissions released from each equipment type (k) specified in Table 14 (CO_2-e tonnes).

Q_{ik} is the quantities of natural gas that pass through each equipment type (k) (tonnes).

EF_{ijk} is the emission factor for methane (j) (CO_2-e tonnes per tonne of natural gas that passes through each equipment type (k)) as shown in Table 14.

Q_i is the total quantity of natural gas (i) that passes through the natural gas production and processing measured in tonnes.

$EF_{(l)\,ij}$ is 1.2×10^{-3}, which is the emission factor for methane (j) from general leaks in the natural gas production and processing, (CO_2-e tonnes per tonne of natural gas throughput). General leaks in the crude oil production comprises the emissions (other than vent emissions) from equipment listed in sections 5.4.3, 5.6.4, 5.6.5 and 6.1.2 of the API Compendium,

Table 15: Natural gas production and processing (other than emissions that are vented or flared) emission factors

Equipment type *(k)*	Emission factor EF_{ijk} (tonnes CO_2-e/tonnes throughput)
	CH_4
Internal floating tank	1.0×10^{-7}
Fixed roof tank	5.0×10^{-6}
Floating tank	3.8×10^{-6}

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.72).

2.4.2.7 Natural gas transmission

Transmission mains are defined as high-pressure pipelines greater than 1050 kilopascals, as used in the Energy Supply Association of Australia natural gas statistics.

$$E_{ij} = Q_i \times EF_{ij}$$

where:

E_{ij} is the fugitive emissions of gas type (j) from natural gas transmission through a system of pipelines of length (i) (CO_2-e tonnes).

Q_i is the length of the system of pipelines (i) (kilometres).

EF_{ij} is the emission factor for gas type (j), (tonnes of CO_2-e emissions per kilometre of pipeline (i)).

Table 16: Natural gas transmission emission factors

Operation or process source	Emission factor (tonnes CO_2-e/km pipeline length)	
	CO_2	CH_4
Natural gas transmission	0.02	10.4

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.76).

Example

A company has a network of natural gas transmission pipelines with a total length of 3600 km, over a year. Emissions are estimated as follows:

$$E_{ij} = Q_i \times EF_{ij}$$

where:

E_{ij} is the emissions measured in CO_2-e tonnes of gas type (j), being either carbon dioxide or methane, released from natural gas transmission through a system of pipelines of length (i) (CO_2-e tonnes).

Q_i is the length of the system of pipelines (i) (kilometres). In this case pipeline length is 3600 km.

EF_{ij} is the emission factor for gas type (j) being 0.02 for carbon dioxide and 10.4 for methane (tonnes of CO2-e emissions per kilometre of pipeline (i)). See Table 15.

Therefore, to estimate greenhouse gas emissions (carbon dioxide and methane) in CO_2-e tonnes:

Emissions of carbon dioxide:

= 3600 x 0.02

= 72 t CO_2-e

Emissions of methane

= 3,600 x 10.4

= 37,440 t CO_2-e

Total scope 1 GHG emissions = 72 + 37,440

= 37,512 t CO_2-e

2.4.2.8 Natural gas distribution

The boundary between natural gas transmission and distribution is generally taken to be the city gate regulator stations at which gas pressures are reduced from transmission pressures to sub-transmission pressures. For the purposes of this methodology, natural gas distribution comprises low, medium and high-pressure reticulation ≤ 1050 kilopascals. Greenhouse gases emitted from utility pipeline systems are estimated from the following equation.

$$E_j = S \times \%UAG \times 0.55 \times C_j$$

where:

E_j is the greenhouse gas emitted from the gas distribution system in utility pipelines system (in tonnes CO_2-e)

S is the total gas utility sales from the pipeline system (in terajoules)

%UAG is the percentage of unaccounted for gas in a state's pipeline system, relative to the amount issued annually by gas utilities (see Table 17)

C_j is the natural gas composition factor for natural gas supplied from the state pipeline system (in tonnes CO_2-e per terajoule) (see Table 17)

0.55 represents the portion of unaccounted for gas allocated as leakage

Table 17: Natural gas leakage factors

State	Unaccounted for gas *(%UAG)*	Natural gas composition factor (tonnes CO_2-e/TJ) *(C)*	
	UAG	CO_2	CH_4
NSW and ACT	2.2	0.8	390
VIC	3.0	0.9	388
QLD	1.7	0.8	377
WA	2.9	1.1	364
SA	4.9	0.8	390
TAS	0.2	0.9	388
NT	2.2	0.0	314

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.80).

2.4.2.9 Natural gas production and processing (emissions that are vented or flared)

Natural gas production and processing - venting

Venting refers to emissions that are the result of processes or equipment design or operational practices. Venting at oil or gas processing facilities is mainly associated with the release of CO_2, which is extracted from the raw gas stream in the course of gas processing. Because separation of the other components of the gas stream from the CO_2 is incomplete, the vented CO_2 contains small quantities of methane.

The API Compendium should be consulted in accordance with the list below for methodologies to estimate vented emissions for the respective emission processes:

Emission process	API Compendium section
Gas treatment processes	Section 5.1
Cold process vents	Section 5.3
Natural gas blanketed tank emissions	Section 5.4.4
Other venting sources — gas driven pneumatic devices	Section 5.6.1
Other venting sources — gas driven chemical injection pumps	Section 5.6.2
Other venting sources — coal seam exploratory drilling, well testing and mud degassing	Section 5.6.3 or 5.6.6
Non-routine activities — production related non-routine emissions	Sections 5.7.1 or 5.7.2
Non-routine activities — gas processing related non-routine emissions	Sections 5.7.1 or 5.7.3

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Natural gas production and processing – flaring

Flaring refers to the controlled release to combustion of a mixed flammable gas stream. At gas processing plants, flared gas may arise from natural gas processing. Where there is no market for gas separated from the wellhead production stream, the gas is reinjected or flared.

This subsector does not include flaring from petroleum refining activities, which should be reported separately under 1.B.2a.iv Crude Oil refining and storage.

$$E_{ij} = Q_i \times EF_{ij}$$

where:

$\boldsymbol{E_{ij}}$ is the emissions of gas type (j) from a fuel type (i) flared (CO_2-e tonnes)

$\boldsymbol{Q_i}$ is the quantity measured in tonnes of gas flared.

$\boldsymbol{EF_{ij}}$ is the emission factor for gas type (j) for fuel type (i) flared (tonnes of CO_2-e per tonne of gas flared).

Table 18: Flaring emission factors

Operation or process source	Emission factor (tonnes CO_2-e/tonnes flared)		
	CO_2	CH_4	N_2O
Gas flared	2.7	0.1	0.03

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.85)

4 Industrial processes including use of synthetic gases

Greenhouse gas emissions from industrial processes other than from combustion of fuels for energy may be estimated by using the methods described in this section. These emission factors are national average emissions factors and can be used in the absence of plant- or company-specific data. For information on estimating activity data, refer to the National Greenhouse and Energy Reporting (Measurement) Determination 2008.

4.1 Cement clinker production

$$E_{ij} = \left(EF_{ij} + EF_{toc,j}\right) \times \left(A_i + A_{ckd} \times F_{ckd}\right)$$

where:

$\boldsymbol{E_{ij}}$ is the emissions of CO_2 released from the production of cement clinker (CO_2 -e tonnes)

$\boldsymbol{EF_{ij}}$ is the emission factor for cement clinker (tonnes of CO_2 emissions per tonne of clinker produced). See Table 18.

$\boldsymbol{A_i}$ is the quantity of cement clinker produced (tonnes)

$\boldsymbol{A_{ckd}}$ is the quantity of cement kiln dust (CKD) produced (tonnes)

$\boldsymbol{EF_{toc,j}}$ is the emission factor for carbon-bearing non-fuel raw material (tonnes of CO_2 emissions per tonne of clinker produced). See Table 18.

$\boldsymbol{F_{ckd}}$ is the degree of calcination of cement kiln dust (range from 0% to 100%). If the information is not available the degree is assumed to be 100%, that $\boldsymbol{F_{ckd}}$ =1

Table 19: Clinker production emission factors

Source	Emission factor (tonnes CO_2-e per tonne)
	CO_2
EF_{ij}	0.534
$EF_{toc,j}$	0.010

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 4.4).

Example: **Calculation of emissions generated from cement clinker production**

A company produces 20,000 tonnes of cement clinker and 300 tonnes of cement kiln dust per year. The degree of calcination of the cement dust is not known. The GHG emissions are calculated as follows:

= (0.534 + 0.01) x (20,000 + 300 x 1)

= 11,043 tonnes CO_2-e

Total scope 1 GHG emissions = 11,043 tonnes CO_2-e

4.2 Lime production

This section applies to lime production other than in-house lime production in the ferrous metals industry, which should apply the method described under “Other uses of carbonates’.

$$E_{ij} = \left(A_i + A_{lkd} \times F_{lkd}\right) \times EF_{ij}$$

where:

E_{ij} is the emissions of CO_2 from the production of lime (CO_2 -e tonnes)

A_i is the amount of lime produced (tonnes)

A_{lkd} is the quantity of lime kiln dust lost in the production of lime (tonnes)

Flkd is:

(a) the fraction of calcination achieved for lime kiln dust in the production of lime during

the year; or

(b) if the data is not available — the value 1.

EF_{ij} is the CO_2 emission factor (tonnes of CO_2 / tonnes lime produced). See Table 20.

Table 20: Lime production emission factors

Source	Emission factor (EF_{ij}) (tonne CO_2-e per tonne)
	CO_2
Commercial lime production	0.675
In-house lime production	0.730
Magnesian lime and dolomitic lime production	0.860

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 4.13).
Note: Dolomitic lime is lime formed from limestone containing more than 35 % magnesium carbonate.
Magnesian lime is lime formed from limestone containing 5-35 % magnesium carbonate.

4.3 Use of carbonates for the production of a product other than cement clinker, lime or soda ash

This section applies to calcination or any other use of carbonates that generates CO_2 (excluding cement clinker, lime production or soda ash production) including the in-house lime production in the ferrous metals industry. Other examples of industrial processes involving the consumption of carbonates include:

- Metallurgy
- Glass manufacturing including fibreglass and mineral wools
- Magnesia production
- Construction
- Environmental pollution control
- Use as a flux or slagging agent
- Phosphoric acid production form phosphate rock containing carbonates

- Brick production
- Ceramic production

$$E_{ij} = Q_i \times EF_{ij} \times F_{cal}$$

where:

E_{ij} is the annual emissions of CO_2 from the consumption of carbonate (CO_2-e tonnes)

Q_j is the quantity of raw carbonate material consumed (tonnes)

EF_{ij} is the CO_2 emission factor for each carbonate material type (tonnes CO_2 per tonne of carbonate). See Table 20.

F_{cal} is the fraction of the carbonate calcined. If the information is not available the degree is assumed to be 100%, that F_{cal} =1

Total greenhouse emissions are calculated by summing the emissions of each carbonate type consumed.

Table 21: Calcination of carbonates emission factors

Source of carbonate consumption	Emission factor (EF_{ij}) (tonne CO_2-e per tonne)
	CO_2
Limestone (calcium carbonate)	0.396
Magnesium carbonate	0.522
Dolomite	0.453

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 4.22).

4.4 Use of carbonates in clay materials

An alternative method 1 for use of carbonates in clay materials is provided. This method 1 uses the inorganic carbon content of the clay material consumed and the quantity of clay material consumed to estimate emissions from this source. Default inorganic carbon content factors are provided by State and Territory.

measure the amount of emissions of carbon dioxide released from each clay material consumed in the industrial process during the reporting year, measured in CO_2-e tonnes, using the following formula:

$$E_j = Q_j \times ICC_j \times 3.664$$

where:

E_j is the emissions of carbon dioxide released from the clay material consumed in the industrial process during the reporting year in a State or Territory (***j***) mentioned in column 2 of an item in the table in subsection (2), measured in CO_2-e tonnes.

Q_j is the quantity of clay material consumed in the industrial process during the reporting year in a State or Territory (***j***) mentioned in column 2 of an item in the table in subsection (2), measured in tonnes and estimated under Division 4.2.5.

ICC_j is the inorganic carbon content factor of clay material specified in column 3 of an item in the table in subsection (2) for each State or Territory (***j***) mentioned in column 2 of the item.

(2) For ICC_j in subsection (1), column 3 of an item in the following table specifies the inorganic carbon content factor for a State or Territory (***j***) mentioned in column 2 of the item.

Item	State or Territory (j)	Inorganic carbon content factor
1	New South Wales	6.068×10^{-3}
2	Victoria	2.333×10^{-4}
3	Queensland	2.509×10^{-3}
4	Western Australia	3.140×10^{-4}
5	South Australia	5.170×10^{-4}
6	Tasmania	1.050×10^{-3}
7	Australian Capital Territory	6.068×10^{-3}
8	Northern Territory	5.170×10^{-4}

4.5 Soda ash use

This section applies to the use of soda ash. Examples of soda ash in industrial processes include:

- Glass production
- Soap and detergent production
- Flue gas desulphurisation
- Pulp and paper production

This Method is derived from the methodology used for the National Greenhouse Accounts. It involves the multiplication of the quantity of soda ash consumed in the production process by the emission factor for soda ash.

$$E_{ij} = Q_i \times EF_{ij}$$

where:

E_{ij} is the emissions of CO_2 from the use of soda ash (CO_2-e tonnes)

Q_i is the amount of soda ash consumed (tonnes)

EF_{ij} is the CO_2 emission factor (tonnes of CO_2 / tonnes of soda ash used). See Table 22.

Table 22: Soda ash consumption emission factor

Source	Emission factor (EF_{ij}) (tonne CO_2-e per tonne)
	CO_2
Soda ash use	0.415

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 4.29).

4.6 Soda ash production

Emissions from soda ash production arise from the consumption of fuels for energy and from the calcination of limestone and sodium bicarbonate. The production of soda ash is a multi-step process involving the generation and reabsorption of carbon dioxide. To obtain a more

accurate estimation of emissions from the consumption of fuels and calcination processes a carbon balance approach is taken.

Step 1 Calculate the carbon content in fuel types (***i***) or carbonate material (***j***) delivered for the activity during the year measured in tonnes of carbon as follows:

$$\sum_i CCF_i \times Q_i + \sum_j \times CCF_j \times F_j \times L_j$$

where:

$\sum_i$ means sum the carbon content values obtained for all fuel types (***i***).

CCF_i is the carbon content factor mentioned in Schedule 3 measured in tonnes of carbon for each appropriate unit of fuel type (***i***) consumed during the year from the operation of the activity.

Q_i is the quantity of fuel type (***i***) delivered for the activity during the year measured in an appropriate unit and estimated in accordance with Division 2.2.5, 2.3.6 and 2.4.6.

$\sum_j$ means sum the carbon content values obtained for all pure carbonate material (***j***).

CCF_j is the carbon content factor mentioned in Schedule 3 measured in tonnes of carbon for each tonne of pure carbonate material (***j***) consumed during the year from the operation of the activity.

F_j is the fraction of pure carbonate material (***j***) in the raw carbonate input material and taken to be 0.97 for calcium carbonate and 0.018 for magnesium carbonate.

L j is the quantity of raw carbonate input material (***j***) delivered for the activity during the year measured in tonnes and estimated in accordance with Division 4.2.5.

Step 2 Calculate the carbon content in products (***p***) leaving the activity during the year measured in tonnes of carbon as follows:

$$\sum_p CCF_p \times F_p \times A_p$$

where:

$\sum_p$ means sum the carbon content values obtained for all product types (***p***).

CCF_p is the carbon content factor mentioned in Schedule 3 and measured in tonnes of carbon for each tonne of product type (***p***) produced during the year.

F_p is the fraction of pure carbonate material in the product type (***p***).

Ap is the quantity of product types (***p***) produced leaving the activity during the year measured in tonnes.

Step 3 Calculate the carbon content in waste by-product types ***(r)*** leaving the activity, other than as an emission of greenhouse gas, during the year, measured in tonnes of carbon, as follows:

$$\sum_r CCF_r \times F_r \times Y_r$$

where:

Σ_r means sum the carbon content values obtained for all waste by-product types (***r***).

CCF_r is the carbon content factor mentioned in Schedule 3 measured in tonnes of carbon for each tonne of waste by-product types (***r***).

Y_r is the quantity of waste by-product types (***r***) leaving the activity during the year measured in tonnes.

Step 4 Calculate the carbon content in the amount of the increase in stocks of inputs, products and waste by-products held within the boundary of the activity during the year in tonnes of carbon as follows:

$$\Sigma_i CCF_i \times \Delta S_{qi} + \Sigma_j CCF_j \times \Delta S_{qj} + \Sigma_p CCF_p \times \Delta S_{ap} + \Sigma_r CCF_r \times \Delta S_{yr}$$

where:

Σ_i has the same meaning as in step 1.

CCF_i has the same meaning as in step 1.

ΔS_{qi} is the increase in stocks of fuel type (***i***) for the activity and held within the boundary of the activity during the year measured in tonnes.

CCF_j has the same meaning as in step 1.

ΔS_{qj} is the increase in stocks of pure carbonate material (***j***) for the activity and held within the boundary of the activity during the year measured in tonnes.

Σ_p has the same meaning as in step 2.

CCF_p has the same meaning as in step 2.

ΔS_{ap} is the increase in stocks of product types (***p)*** produced by the activity and held within the boundary of the activity during the year measured in tonnes.

Σ_r has the same meaning as in step 3.

CCF_r has the same meaning as in step 3.

ΔS_{yr} is the increase in stocks of waste by-product types (***r***) produced from the operation of the activity and held within the boundary of the activity during the year measured in tonnes.

Step 5 Calculate the emissions of carbon dioxide released from the operation of the activity during the year measured in CO_2-e tonnes as follows:

(a) add the amounts worked out under steps 2, 3 and 4 to work out a new amount (***amount A***);

(b) subtract amount A from the amount worked out under step 1 to work out a new amount (***amount B***);

(c) multiply amount B by 3.664 to work out the amount of emissions released from the operation of the activity during a year.

4.7 Ammonia production

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ij}}{1000} - R$$

where:

E_{ij} is emissions of CO_2 (tonnes of CO_2-e)

Q_i is the quantity of each fuel consumed as a feedstock(cubic metres)

EC_i is the energy content of the fuel type ***(i)*** used as a feedstock (gigajoules per cubic metre)

If ***Q_i*** is measured in gigajoules, then ***EC_i*** is 1.

EF_{ij} is the emission factor for each fuel type ***(i)*** used as a feedstock (kilograms CO_2-e per gigajoule)

R is the CO_2 recovered for downstream use (tonnes of CO_2-e)

Energy content and gas emission factors for each fuel type should be taken from the fuel combustion emission factors listed in Tables 1, 2 and 3.

4.8 Nitric acid production

$$E_{ijk} = EF_{ijk} \times A_{ik}$$

where:

E_{ijk} is the emissions of nitrous oxide from the production of nitric acid at the plant type k (tonnes)

A_{ik} is the quantity of nitric acid produced from plant type k (tonnes)

EF_{ijk} is the emission factor of nitrous oxide from plant type k (tonnes). See Table 23.

Table 23: Nitric acid production emission factors

Plant type (k)	Emission factor (tonnes CO_2-e per tonne of production)
	N_2O
Atmospheric pressure plants (low pressure)	1.49
Medium pressure combustion plant	2.09
High pressure plant	2.68

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 4.47).

4.9 Adipic acid production

Methods for estimating emissions from the production of adipic acid are given in section 3.4 of the 2006 IPCC Guidelines.

4.10 Carbide production

Methods for estimating emissions from the carbide production are given in section 3.6 of the 2006 IPCC Guidelines.

4.11 Chemical or mineral production, other than carbide production, using a carbon reductant

This section covers emissions from the production of chemical or mineral products, other than carbide where a carbon reductant is used (for example, the production of titanium dioxide or synthetic rutile)

Step 1 Work out the carbon content in fuel types (i) or carbonaceous input material delivered for the activity during the year measured in tonnes of carbon as follows:

$$\Sigma_i \, CCF_i \times Q_i$$

where:

Σ_i means sum the carbon content values obtained for all fuel types (***i***) or carbonaceous input material.

CCF_i is the carbon content factor mentioned in Schedule 3 measured in tonnes of carbon for each appropriate unit of fuel type (***i***) or carbonaceous input material consumed during the year from the operation of the activity.

Q_i is the quantity of fuel type (***i***) or carbonaceous input material delivered for the activity during the year measured in an appropriate unit and estimated in accordance with criterion A in Division 2.2.5, 2.3.6 and 2.4.6.

Step 2 Work out the carbon content in products (***p***) leaving the activity during the year measured in tonnes of carbon as follows:

$$\Sigma_p \, CCF_p \times A_p$$

where:

Σ_p means sum the carbon content values obtained for all product types (***p***).

CCF_p is the carbon content factor measured in tonnes of carbon for each tonne of product type (***p***) produced during the year.

A_p is the quantity of product types (***p***) produced leaving the activity during the year measured in tonnes.

Step 3 Work out the carbon content in waste by-product types ***(r)*** leaving the activity, other than as an emission of greenhouse gas, during the year, measured in tonnes of carbon, as follows:

$$\Sigma_r \, CCF_r \times Y_r$$

where:

Σ_r means sum the carbon content values obtained for all waste by-product types (***r***).

CCF_r is the carbon content factor measured in tonnes of carbon for each tonne of waste by-product types (***r***).

Y_r is the quantity of waste by-product types (***r***) leaving the activity during the year measured in tonnes.

Step 4 Work out the carbon content in the amount of the increase in stocks of inputs, products and waste by-products held within the boundary of the activity during the year in tonnes of carbon as follows:

$$\Sigma_i CCF_i \times \Delta S_{qi} + \Sigma_p CCF_p \times \Delta S_{ap} + \Sigma_r CCF_r \times \Delta S_{yr}$$

where:

Σ_i has the same meaning as in step 1.

CCF_i has the same meaning as in step 1.

ΔS_{qi} is the increase in stocks of fuel type (***i***) for the activity and held within the boundary of the activity during the year measured in tonnes.

Σ_p has the same meaning as in step 2.

CCF_p has the same meaning as in step 2.

ΔS_{ap} is the increase in stocks of product types (***p***) produced by the activity and held within the boundary of the activity during the year measured in tonnes.

Σ_r has the same meaning as in step 3.

CCF_r has the same meaning as in step 3.

ΔS_{yr} is the increase in stocks of waste by-product types (***r***) produced from the operation of the activity and held within the boundary of the activity during the year measured in tonnes.

Step 5 Work out the emissions of carbon dioxide released from the operation of the activity during the year measured in CO_2-e tonnes as follows:

(a) add the amounts worked out under steps 2, 3 and 4 to work out a new amount (***amount A***);

(b) subtract amount A from the amount worked out under step 1 to work out a new amount (***amount B***);

(c) multiply amount B by 3.664 to work out the amount of emissions released from the operation of the activity during a year.

4.12 Sodium Cyanide

The division for sodium cyanide production now provides a carbon balance methodology for estimating emissions of carbon dioxide and direct measurement for estimating emissions of nitrous oxide applying to emissions of carbon dioxide and nitrous oxide from this source.

The methods available are the carbon balance methodology under Division 4.3.5 and direct measurement under Part 1.3 of the NGERS Measurement Determination 2008.

4.13 Iron and steel or other metal production using an integrated metalworks

Carbon dioxide emissions from the production of iron, steel and any metals produced form an integrated metalworks are estimated using a mass balance approach. Total quantities of carbon inputs, outputs and consumption are considered in steps 1 to 5 detailed below.

Primary sources of emissions from integrated metalworks include combustion of fuels for making coke and from the use of fuel as a carbon reductant in iron and steel production. Other sources include emissions from use of carbonates.

STEP 1

Calculate the carbon content in fuel types (***i***) or carbonaceous input material delivered for the activity during the year measured in tonnes of carbon as follows:

$$\Sigma_i \; CCF_i \times Q_i$$

where:

Σ_i means sum the carbon content values obtained for all fuel types (***i***) or carbonaceous input material.

CCF_i is the carbon content factor in Appendix 3, measured in tonnes of carbon for each appropriate unit of fuel type (***i***) or carbonaceous input material consumed during the year from the operation of the activity.

Q_i is the quantity of fuel type (***i***) or carbonaceous input material delivered for the activity during the year measured in an appropriate unit.

STEP 2

Calculate the carbon content in products (***p***) leaving the activity during the year measured in tonnes of carbon as follows:

$$\Sigma_p \; CCF_p \times A_p$$

where:

Σ_p means sum the carbon content values obtained for all product types (***p***).

CCF_p is the carbon content factor measured in tonnes of carbon for each tonne of product type (***p***) produced during the year.

A_p is the quantity of product types (***p***) produced leaving the activity during the year measured in tonnes.

STEP 3

Calculate the carbon content in waste by-product types ***(r)*** leaving the activity, other than as an emission of greenhouse gas, during the year, measured in tonnes of carbon, as follows:

$$\Sigma_r \; CCF_r \times Y_r$$

where:

Σ_r means sum the carbon content values obtained for all waste by-product types (***r***).

CCF_r is the carbon content factor measured in tonnes of carbon for each tonne of waste by-product types (***r***).

Y_r is the quantity of waste by-product types (***r***) leaving the activity during the year measured in tonnes.

STEP 4

Calculate the carbon content in the amount of the increase in stocks of inputs, products and waste by-products held within the boundary of the activity during the year in tonnes of carbon as follows:

$$\Sigma_i \, CCF_i \times \Delta S_{qi} + \Sigma_p \, CCF_p \times \Delta S_{ap} + \Sigma_r \, CCF_r \times \Delta S_{yr}$$

where:

Σ_i has the same meaning as in step 1.

CCF_i has the same meaning as in step 1.

ΔS_{qi} is the increase in stocks of fuel type (***i***) for the activity and held within the boundary of the activity during the year measured in tonnes.

Σ_p has the same meaning as in step 2.

CCF_p has the same meaning as in step 2.

ΔS_{ap} is the increase in stocks of product types (***p***) produced by the activity and held within the boundary of the activity during the year measured in tonnes.

Σ_r has the same meaning as in step 3.

CCF_r has the same meaning as in step 3.

ΔS_{yr} is the increase in stocks of waste by-product types (***r***) produced from the operation of the activity and held within the boundary of the activity during the year measured in tonnes.

STEP 5

Calculate the emissions of carbon dioxide released from the operation of the activity during the year measured in CO_2-e tonnes as follows:

(a) add the amounts worked out under steps 2, 3 and 4 to work out a new amount (***amount A***);

(b) subtract amount A from the amount worked out under step 1 to work out a new amount (***amount B***);

(c) multiply amount B by 3.664 to work out the amount of emissions released from the operation of the activity during a year.

4.14 Ferroalloys production

Emissions of CO_2 occur during ferroalloy production as a result of the use of carbon reductants such as coke and the oxidation of a fossil fuel electrode.

This section is relevant to the estimation of carbon dioxide emissions from any of the following:

(a) the consumption of a fossil fuel reductant during the production of:
  - (i) a ferroalloy; or
  - (ii) silicomanganese; or
  - (iii) silicon;

(b) the oxidation of a fossil fuel electrode in the production of:
  - (i) a ferroalloy; or
  - (ii) silicomanganese; or
  - (iii) silicon.

A ferroalloy means an alloy of 1 or more elements with iron including, but not limited to, any of the following:

(a) ferrochrome;
(b) ferromanganese;
(c) ferromolybdenum;
(d) ferronickel;
(e) ferrosilicon;
(f) ferrotitanium;
(g) ferrotungsten;
(h) ferrovanadium.

The following formula can be used to estimate greenhouse gas emissions from ferroalloys production.

Work out the carbon content in fuel types (***i***) or carbonaceous input material delivered for the activity during the year, measured in tonnes of carbon, as follows:

$$\Sigma_i \ CCF_i \times Q_i$$

where:

$\boldsymbol{\Sigma_i}$ means the sum of the carbon content values obtained for all fuel types (***i***) or carbonaceous input material.

$\boldsymbol{CCF_i}$ is the carbon content factor mentioned in Schedule 3, measured in tonnes of carbon, for each appropriate unit of fuel type (***i***) or carbonaceous input material consumed during the year from the operation of the activity.

$\boldsymbol{Q_i}$ is the quantity of fuel type (***i***) or carbonaceous input material delivered for the activity during the year, measured in an appropriate unit and estimated in accordance with:

(a)criterion A in Divisions 2.2.5, 2.3.6 and 2.4.6; or

(b)if the quantity of fuel or carbonaceous input material is not acquired as part of a commercial transaction — industry practice, consistent with the principles in section 1.13.

Work out the carbon content in products (***p***) leaving the activity during the year, measured in tonnes of carbon, as follows:

$$\Sigma_p \ CCF_p \times A_p$$

where:

$\boldsymbol{\Sigma_p}$ means the sum of the carbon content values obtained for all product types (***p***).

$\boldsymbol{CCF_p}$ is the carbon content factor, measured in tonnes of carbon, for each tonne of product type (***p***) produced during the year.

$\boldsymbol{A_p}$ is the quantity of product types (***p***) produced leaving the activity during the year, measured in tonnes.

Work out the carbon content in waste by-product types ***(r)*** leaving the activity, other than as an emission of greenhouse gas, during the year, measured in tonnes of carbon, as follows:

$$\Sigma_r \ CCF_r \times Y_r$$

where:

Σ_r means the sum of the carbon content values obtained for all waste by-product types (***r***).

CCF_r is the carbon content factor, measured in tonnes of carbon, for each tonne of waste by-product types (***r***).

Y_r is the quantity of waste by-product types (***r***) leaving the activity during the year, measured in tonnes.

Work out the carbon content in the amount of the change in stocks of inputs, products and waste by-products held within the boundary of the activity during the year, measured in tonnes of carbon, as follows:

$$\Sigma_i \ CCF_i \times \Delta S_{qi} + \Sigma_p \ CCF_p \times \Delta S_{ap} + \Sigma_r \ CCF_r \times \Delta S_{yr}$$

where:

Σ_i has the same meaning as in step 1.

CCF_i has the same meaning as in step 1.

ΔS_{qi} is the change in stocks of fuel type (***i***) for the activity and held within the boundary of the activity during the year, measured in tonnes.

Σ_p has the same meaning as in step 2.

CCF_p has the same meaning as in step 2.

ΔS_{ap} is the change in stocks of product types (***p)*** produced by the activity and held within the boundary of the activity during the year, measured in tonnes.

Σ_r has the same meaning as in step 3.

CCF_r has the same meaning as in step 3.

ΔS_{yr} is the change in stocks of waste by-product types (***r***) produced from the operation of the activity and held within the boundary of the activity during the year, measured in tonnes.

Work out the emissions of carbon dioxide released from the operation of the activity during the year, measured in CO_2-e tonnes, as follows:

(a)add the amounts worked out under steps 2, 3 and 4 to work out a new amount (***amount A***);

(b)subtract amount A from the amount worked out under step 1 to work out a new amount (***amount B***);

(c)multiply amount B by 3.664 to work out the amount of emissions released from the operation of the activity during the year.

4.15 Other Metals

This section applies to the production of metal, other than iron and steel, ferro-alloy metal, aluminium or any other metal produced in an integrated metalworks, that involves the use of fuels as carbon reductants or consumption of a fossil fuel electrode.

The following formula can be used to estimate greenhouse gas emissions.

Work out the carbon content in fuel types (***i***) or carbonaceous input material delivered for the activity during the year, measured in tonnes of carbon, as follows:

$$\Sigma_i \ CCF_i \times Q_i$$

where:

Σ_i means the sum of the carbon content values obtained for all fuel types (***i***) or carbonaceous input material.

CCF_i is the carbon content factor mentioned in Schedule 3, measured in tonnes of carbon, for each appropriate unit of fuel type (***i***) or carbonaceous input material consumed during the year from the operation of the activity.

Q_i is the quantity of fuel type (***i***) or carbonaceous input material delivered for the activity during the year, measured in an appropriate unit and estimated in accordance with:

(a) criterion A in Divisions 2.2.5, 2.3.6 and 2.4.6; or

(b) if the quantity of fuel or carbonaceous input material is not acquired as part of a commercial transaction — industry practice, consistent with the principles in section 1.13.

Work out the carbon content in products (***p***) leaving the activity during the year, measured in tonnes of carbon, as follows:

$$\Sigma_p \ CCF_p \times A_p$$

where:

Σ_p means the sum of the carbon content values obtained for all product types (***p***).

CCF_p is the carbon content factor, measured in tonnes of carbon, for each tonne of product type (***p***) produced during the year.

A_p is the quantity of product types (***p***) produced leaving the activity during the year, measured in tonnes.

Work out the carbon content in waste by-product types ***(r)*** leaving the activity, other than as an emission of greenhouse gas, during the year, measured in tonnes of carbon, as follows:

$$\Sigma_r \ CCF_r \times Y_r$$

where:

Σ_r means the sum of the carbon content values obtained for all waste by-product types (***r***).

CCF_r is the carbon content factor, measured in tonnes of carbon, for each tonne of waste by-product types (***r***).

Y_r is the quantity of waste by-product types (***r***) leaving the activity during the year, measured in tonnes.

Work out the carbon content in the amount of the change in stocks of inputs, products and waste by-products held within the boundary of the activity during the year, measured in tonnes of carbon, as follows:

$$\Sigma_i \ CCF_i \times \Delta S_{qi} + \Sigma_p \ CCF_p \times \Delta S_{ap} + \Sigma_r \ CCF_r \times \Delta S_{yr}$$

where:

Σ_i has the same meaning as in step 1.

CCF_i has the same meaning as in step 1.

ΔS_{qi} is the change in stocks of fuel type (***i***) for the activity and held within the boundary of the activity during the year, measured in tonnes.

Σ_p has the same meaning as in step 2.

CCF_p has the same meaning as in step 2.

ΔS_{ap} is the change in stocks of product types (***p***) produced by the activity and held within the boundary of the activity during the year, measured in tonnes.

Σ_r has the same meaning as in step 3.

CCF_r has the same meaning as in step 3.

ΔS_{yr} is the change in stocks of waste by-product types (***r***) produced from the operation of the activity and held within the boundary of the activity during the year, measured in tonnes.

Work out the emissions of carbon dioxide released from the operation of the activity during the year, measured in CO_2-e tonnes, as follows:

(a) add the amounts worked out under steps 2, 3 and 4 to work out a new amount (***amount A***);

(b) subtract amount A from the amount worked out under step 1 to work out a new amount (***amount B***);

(c) multiply amount B by 3.664 to work out the amount of emissions released from the operation of the activity during the year.

4.16 Aluminium — emissions from consumption of carbon anodes in aluminium production

$$E_{ij} = A_i \times EF_{ij}$$

where:

E_{ij} is the emission of CO_2 from aluminium smelting (tonnes)

A_i is the amount of aluminium produced (tonnes)

EF_{ij} is the CO_2 emission factor for carbon anode consumption (tonnes of CO_2-e emissions per tonne of aluminium produced), estimated according to:

$$EF_{ij} = NAC \times \left(\frac{100 - S_a - Ash_a}{100} \right) \times 3.664$$

where:

NAC is the amount of carbon consumed from a carbon anode consumed in the production of aluminium during the year, worked out at the rate of ***0.413*** tonnes of carbon anode consumed per tonne of aluminium produced

S_a is the sulphur content in anodes (by % weight; the default is assumed to be equal to 2%)

Ash_a is the ash content in anodes (by % weight, the default is assumed to be equal to 0.4%)

4.17 Aluminium — emissions from production of baked carbon anodes in aluminium production

$$E_{ij} = (GA - Hw - BA - WT) \times 3.664 + \left(\frac{\sum Q_i}{BA} \times BA \times \frac{(100 - S_i - Ash_i)}{100} \right) \times 3.664$$

where:

E_{ij} is the emissions of CO_2 from baked carbon anode production

GA is the initial weight of green anodes used in the production process of the baked carbon anode

BA is baked anode production (tonnes)

Hw is the weight of the hydrogen content in green anodes (tonnes) (the default value for *Hw* is 0.5% of GA)

WT is waste tar collected (tonnes)

$\sum Q_i$ is the quantity of fuel consumed in the production of baked carbon anodes (tonnes)

S_i is the sulphur content in packing coke (by % weight, assumed to be 2%)

Ash_i is the ash content in packing coke (by % weight, assumed to be 0.4%)

4.18 Aluminium (perfluoronated carbon compound emissions) – tetrafluoromethane and hexafluoroethane

$$E_{ij} = A_i \times EF_{ij}$$

where:

E_{ij} is the process emission of tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) from primary aluminium production (CO_2-e tonnes)

A_i is the amount of primary aluminium production (tonnes)

EF_{ij} is the emission factor for CF_4 or C_2F_6, (tonne CO_2-e per tonne aluminium).

Table 24: Aluminium perfluoronated carbon compound emission factors

Source	Emission factor (EF_{pfi}) tonne CO_2-e per tonne	
	Tetrafluoromethane CF_4	Hexafluoroethane C_2F_6
Aluminium production	0.30	0.07

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Division 4.4.4).

4.19 Industrial processes — emissions of hydrofluorocarbons and sulphur hexafluoride gases

$$E_{jk} = Stock_{jk} \times L_{jk}$$

where

E_{jk} is the emissions of HFC or SF_6, summed over each equipment type (tonnes of CO_2-equivalent);

$Stock_{jk}$ is the stock of HFC or SF_6 contained in equipment, by equipment type (tonnes of CO_2-e); and

L_{jk} is the default leakage rates by equipment type.

For the factor $Stock_{jk}$, an estimation of the stock of synthetic gases contained in an equipment type may be based on the following sources:

(a) the stated capacity of the equipment according to the manufacturer's nameplate;

(b) estimates based on:

(i) the opening stock of gas in the equipment; and

(ii) transfers into the facility from additions of gas from purchases of new equipment and replenishments; and
(iii) transfers out of the facility from disposal of equipment or gas.

Table 25: Leakage rates for synthetic gases

Equipment type	Default annual leakage rates of gas	
	HFCs	SF_6
Commercial air conditioning—chillers	0.09	
Commercial refrigeration - supermarket systems	0.23	
Industrial refrigeration including food processing and cold storage	0.16	
Gas insulated switchgear and circuit breaker applications		0.0089

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 4.102).

Example: Calculation of emissions generated from the operation of a commercial chiller

A company operates a commercial air conditioning-chiller, which contains 160 kg charge of HFC134a.

Convert HFC134a into a CO_2-equivalent using the global warming potential of 1430 (from Appendix 1)

= 160 x 1430/1000

= 229 tonnes CO_2-e

Applying the annual leakage rate of 0.09 (i.e. 9%) gives:

= 0.09 x 229

Total scope 1 GHG emissions = 21 tonnes CO_2-e

5 Waste emissions

Throughout this Waste chapter, emissions of CO_2 generated from waste management are considered to be from biomass sources and therefore do not need to be estimated. For example, landfill gas comprises both methane and carbon dioxide but only the methane component should be considered.

Carbon dioxide produced from the flaring of methane from landfill gas or other emission sources is also considered as having been derived from biomass sources.

Emissions of all gases arising from other non-waste processes from a facility, such as emissions from the combustion of fuels for energy, should be estimated using methods described in the appropriate chapter.

5.1 Methane released from landfills - (other than from flaring of methane)

For companies that operate landfill sites and wish to calculate scope 1 emissions, please refer to Chapter 5 – Part 5.2 of the *National Greenhouse and Energy Reporting (Measurement) Technical Guidelines* for guidance. For companies wishing to calculate scope 3 emissions from the disposal of their waste outside the organisation boundaries (eg, waste taken to municipal landfill), please refer to Appendix 4 of this workbook.

5.2 Biological treatment of solid waste at the landfill – composting and anaerobic digestion

Greenhouse emissions from biological treatment of solid waste may be estimated according to:

$$CH_4\ Emissions = \Sigma_i (Q_i \text{ x } EF_i) - R$$

where:

$\boldsymbol{CH_4}$ Emissions = total CH_4 emissions in inventory year, tonnes

$\boldsymbol{Q_i}$ = mass of wet organic waste treated by biological treatment type i, tonnes

$\boldsymbol{EF}$ = emission factor for treatment i, tonnes CO_2-e/tonne of wet waste treated and equal to:

- for composting: 0.019
- for anaerobic digestion: 0.025

$\boldsymbol{R}$ = total amount of CH_4 recovered in inventory year, tonnes CO_2-e

Nitrous oxide emissions from biological treatment

$$N_2O\ Emissions = \Sigma_i\ (Q_i \times EF_i)$$

where:

N_2O Emissions = total N_2O emissions in inventory year, tonnes of CO_2-e

Q_i = mass of wet organic waste treated by biological treatment type i, tonnes

EF = emission factor for treatment i, tonnes of CO_2-e/tonnes of wet waste treated and equal to:

- for composting: 0.002
- for anaerobic digestion: 0.0

5.3 Wastewater handling (domestic and commercial)

Companies that own and operate wastewater treatment facilities and wish to calculate a scope 1 emissions estimate for this source, please refer to Chapter 5 – Part 5.3 of the *National Greenhouse and Energy Reporting (Measurement) Technical Guidelines* for guidance. For companies wishing to calculate scope 3 emissions from the treatment of their waste outside the organisation boundaries (eg, waste disposed to municipal treatment works), please refer to Appendix 4 of this workbook.

5.4 Wastewater handling (Industrial) - wastewater treatment

For companies that treat industrial wastewater onsite and capture less than 75% of the estimated methane generated, the following equations can be used to calculate an emissions estimate from this source:

$$CH_{4gen} = \{[(\sum COD_{wi} - COD_{sl} - COD_{eff}) \times (MCF_{ww} \times EF_{wij})] + [(COD_{sl} - COD_{trl} - COD_{tro}) \times MCF_{sl} \times EF_{slij}]\} - \gamma(Q_{total})$$

where:

CH_{4gen} is the annual methane emissions from the on-site treatment of industrial wastewater in tonnes

$\Sigma_{w,i}$ is the total ***$COD_{w,i}$*** of wastewater entering the plant.

$COD_{w,i}$ is the COD in wastewater entering the plant related to the production by the plant of the commodities listed in Table 26 during the year measured in tonnes of COD. Where facility-specific data are available on COD quantities, these should be used. Where these data are not available the following equation together with the default values in Table 26 can be used:

$$COD_{w,i} = Prod_i \times W_{gen,i} \times \frac{COD_{con,i}}{1\ 000}$$

where:

$Prod_i$ is the total production by the plant of each commodity during the year measured in tonnes.

$W_{gen,i}$ is the wastewater generation rate from the production of each commodity produced during the year and measured in cubic metres or kilolitres per tonne of commodity.

$COD_{con,i}$ is the COD concentration in kilograms of COD per cubic metre of wastewater entering the plant during the year from the production of each commodity (defaults by commodity type are listed in Table 26 below).

COD_{sl} is the quantity of COD removed as sludge from wastewater during the year measured in tonnes of COD**,** worked out as follows:

$$COD_{sl} = COD_{w,i} \times F_{sl}$$

where:

$COD_{w,i}$ is the COD in wastewater entering the plant used in the production of each commodity during the year measured in tonnes of COD.

F_{sl} is the fraction of COD removed from wastewater as sludge by the plant during the year (in the absence of a plant-specific factor, the default value is 0.15).

COD_{eff} is the quantity of COD in effluent leaving the plant during the year measured in tonnes.

MCF_{ww} is the fraction of COD in wastewater anaerobically treated by the plant during the year (defaults by commodity type are listed in Table 26 below).

$EF_{w\,ij}$ is the methane emission factor for industrial wastewater (default is 6.3).

COD_{trl} is the quantity of COD in sludge transferred out of the plant and removed to landfill during the year measured in tonnes of COD.

COD_{tro} is the quantity of COD in sludge transferred out of the plant and removed to a site other than landfill during the year measured in tonnes of COD.

MCF_{sl} is the fraction of COD in sludge anaerobically treated by the plant during the year.

$EF_{sl\,ij}$ is the methane emission factor for the treatment of sludge by the plant (default is 6.3).

Q_{total} is the quantity of methane captured for combustion, flaring or transfer off-site measured in cubic metres.

γ is the factor $6.784 \times 10^{-4} \times 25$ converting cubic metres of methane at standard conditions to tonnes

Table 26: Default industrial wastewater treatment parameters by commodity type

Commodity	$W_{gen,i}$, default value	$COD_{con,i}$ default value	MCF_{ww} default value
Dairy Product (ANZSIC code 113)	5.7	0.9	0.4
Pulp,Paper and Paperboard (ANZSIC code 1510)	26.7	0.4	0.0
Meat and Poultry (ANZSIC codes 1111 and 1112)	13.7	6.1	0.4
Organic chemicals (ANZSIC codes 18 and 19)	67.0	3.0	0.1
Raw Sugar (ANZSIC code 1181)	0.4	3.8	0.3
Beer (ANZSIC code 1212)	5.3	6.0	0.5
Wine and Other Alcoholic Beverage (ANZSIC code 1214)	23.0	1.5	0.0
Fruit and Vegetables (ANZSIC code 1140)	20.0	0.2	1.0

For full details of all methodologies available to companies treating their industrial wastewater on-site, please refer to Part 5.4 of the *National Greenhouse and Energy Reporting System Measurement Technical Guidelines*.

5.5 Wastewater handling (industrial) — Flaring of methane in sludge biogas

Greenhouse emissions from the flaring of methane in sludge biogas may be estimated according to:

$$E_{j\ flared} = Q_{flared} \times EC_i \times \frac{EF_{ij}}{1\ 000}$$

where:

$E_{j\ flared}$ is the emissions of gas type ***(j)*** released from flaring of the methane in sludge biogas by the plant during the year measured in CO_2-e tonnes.

Q_{flared} is the quantity of methane in sludge biogas flared by the plant during the year measured in cubic metres.

EC_i is the energy content of methane in sludge biogas measured in gigajoules per cubic metre.

EF_{ij} is the relevant emission factor for gas type ***(j)*** for methane in sludge biogas in CO_2-e tonnes per gigajoule.

For Q_{flared}, the methane in sludge biogas is taken to constitute 70% of the sludge biogas.

5.6 Waste incineration - carbon dioxide emissions

Emissions from the incineration of waste may be estimated according to:

$$E_i = Q_i \times CC_i \times FCC_i \times OF_i \times 3.664$$

where:

E_i is the emissions of carbon dioxide released from the incineration of waste type ***(i)*** by the plant during the year measured in CO_2-e tonnes.

Q_i is the quantity of waste type ***(i)*** incinerated by the plant during the year measured in tonnes of wet weight value in accordance with Division 2.3.6.

CC_i is the carbon content of waste type ***(i)*** (default is 0.60 for clinical waste).

FCC_i is the proportion of carbon in waste type ***(i)*** that is of fossil origin (default 0.4).

OF_i is the oxidation factor for waste type ***(i)*** (default 1).

6 Agriculture

6.1 Introduction

This section covers the estimation of emissions from agricultural sources including grazing and cropping, and from agricultural burning.

Emissions from other on-farm activities accounted for in other sections include:

- Vehicle fuel use (covered in Section 2.2 Transport fuels);
- The burning of fuels in plant and equipment (covered in Section 2.1 Stationary energy emissions).
- Carbon dioxide (CO_2) emissions and removals associated with land conversion, tree planting and crop and grazing land management (Section 7 Land-use change and forestry).

6.2 Greenhouse gas emissions from agriculture

Emissions of greenhouse gases are produced on agricultural lands as a result of a number of natural and human-induced processes. These include the decay or burning of biomass, feed digestion by ruminant livestock, the addition of nitrogen and carbon containing fertiliser and animal manure, crop residues returned to the soil, nitrogen leaching and runoff, atmospheric deposition, and the anaerobic decomposition of organic matter during flood irrigation.

The principal greenhouse gases estimated for agriculture are methane (CH_4) and nitrous oxide (N_2O). CO_2 emissions associated with the application of lime and urea are also accounted for in agriculture. Emissions and removals of CO_2 from agriculture associated with biological sources are covered in Section 7.

The main agricultural sources of CH_4 are the digestion of feed by livestock and manure management. The main agricultural source of N_2O is soils, primarily as a result of the use of nitrogen-based fertilisers on crops and pastures. Manure management is also a source of N_2O. Crop residue burning produces some CH_4 and N_2O.

Greenhouse gas emissions represent a loss of valuable resources from farming systems. There is a wide range of actions that land managers can take in order to enhance the efficiency with which these resources are used, thereby reducing their greenhouse impacts and improving productivity at the same time.

6.3 Estimating agricultural emissions

State and national-level estimates of greenhouse gas emissions from agriculture are prepared using the methodology set out in the *National Inventory Report2015.*

Organisations wishing to report emissions from their agricultural operations may draw on this national methodology to make indicative estimates, but should note that the methodology uses regional averages not directly applicable to specific operations dependent on local conditions.

For information on emissions reporting in the agriculture sector contact:
Department of the Environment and Energy
GPO Box 787
Canberra ACT 2601
Email: nationalgreenhouseaccounts@environment.gov.au

7 Land use, Land use change and forestry

7.1 Introduction

This section covers the estimation of emissions and removals of CO_2 associated with activities that change the amount of carbon in the land sector. These can include activities such as:

- Forestry activities which can take up (sequester) carbon from the atmosphere through actively growing trees. Natural events, e.g. fire and pest attack, and management actions such as harvesting can reduce these forest carbon stocks.
- The burning of Grasslands and Woodlands for the management of vegetation and fuel loads.
- Deforestation produces greenhouse gas emissions from the burning and decay of cleared vegetation and changes in soil carbon.
- Management of cropland and grazing lands which can lead to losses and gains in soil carbon.

7.2 Activities covered under Australia's national inventory

Australia reports greenhouse gas emissions and carbon sequestration from land use change and forestry according to both the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC) classification systems. Under the Kyoto system Australia estimates emissions for the following land classifications/activities:

- Deforestation – occurring since 1 January 1990
- Afforestation and reforestation – occurring since 1 January 1990.
- Forest Management – limited to forests managed under a system of practices to support commercial timber production or practices designed to implement specific sink enhancement activities.
- Cropland and Grazing Land Management
- Revegetation – gains and losses in sparse vegetation that does not meet the definition of forest and is not already included in Cropland or Grazing Land Management.

The UNFCCC requirements cover a broader range of land classifications/activities, including reporting changes in carbon stocks in all forests

Land sector reporting within Australia's National Inventory System integrates a wide range of spatially referenced data through a hybrid process-empirical model to estimate carbon stock change and greenhouse gas emissions at fine temporal and spatial scales. The model implemented within the National Inventory System is the Full Carbon Accounting Model (FullCAM).

FullCAM simulates all carbon pools, which includes biomass, dead organic matter and soil. FullCAM is parameterised using management, site, climate and species data drawn from resource inventories, field studies and remote sensing methods.

FullCAM is publically available for download on the Department's website and is equipped with a Data Builder function to allow access to National Inventory input data over the internet. The software provides the user with flexibility in entering species parameters and management events which influence carbon stock change. The target audience for the public version of FullCAM is emissions inventory experts, the scientific community, industry and policy makers with an interest in land sector reporting within the National Inventory System.

7.3 Further information and advice

FullCAM is available for download at:

http://www.environment.gov.au/climate-change/greenhouse-gas-measurement/land-sector

Details of the land use, land use change and forestry sector within the National Inventory System can be found in the National Inventory Report which can be downloaded here:

http://www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications#national

For information on land use, land use change and forestry contact:

Department of the Environment and Energy
GPO Box 787
Canberra ACT 2601

Email: nationalgreenhouseaccounts@environment.gov.au

Appendix 1 Greenhouse Gas Global Warming Potentials

The Global Warming Potential (GWP) is an index used to convert relevant non-carbon dioxide gases to a carbon dioxide equivalent (CO_2-e) by multiplying the quantity of the gas by its GWP in the table below.

Table 27: Global Warming Potentials

Gas	Chemical formula	Global Warming Potential
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Hydrofluorocarbons HFCs		
HFC-23	CHF_3	14,800
HFC-32	CH_2F_2	675
HFC-41	CH_3F	92
HFC-43-10mee	$C_5H_2F_{10}$	1,640
HFC-125	C_2HF_5	3,500
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1,100
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1,430
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	353
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	4,470
HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	124
HFC-227ea	C_3HF_7	3,220
HFC-236fa	$C_3H_2F_6$	9,810
HFC-245ca	$C_3H_3F_5$	693
Perfluorocarbons PFCs		
Perfluoromethane (tetrafluoromethane)	CF_4	7,390
Perfluoroethane (hexafluoroethane)	C_2F_6	12,200
Perfluoropropane	C_3F_8	8,830
Perfluorobutane	C_4F_{10}	8,860
Perfluorocyclobutane	c-C_4F_8	10,300
Perfluoropentane	C_5F_{12}	9,160
Perfluorohexane	C_6F_{14}	9,300

Gas	Chemical formula	Global Warming Potential
Sulphur hexafluoride	SF_6	22,800

Note:

Global Warming Potentials (GWPs) are used to convert masses of different greenhouse gases into a single carbon dioxide-equivalent metric (CO2-e). In broad terms, multiplying a mass of a particular gas by its GWP gives the mass of carbon dioxide emissions that would produce the same warming effect over a 100 year period. Australia's National Greenhouse Gas Accounts apply GWPs to convert emissions to a CO2-e total.

Appendix 2 Units and conversions

Table 28: Metric prefixes

Abbreviation	Prefix	Symbol
10^{15} (10^6x10^9)	Peta (million billion [thousand trillion])	P
10^{12} (10^3x10^9)	Tera (thousand billion [trillion])	T
10^9	Giga (billion)	G
10^6	Mega (million)	M
10^3	kilo (thousand)	k
10^2	hecto	h
10^1	deca	da
10^0	- (e.g. gram)	g
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p

Table 29: Unit equivalences

10^{15} grams (Petagram)	Gigatonne (Gt)
10^{12} grams (Teragram)	Megatonne (Mt)
10^9 grams (Gigagram)	kilotonnes (kt) (10^3 tonnes)
10^6 grams (million grams)	1 tonne
kg/GJ (10^3g/10^9J)	Gg/PJ (10^9g/10^{15}J)
Mg/PJ (10^6g/10^{15}J)	g/GJ 10^0g/10^9J)

e.g. 423,000 Gg is equivalent to 423,000 kt and to 423 Mt

Table 30: Energy conversion factors

Conversion factors		
1 Watt	= 1 Joule/Sec	
3600 Watt-seconds	= 1 Watt-hour (3600 seconds in one hour)	
1 Watt-hour	= 3600 Joules	
1000 Watt-hours	= 1Kilowatt hour (kWh)	
1 kWh	= 3.6×10^{6} Joules = 3.6 MJ	
1 kWh	= 3.6×10^{-3} GJ	
1 GJ	= 278 kWh	
1 PJ	= 278×10^{6} kWh = 278 GWh	
(A) For conversion from first unit to second unit:	**(B) Multiply quantity in first unit by conversion factor:**	**(C) To calculate quantity in second unit:**
kWh to J	kWh x 3.6×10^{6}	Joules
J to kWh	J x $1/3.6 \times 10^{-6}$	kWh
kWh to MJ	kWh x 3.6	MJ
MJ to kWh	MJ x 0.278	kWh
kWh to GJ	kWh x 3.6×10^{-3}	GJ
GJ to kWh	GJ x 278	kWh
kWh to PJ	kWh x 3.6×10^{-9}	PJ
PJ to kWh	PJ x 278×10^{6}	kWh

Table 31: Municipal solid waste volume to weight conversion factors

Material type	**Volume to weight (t/m^3)**
Paper	0.09
Textiles	0.14
Wood	0.15
Garden	0.24
Food	0.50
Sludge (wet)	0.72
Nappies	0.39
Rubber and leather	0.14

Appendix 3 Carbon content factors for fuels

Note 1 Under the 2006 IPCC Guidelines, the emission factor for CO_2 released from combustion of biogenic carbon fuels is zero.

Note 2 The carbon content factors in this Schedule do not include relevant oxidation factors.

Table 32: Carbon content factors - Solid fuels and certain coal based products

Fuel type	Carbon content factor tC/t fuel
Solid fossil fuels	
Bituminous coal	0.663
Sub-bituminous coal	0.515
Anthracite	0.712
Brown coal	0.260
Coking coal	0.752
Coal briquettes	0.574
Coal coke	0.789
Coal tar	0.837
Solid fossil fuels other than those mentioned above	0.574
Fuels derived from recycled materials	
Industrial materials and tyres that are derived from fossil fuels, if recycled and combusted to produce heat or electricity	0.585
Non-biomass municipal materials, if recycled and combusted to produce heat or electricity	0.250
Primary solid biomass fuels	
Dry wood	0
Green and air dried wood	0
Sulphite lyes	0
Bagasse	0
Biomass municipal and industrial materials, if recycled and combusted to produce heat or electricity	0
Charcoal	0
Primary solid biomass fuels other than those mentioned above	0

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 3, Part 1).

Table 33: Carbon content factors - Gaseous fuels

Fuel type	Carbon content factor (tC/m^3 of fuel unless otherwise specified)
Gaseous fossil fuels	
Natural gas if distributed in a pipeline	5.52×10^{-4}
Coal seam methane that is captured for combustion	5.52×10^{-4}
Coal mine waste gas that is captured for combustion	5.34×10^{-4}
Compressed natural gas	5.52×10^{-4}
Unprocessed natural gas	5.52×10^{-4}
Ethane	9.70×10^{-4}
Coke oven gas	1.83×10^{-4}
Blast furnace gas	2.55×10^{-4}
Town gas	6.41×10^{-4}
Liquefied natural gas	0.355 tC/kL of fuel
Gaseous fossil fuels other than those mentioned above	5.52×10^{-4}
Biogas captured for combustion	
Landfill biogas (methane) that is captured for combustion	0
Sludge biogas (methane) that is captured for combustion	0
A biogas (methane) that is captured for combustion, other than those mentioned above	0

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 3, Part 2).

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Table 34: Carbon content factors - Liquid fuels and certain petroleum based products

Fuel type	Carbon content factor (tC/kL of fuel unless otherwise specified)
Petroleum based oils and petroleum based greases	
Petroleum based oils (other than petroleum based oils used as fuel, eg lubricants)	0.737
Petroleum based greases	0.737
Petroleum based products other than petroleum based oils and petroleum based greases	
Crude oil including crude oil condensates	0.861 tC/t fuel
Other natural gas liquids	0.774 tC/t fuel
Gasoline (other than for use as fuel in an aircraft)	0.629
Gasoline for use as fuel in an aircraft	0.605
Kerosene (other than for use as fuel in an aircraft)	0.705
Kerosene for use as fuel in an aircraft	0.699

Fuel type	Carbon content factor (tC/kL of fuel unless otherwise specified)
Heating oil	0.708
Diesel oil	0.736
Fuel oil	0.797
Liquefied aromatic hydrocarbons	0.654
Solvents if mineral turpentine or white spirits	0.654
Liquefied petroleum gas	0.422
Naphtha	0.598
Petroleum coke	0.856 tC/t fuel
Refinery gas and liquids	0.641 tC/t fuel
Refinery coke	0.864 tC/t fuel
Bitumen	0.951 tC/t fuel
Waxes	0.871 tC/t fuel
Petroleum based products other than mentioned above	0.655
Biofuels	
Biodiesel	0
Ethanol for use as a fuel in an internal combustion engine	0
Biofuels other than those mentioned above	0

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 3, Part 3).

Table 35: Carbon content factors - Petroleum feedstocks and products

Fuel type	Carbon content factor (tC/t fuel unless otherwise specified)
Petrochemical feedstocks	
Carbon black if used as a petrochemical feedstock	1
Ethylene if used as a petrochemical feedstock	0.856
Petrochemical feedstock other than those mentioned in items above	0.856
Petrochemical products	
Propylene	0.856
Polyethylene	0.856
Polypropylene	0.856
Butadiene	0.888
Styrene	0.923

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 3, Part 4).

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Table 36: Carbon content factors – carbonates

Carbonate type	Carbon content factor (tC/t pure carbonate material unless otherwise specified)
Calcium carbonate	0.120
Magnesium carbonate	0.142
Sodium carbonate	0.113
Sodium bicarbonate	0.143

Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Schedule 3, Part 5).

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Appendix 4 Scope 3 emission factors

Various emission factors can be used to calculate scope 3 emissions. For ease of use, this workbook reports specific 'scope 3' emission factors for organisations that:

- burn fossil fuels: to estimate their indirect emissions attributable to the extraction, production and transport of those fuels; or
- consume purchased electricity: to estimate their indirect emissions from the extraction, production and transport of fuel burned at generation and the indirect emissions attributable to the electricity lost in delivery in the T&D network.

More broadly, scope 3 emissions can include:

- Disposal of waste generated (e.g. if the waste is transported outside the organisation and disposed of);
- Use of products manufactured and sold;
- Disposal (end of life) of products sold;
- Employee business travel (in vehicles or aircraft not owned or operated by the reporting organisation);
- Employees commuting to and from work;
- Extraction, production and transport of purchased fuels consumed;
- Extraction, production and transport of other purchased materials or goods;
- Purchase of electricity that is sold to an end user (reported by electricity retailer);
- Generation of electricity that is consumed in a T&D system (reported by end user);
- Out-sourced activities; and
- Transportation of products, materials and waste.

In some cases, scope 3 emissions from these activities can be calculated with the scope 1 emission factors provided in this document. For example, if a company decides to report on emissions from an off-site activity, and has the necessary data, then the direct (scope 1) emission factor could be used to calculate emissions, and these emissions would be reported as scope 3.

Table 37: Scope 3 emission factors –solid fuels and certain coal based products

Solid Fuels combusted	EF for scope 3
	kg CO_2-e/GJ
Bituminous coal	3.0
Sub-bituminous coal	2.5
Brown coal	0.4
Coking coal	6.4
Coal briquettes	NE
Coal coke	NE
Solid fossil fuels other than those mentioned above	NE

Note: NE = Not estimated

Gaseous fuel emissions scope 3 factors for end users

Greenhouse gas emissions from gaseous fuels are generated from a large number of processes and from a range of often diffuse sources and production, distribution and consumption processes. Emissions are not usually monitored directly but are estimated through the application of models and methodologies that link emissions to data on observable activities.

In line with its IPCC obligations, the Department routinely considers ways to improve the quality of activity data, emissions factors, methods and other relevant technical elements of inventories - that this and other factors are subject to a rigorous and ongoing improvement plan, including annual public consultation on emissions measurement methods provided in NGERs Measurement Determination.

The methods used to develop scope 3 emission factors for gaseous fuels are consistent with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997) and are comparable with international practice.

Scope 3 emissions factors for natural gas are based on data collected under the *National Greenhouse and Energy Reporting (NGER) Act 2007* covering the period 1 July 2008 to 30 June 2009. Data associated with the following emission sources reported under NGERS were incorporated in the scope 3 factors:

Emission source	Fuel combustion	Fugitive emissions
Natural gas exploration	Included	Included
Natural gas production or processing	Included	Included
Natural gas transmission	Included	Included
Natural gas distribution	Included	Not included

As Scope 3 factors are calculated at the point where natural gas is delivered to end users, it is necessary to calculate consumption at each of the load centres. Gas reaches end users either from the metro distribution networks or direct from the high-pressure distribution pipelines. Households and commercial users tend to be served by the former, and electricity generators and large industrial plant from the latter.

Scope 3 emission factors for natural gas for a product that is not ethane (inclusive of coal seam gas) are presented by state and metro/non-metro regions in Table 38. Separate emission factors for ethane are provided for New South Wales and Victoria in Table 39.

Table 38: Scope 3 emission factors – natural gas for a product that is not ethane (inclusive of coal seam gas)

State or territory	Natural Gas EF for scope 3	Natural Gas EF for scope 3
	Metro	Non-metro
	kg CO_2-e /GJ	kg CO_2-e /GJ
New South Wales and ACT	12.8	13.6
Victoria	3.9	3.9
Queensland	8.7	7.8
South Australia	10.4	10.3
Western Australia	4.0	3.9
Tasmania	NA	NA
Northern Territory	NA	NA

Source: Wilkenfeld and Associates (2012), derived from NGER data

Notes:

- Factors are calculated for all natural gas distributed in a pipeline which may include coal seam methane.
- Metro is defined as located on or east of the dividing range in NSW, including Canberra and Queanbeyan , Melbourne, Brisbane, Adelaide or Perth. Otherwise, the non-metro factor should be used.
- Updated factors for Tasmania and the Northern Territory are not available due to confidentiality constraints that arise from the use of a limited number of NGER data inputs.
- The scope 3 natural gas emission factors above do not include fugitive emission leakage from low pressure natural gas distribution pipeline networks. Emissions from combustion associated with low pressure natural gas distribution pipeline networks are included in the scope 3 emission factors.

Table 39: Scope 3 emission factors – ethane

Ethane produced in accordance with Division 23 of Part 3 of the Clean Energy Regulations 2011	kg CO2-e/GJ
New South Wales	23
Victoria	5.6

Source: Wilkenfeld and Associates (2012), derived from NGER data

Table 40: Scope 3 emission factors – liquid fuels and certain petroleum based products

Liquid Fuels combusted	EF for scope 3
	kg CO_2-e/GJ
Petroleum based oils (other than petroleum based oil used as fuel, eg lubricants)	3.6
Petroleum based greases	3.6
Crude oil including crude oil condensates	3.6
Other natural gas liquids	3.6
Gasoline (other than for use as fuel in an aircraft)	3.6
Gasoline for use as fuel in an aircraft (avgas)	3.6
Kerosene (other than for use as fuel in an aircraft)	3.6
Kerosene for use as fuel in an aircraft (avtur)	3.6
Heating oil	3.6
Diesel oil	3.6
Fuel oil	3.6
Liquefied aromatic hydrocarbons	3.6
Solvents if mineral turpentine or white spirits	3.6
Liquefied Petroleum Gas	3.6
Naphtha	3.6
Petroleum coke	3.6
Refinery gas and liquids	3.6
Refinery coke	3.6
Petroleum based products other than mentioned in items above	3.6
Biofuels	NE

Note: NE = Not estimated

Note: Scope 3 factors for biofuels such as biodiesels and ethanol are highly dependent on individual plant and project characteristics, and therefore have not been estimated

Electricity emission factors for end users

Table 41: Scope 2 and 3 emissions factors - consumption of purchased electricity by end users

Financial year	EF for scope 2		EF for scope 3		Full fuel cycle EF (EF for scope 2 + EF for scope 3)	
	A	B	C	D	E	F
	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ
NEW SOUTH WALES and AUSTRALIAN CAPITAL TERRITORY						
1989/90	0.90	249	0.09	24	0.98	273
1994/95	0.85	236	0.08	23	0.93	259
1999/2000	0.86	239	0.09	24	0.95	263
2004/05	0.89	247	0.11	31	1.00	278
2005/06	0.89	248	0.12	34	1.01	282
2006/07	0.89	248	0.11	32	1.01	279
2007/08	0.89	248	0.11	30	1.00	278
2008/09	0.89	248	0.11	29	1.00	277
2009/10	0.89	247	0.11	31	1.00	278
2010/11	0.88	244	0.12	33	1.00	277
2011/12	0.87	241	0.12	34	0.99	276
2012/13	0.86	238	0.12	33	0.98	271
2013/14	0.84	234	0.13	35	0.97	269
2014/15	0.83	232	0.12	34	0.96	266
Latest Estimate	0.83	230	0.12	33	0.95	263
VICTORIA						
1989/90	1.24	345	0.20	55	1.44	400
1994/95	1.22	340	0.14	38	1.36	378
1999/2000	1.33	370	0.12	33	1.45	404
2004/05	1.23	342	0.10	28	1.33	370
2005/06	1.23	342	0.10	28	1.33	370
2006/07	1.23	341	0.09	24	1.31	365
2007/08	1.22	340	0.10	28	1.32	367
2008/09	1.22	338	0.13	37	1.35	375
2009/10	1.22	339	0.14	39	1.36	378
2010/11	1.20	334	0.15	42	1.35	376
2011/12	1.19	330	0.15	42	1.34	371
2012/13	1.18	329	0.15	43	1.34	372
2013/14	1.16	322	0.14	40	1.30	362
2014/15	1.12	312	0.12	34	1.25	346
Latest Estimate	1.08	301	0.10	28	1.18	329
QUEENSLAND						
1989/90	0.94	261	0.13	36	1.07	297
1994/95	0.94	262	0.13	36	1.07	298
1999/2000	0.91	252	0.14	38	1.04	290

Financial year	EF for scope 2		EF for scope 3		Full fuel cycle EF (EF for scope 2 + EF for scope 3)	
	A	B	C	D	E	F
	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ
2004/05	0.88	244	0.12	32	1.00	277
2005/06	0.89	248	0.13	37	1.03	285
2006/07	0.89	246	0.14	39	1.03	285
2007/08	0.88	245	0.14	38	1.02	283
2008/09	0.88	244	0.13	37	1.01	281
2009/10	0.87	242	0.13	35	1.00	277
2010/11	0.85	235	0.12	34	0.97	270
2011/12	0.82	227	0.13	35	0.94	262
2012/13	0.80	223	0.13	36	0.93	260
2013/14	0.79	220	0.14	38	0.93	258
2014/15	0.78	218	0.14	38	0.92	256
Latest Estimate	0.79	219	0.14	38	0.92	257
SOUTH AUSTRALIA						
1989/90	0.81	226	0.15	41	0.96	267
1994/95	0.87	241	0.14	38	1.01	279
1999/2000	0.91	254	0.13	35	1.04	289
2004/05	0.86	238	0.11	32	0.97	270
2005/06	0.86	239	0.11	31	0.97	269
2006/07	0.83	232	0.12	32	0.95	264
2007/08	0.77	215	0.12	34	0.89	248
2008/09	0.72	199	0.14	38	0.85	237
2009/10	0.67	187	0.12	34	0.80	221
2010/11	0.65	180	0.12	32	0.76	212
2011/12	0.62	171	0.11	29	0.72	201
2012/13	0.58	162	0.11	30	0.69	192
2013/14	0.55	152	0.10	29	0.65	181
2014/15	0.53	147	0.10	28	0.63	175
Latest Estimate	0.49	137	0.09	26	0.58	162
WESTERN AUSTRALIA—South-West Interconnected System (SWIS)						
1989/90	1.13	314	0.20	54	1.33	369
1994/95	1.11	308	0.15	42	1.26	350
1999/2000	1.14	318	0.14	39	1.29	357
2004/05	0.88	246	0.09	24	0.97	270
2005/06	0.88	244	0.08	23	0.96	267
2006/07	0.86	239	0.10	27	0.96	265
2007/08	0.86	239	0.11	31	0.97	270
2008/09	0.83	231	0.12	33	0.95	264
2009/10	0.81	224	0.10	28	0.91	251
2010/11	0.79	219	0.08	22	0.87	241

Financial year	EF for scope 2		EF for scope 3		Full fuel cycle EF (EF for scope 2 + EF for scope 3)	
	A	B	C	D	E	F
	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ
2011/12	0.77	214	0.07	19	0.84	233
2012/13	0.76	212	0.07	19	0.83	231
2013/14	0.74	205	0.07	20	0.81	225
2014/15	0.72	199	0.07	18	0.78	217
Latest Estimate	0.70	196	0.06	16	0.76	212
TASMANIA						
1989/90	0.06	18	0.01	3	0.07	20
1994/95	0.01	2	0.00	0	0.01	2
1999/2000	0.01	2	0.00	0	0.01	2
2004/05	0.03	9	0.01	3	0.04	12
2005/06	0.05	13	0.01	4	0.06	16
2006/07	0.13	35	0.02	5	0.14	39
2007/08	0.22	62	0.02	6	0.24	68
2008/09	0.31	87	0.03	8	0.34	94
2009/10	0.30	84	0.03	8	0.33	92
2010/11	0.25	70	0.03	8	0.28	78
2011/12	0.21	58	0.03	7	0.24	66
2012/13	0.16	44	0.02	7	0.18	51
2013/14	0.11	29	0.02	6	0.13	35
2014/15	0.12	33	0.02	6	0.14	39
Latest Estimate	0.14	40	0.03	7	0.17	47
NORTHERN TERRITORY						
2005/06	0.73	203	0.10	27	0.83	230
2006/07	0.72	200	0.11	30	0.83	230
2007/08	0.70	195	0.11	30	0.81	226
2008/09	0.70	194	0.11	29	0.80	223
2009/10	0.69	192	0.10	28	0.79	220
2010/11	0.68	189	0.10	27	0.78	216
2011/12	0.68	190	0.10	28	0.78	217
2012/13	0.67	187	0.10	27	0.77	214
2013/14	0.67	186	0.09	26	0.76	212
2014/15	0.66	184	0.09	25	0.75	209
Latest Estimate	0.64	179	0.09	24	0.73	203
AUSTRALIA						
2005/06	0.92	256	0.11	30	1.03	286
2006/07	0.92	256	0.11	31	1.03	286
2007/08	0.92	255	0.12	32	1.03	287
2008/09	0.92	255	0.12	32	1.03	287

Financial year	EF for scope 2		EF for scope 3		Full fuel cycle EF (EF for scope 2 + EF for scope 3)	
	A	B	C	D	E	F
	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ
2009/10	0.90	251	0.12	32	1.02	283
2010/11	0.88	246	0.12	32	1.00	278
2011/12	0.87	241	0.12	32	0.98	274
2012/13	0.85	236	0.11	32	0.96	268
2013/14	0.83	229	0.12	32	0.94	261
2014/15	0.81	225	0.11	31	0.92	255
Latest Estimate	0.81	224	0.11	29	0.91	253

Notes:

- Data are for financial years ending in June.
- Emission factors are representative of the state's primary electricity grid. To minimise volatility emission factors are calculated as a three-year average.
- Scope 3 emission factors for transmission and distribution network operators are lower as they include only emissions attributable to the extraction, production and transport of fuels and not emissions attributable to the electricity lost in transmission and distribution networks. Transmission and distribution network operators should use the scope 2 factors in the table above and the following latest estimate scope 3 factors: NSW and ACT: 0.02kg CO_2-e/kWh, VIC: 0.01kg CO_2-e/kWh, QLD: 0.04kg CO_2-e/kWh, SA: 0.04kg CO_2-e/kWh, WA: 0.02kg CO_2-e/kWh, TAS: 0.01kg CO_2-e/kWh, NT: 0.05 kg CO_2-e/kWh.
- Depending on the intended use, the publication of these revised factors does not necessarily imply any need to revise past estimates of emissions. Previously published emission factor estimates are available from the Department of the Environment.
- The factors in this table are not the relevant grid emissions factors for methodology determinations under the *Carbon Credits (Carbon Farming Initiative) Act 2011* which can be found at 2.3.3.
- Sources: Department of the Environment and Energy. Primary data sources comprise NGER, Australian Energy Statistics, Clean Energy Regulator and AEMO data.

Emissions from waste disposal to landfill and wastewater treatment

Methane (CH_4) vented to the atmosphere is considered an emission as this action would be adding to atmospheric CH_4. The emissions are multiplied by 25 to calculate the carbon dioxide equivalent (CO_2-e) emissions.

Where methane from waste biomass is recovered and flared or combusted for energy, the CO_2 emitted is not counted as an emission but regarded as part of the natural carbon cycle. The total amount of CH_4 recovered is therefore regarded as saved (not emitted) so long as it does not enter the atmosphere as CH_4.

Where waste material is diverted from landfill to recycling or to energy use, the reporting organisation will have less emissions attributed to its activities because less waste is going to landfill.

Municipal solid waste

Estimates of Scope 3 greenhouse gas emissions associated with the disposal of waste can be calculated according to the general equation:

$$\text{GHG emissions (t } CO_2\text{-e)} = Q_j \times EF_j$$

where:

Q_j is the quantity of waste by type j

EF_j is the emission factor of waste type j (see Table 41, column B)

Organisations that do not know the composition of their waste can use the emission factors in Table 44, which gives the weighted average emission factors for the municipal, commercial and industrial, and construction and demolition waste categories.

Note: This method is used to produce an estimate of lifetime emissions from waste degradation in a landfill. In reality, waste disposed in a landfill will degrade and emit over a period of decades.

Table 42: Waste mix methane conversion factors

Waste types	**Default DOC proportion**	**Conversion factor CO_2-e (t=tonnes)**
	A	B
Food	0.15	t x 1.9
Paper and cardboard	0.4	t x 2.9
Garden and green	0.2	t x 1.4
Wood	0.43	t x 0.6
Textiles	0.24	t x 1.8
Sludge	0.05	t x 0.4
Nappies	0.24	t x 1.8
Rubber and leather	0.39	t x 2.9
Inert waste (including concrete/metal/plastics/glass)	0	t x 0
Alternative waste treatment residues	0.08	t x 0.6

Note: Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008. The proportions represent the quantity of DOC of the various waste types in the mix that may be available for conversion to methane. If waste is measured by volume and not by weight, conversion factors are available in Appendix 2.

The emission factors in column B of Table 41 have been calculated according to the default variables detailed in Table 42 and the following formula:

$$\text{GHG Emissions (t } CO_2\text{-e)} = [((Q \times DOC \times DOC_F \times F_1 \times 1.336) - R) \times (1 - OX)] \times 25$$

Table 43: Waste variables and default values

Variable	Default values
Q (Activity)	Quantity of municipal solid waste expressed in tonnes and sourced from waste records or contractor invoices
DOC	Degradable Organic Carbon expressed as a proportion of the particular waste type and contained in Table 41.
DOC_F	Fraction of degradable organic carbon dissimilated for the waste type produced with default values as follows: Food – 0.84 Paper and cardboard – 0.49 Garden and green – 0.47 Wood – 0.10 Textiles – 0.5 Sludge – 0.5 Nappies – 0.5 Rubber and leather – 0.5 Inert waste, including concrete, metal, plastic and glass – 0.0 Alternative waste treatment residues – 0.5
F_I	Methane fraction of landfill gas which has a default value of 0.50
1.336	Conversion rate of carbon to methane
R	Recovered methane during the year, measured/expressed in tonnes
OX	Oxidation factor which has a default value of 0.1 for covered, well-managed landfills (and a value of 0 for uncovered landfills)
25	CH_4 global warming potential used to convert the quantity of methane emitted to CO_2-e from the quantity of waste produced

Note: The CH_4 recovered must be subtracted from the amount generated before applying the oxidation factor because only the landfill gas that is not captured is subject to oxidation.

Table 44: Waste emission factors for total waste disposed to landfill by broad waste stream category

Waste types	Municipal solid waste	Commercial and industrial waste	Construction and demolition waste
	A	B	C
Emission factor (t CO_2-e/t waste)	1.4	1.2	0.2

Note: Organisations that have data on their own waste streams and waste mix should use that data.
Source: Derived from National Greenhouse and Energy Reporting (Measurement) Determination 2008.

Example: Calculation of lifetime emissions generated from solid waste

A higher education facility produced a total solid waste stream of 240 tonnes which was disposed of in the local landfill. This waste comprises 140 tonnes of food waste, 50 tonnes of paper/paper board, 10 tonnes of garden and park waste and 40 tonnes of inert waste. No methane (R) was recovered. As each waste stream needs to be treated separately, their lifetime greenhouse gas emissions (GHG) are calculated as follows:

GHG emissions (t CO_2-e) = Qt x EF (Table 41, Column B)

Food = 140 x 1.9 = 265 tonnes CO_2-e

Paper = 50 x 2.9 = 147 tonnes CO_2-e

Garden = 10 x1.4 = 14 tonnes CO_2-e

Inert = 40 x 0.0 = 0 tonnes CO_2-e

Total Waste GHG emissions = 426 tonnes CO_2-e

Example: Calculation of lifetime emissions generated from waste of unknown composition

A commercial company in the finance industry disposes 1 kilotonne of commercial and industrial waste.

GHG emissions (t CO_2-e) = Q x EF (Table 44, Column B) = 1000 t x 1.2 = 1200 t CO_2-e

Wastewater handling (domestic and commercial)

Total greenhouse gas emissions from municipal wastewater are the sum of emissions from wastewater treatment and sludge treatment. The total quantity of wastewater treated depends on the population that is generating wastewater.

The following formula should be used to estimate the CO_2-e emissions from treating municipal wastewater. This formula is most relevant to local government authorities.

GHG Emissions (t CO_2-e) = $((((P \times DC_w) \times (1 - F_{sl}) - COD_{eff}) \times MCF_{ww} \times EF_w)) + (P \times DC_w \times F_{sl} \times MCF_{sl} \times EF_{SL})) - R$

The parameters used in the above equation are explained in Table 45 together with a listing of the various default values.

Example: Calculation of emissions generated from municipal wastewater

A local government wastewater treatment plant services a population of 20,000 people. The treatment process is characterised as a deep anaerobic lagoon. Based on internal records, the fraction of COD that is removed and treated as sludge in an anaerobic digester is 0.54. The treatment plant recovers all the methane generated in the anaerobic digester. The plant has measured the COD in their effluent as 100 tonnes. Their CO_2-e greenhouse gas emissions are calculated as follows:

COD calculation:

COD_w (tonnes) = Population x DC_w

= 20,000 x 0.0585

= 1,170 tonnes COD

Emissions from wastewater treatment calculation:

GHG emissions (tonnes CO_2-e) = (COD x (1-F_{sl}) – COD_{eff}) x MCF_{ww} x EF_w

= (1,170 x (1-0.54) –100) x 0.8 x 6.3

= 2,191 tonnes CO_2-e

Emissions from sludge calculation:

GHG emissions (tonnes CO_2-e) = CODw x F_{sl} x MCF_{sl} x EF_{sl} = 1,170 x 0.54 x 0.8 x 6.3

= 3,159 tonnes CO_2-e

Total emissions:

Accounting for the recovery of methane in the anaerobic digester, the sum of wastewater and sludge GHG emissions = 2,191 tonnes CO2-e

Table 45: Municipal waste variables and default values

Variable	Default values
P	The population served and measured in persons and sourced from waste treatment records
DC_w	The quantity in kilograms of Chemical Oxygen Demand (COD) per capita per year of wastewater. In the event that no waste analysis data is available, a default value of 0.0585 tonnes per person per year can be used
COD_w	Chemical Oxygen Demand (COD) in tonnes of COD per year which is the product of DC_w and population
COD_{eff}	The quantity of COD in wastewater discharged in effluent from the treatment plant
F_{sl}	Default fraction of COD removed as sludge. Should be readily available from internal records of wastewater treatment plants (default value of 0.29)
EF_w	Default methane emission factor for wastewater with value of 6.3 tonnes CO_2-e/tonne COD (wastewater)
EF_{sl}	Default methane emission factor for sludge with value of 6.3 tonnes CO_2-e/tonne COD (sludge)
MCFww and MCF_{sl}	Fraction of COD anaerobically treated in wastewater (ww) and sludge (sl). This value varies according to wastewater treatment type. IPCC defaults are:

Variable	Default values
	Managed aerobic treatment – 0 Unmanaged aerobic treatment – 0.3 Anaerobic digester/reactor – 0.8 Shallow anaerobic lagoon (<2 metres) – 0.2 Deep anaerobic lagoon (>2 metres)– 0.8
R	Recovered methane from wastewater in an inventory year, measured/expressed in tonnes

Appendix 5 Revisions to factors from previous issue

The *National Greenhouse Accounts (NGA) Factors Workbook* has been updated to include the latest amendments to Method 1 methodologies within the *National Greenhouse and Energy Reporting (Measurement) Amendment (Energy) Determination 2017.*

Updates in this workbook include:

1. In response to stakeholder feedback a section providing information on how scope 2 emission factors are calculated has been added to section 2.3 (Section 2.3.1 page 18).

2. Electricity – scope 2 emission factors have been updated to reflect the latest estimates (Tables 5 and 6, page 20 and 21).

- Scope 2 emission factors allow for the derivation of emissions associated with the consumption of purchased electricity from the grid, or loss of electricity from an electricity transmission or distribution network that is, or is part of, the main electricity grid in a State or Territory.

3. Electricity – scope 2 and 3 emission factors "latest estimate" figures in the previous 2015 NGA Factors publication have been updated with 2016 figures (Table 41, page 69).

State or territory	EF for scope 2				EF for scope 3			
	Revised values		Previous values		Revised values		Previous values	
	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ	kg CO_2-e/kWh	kg CO_2-e/GJ
New South Wales and ACT	0.83	230	0.84	232	0.12	33	0.12	33
Victoria	1.08	300	1.09	302	0.09	25	0.10	27
Queensland	0.79	219	0.78	218	0.14	38	0.16	44
South Australia	0.49	137	0.53	148	0.09	26	0.11	29
Western Australia (SWIS)	0.70	196	0.72	199	0.06	16	0.10	28
Tasmania	0.14	40	0.12	32	0.03	7	0.02	4
Northern Territory	0.64	179	0.67	185	0.09	24	0.10	28
Australia	0.81	224	0.81	225	0.11	29	0.11	31

4. The factor for N_2O emissions from the biological treatment of solid waste has been updated to align with the National Inventory Report (section 5.2 page 51).