Australian Government
Australian Greenhouse Office

AGO Factors and Methods Workbook

August 2004

For use in Australian Greenhouse Office Programmes

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Introduction

The AGO Factors and Methods Workbook provides AGO programme participants with a single source of current greenhouse gas emission factors (EFs) for use in the estimation of their emissions and emission abatement related to programme activities.

The emission factors presented are designed to be consistent with the estimates of emissions reported in *Australia's National Greenhouse Gas Inventory 2002.* They are largely drawn or derived from material in the *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002* series, which documents the methodologies and emission factors used in the estimation of Australia's National Inventory.

The emission factors in this publication are generally state or national **averages**. They have been updated from the previous version of the *AGO Factors and Methods Workbook*, released in March 2003, to reflect changing information on Australia's emission sources. Updated emission factors reflect, for example, changes in the composition of the national fuel mix used to produce electricity. Past emission factors remain valid, nevertheless, and changes to this year's emission factors do not imply necessarily any need to revise estimates of emissions from previous years.

The emission factors presented may also be used in conjunction with international reporting frameworks such as the World Business Council for Sustainable Development/World Resources Institute *The Greenhouse Gas Protocol: a corporate accounting and reporting standard (*'The WBCSD/WRI GHG Protocol' http://www.ghgprotocol.org/), as appropriate (see page 11).

NOTE FOR GREENHOUSE CHALLENGE MEMBERS!

Greenhouse Challenge Programme members can draw on material outlined in this Workbook in completing their annual progress reports under the Programme. For simplicity,

- A summary of energy emission factors for Greenhouse Challenge members is provided at **Appendix 1**.
- Alternatively a spreadsheet calculator is available, for less complex emission profiles, with the most commonly used emission factors incorporated. (see: www.greenhouse.gov.au/challenge/tools/spreadsheet/index.html

1 Key definitions and terms

Direct and indirect emissions

Participants for many AGO programmes are required to report both direct and some indirect emission estimates.

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:

- production of energy, heat, steam and electricity, including carbon dioxide and products of incomplete combustion (methane and nitrous oxide);
- manufacturing processes, which themselves produce emissions (example, cement manufacture, aluminium, ammonia);

- transportation of materials, products, waste and people; for example, use of mobile combustion sources, such as trucks and cars but not those owned and operated by another organisation;
- fugitive emissions: intentional or unintentional GHG releases (such as methane emissions from coal mines, natural gas leaks from joints and seals); and
- waste emissions from the disposal of waste in landfill sites.

From the point of view of a company with a car fleet, for example, emissions from the combustion of petrol in motor vehicles will represent a source of direct emissions. Similarly, for a mining company, methane escaping from a coal seam during mining (fugitive emissions) and, for a cement manufacturer, CO_2 released during cement production also represent sources of direct emissions for the companies concerned.

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 (eg kg CO_2/GJ energy in petrol) with activity data (eg kilolitres x energy density of petrol used).

Indirect emissions include those 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 results from the consumption of electricity. Other examples of indirect emissions resulting from an organisation's activities include upstream emissions generated in the extraction and production of fossil fuels and the downstream emission implications of the transport of an organisation's product to customers or from contracting/outsourcing of activities. The appropriate emissions factor for these activities depends on the parts of the processes of upstream production and downstream use you wish to consider in counting the emissions associated with the activity.

Types of emissions factors

The world of emissions factors can become confusing – the following is provided in an attempt to clarify the purpose of the types of emissions factors contained in this workbook.

- A '**point-source emissions factor'** gives the quantity of a given GHG emitted per unit of energy, fuel etc., at the point of release of the emission. Combustion emissions occurring at the point of final fuel consumption (eg emissions from the combustion of petrol in a motor vehicle) or methane escaping from a coal seam during mining (fugitive emissions) constitute point-source emissions. Emissions from the on-site disposal of waste would also be calculated using a 'point source' emissions factor.
- **'A full fuel cycle emissions factor'** gives the quantity of GHG emissions emitted per unit of energy for the entire fuel production and consumption chain. As an example, in the case of electricity, the full fuel cycle emission factor includes the sum of the emissions generated at the point of combustion in the power station; the fugitive and energy emissions from the mining and production of the fuels used in the power station, and any subsequent losses in the transmission and distribution networks during the delivery of the electricity.
- **Other emission factors** –
  - for example the factors used to calculate the quantity of emissions from waste generated by an organization which occur after the volume of waste has been transported to and disposed of in an alternative location.
  - Alternative means of defining the scope for which indirect emissions should be reported (such as under the WBCSD/WRI GHG Protocol – see below)

Which emissions factor to use?

AGO programs regularly require organisations to consider the full greenhouse impact of their activities – that is both upstream and downstream activities – direct and indirect emissions.

For the purpose of energy related emissions, these consequences are captured through the use of **'full fuel cycle emission factors**'

The Greenhouse Challenge Programme covers both direct and some indirect emissions (with the exception of the use of transport fuels). The emissions factors provided for calculating emissions inventories for Greenhouse Challenge members reflect this coverage of emissions:

- Transport fuel emissions under the Greenhouse Challenge reflect emissions for combustion of the fuel only;
- All other emissions from fuel and energy use (including electricity) are calculated using full fuel cycle emissions factors; and
- Waste emissions are calculated on the basis of emissions on site and downstream disposal using consistent factors.

It should be noted, however, that the WRI/WBCSD Greenhouse Gas Emissions Reporting Protocol calls for a separate reporting of direct and indirect emissions. Furthermore, in the case of indirect emissions for electricity, it advocates including only those emissions at the point of generation – not extraction nor transmission and distribution. An explanation of the relationship between the 'Full Fuel Cycle Emissions Factor' for electricity used by the AGO and the WRI/WBCSD approach is provided on page 11 for those readers who are interested.

A review of the factors used within the Greenhouse Challenge Programme is underway, with a view to harmonising the Challenge reporting approach with the WRI/WBCSD Greenhouse Gas Emissions Reporting Protocol and simplifying the range of emissions factors applied. For the 2004-05 version of the AGO Factors and Methods workbook the existing conventions for the Greenhouse Challenge have been preserved and Greenhouse Challenge members are requested to continue with established practices. A revised approach will be developed in consultation with stakeholders and released in time for the 2005-06 workbook. An appendix summarizing the current appropriate energy emissions factors for Greenhouse Challenge Members has been provided to simplify the process of locating the right factor for this year.

Average versus marginal emissions factors

When calculating the impact of an abatement project that results in a change in electricity usage, it may be more appropriate to use a marginal factor rather than the average emission factors presented in this workbook. The AGO provides estimates of marginal EFs for electricity and these may be found at http://www.greenhouse.gov.au/ggap/round3/index.html

2 Information sources

The principal sources of information used in developing this workbook are:

1. Australian Greenhouse Office (2004a), *National Greenhouse Gas Inventory 2002*, Commonwealth of Australia.
2. Australian Greenhouse Office (2004b), *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002*, Commonwealth of Australia.
3. Intergovernmental Report on Climate Change (2000), *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* Japan.
4. Intergovernmental Report on Climate Change (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories;* Paris.
5. George Wilkenfeld & Associates Pty Ltd and Energy Strategies (2002), *Australia's National Greenhouse Gas Inventory, End Use Allocation of Emissions*, Report to the Australian Greenhouse Office, Commonwealth of Australia.
6. George Wilkenfeld and Associates Pty Ltd (2004), *National Greenhouse Gas Inventory 1990 to 2002*, *Trends Analysis Project Report,* unpublished report to the Australian Greenhouse Office.

3 Additional Information and web sites

1. Greenhouse Challenge Programme.
   http://www.greenhouse.gov.au/challenge
   http://www.greenhouse.gov.au/challenge/publications/index.html
2. Australian National Greenhouse Gas Inventory and related topics.
   http://www.greenhouse.gov.au/inventory/index.html
3. Intergovernmental Panel on Climate Change (IPCC) National Greenhouse Gas Inventories Programme.
   http://www.ipcc-nggip.iges.or.jp
4. IPCC web site. http://www.ipcc.ch/
5. United Nations Convention on Climate Change and relate topics including the Kyoto Protocol. http://unfccc.int
6. The GHG Protocol Initiative (initiative convened by the World Business Council for Sustainable Development (WBCSD) & the World Resources Institute (WRI)).
   http://www.ghgprotocol.org/

4 AGO contact

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Factors, Methods and Calculations

1 Energy

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

- point source and full fuel cycle emission factors from the combustion of solid, gaseous and liquid fuels (section 1.1);
- point source and full fuel cycle emission factors for the combustion of liquid and gaseous fuels for **transport** (section 1.2);
- full fuel cycle emission factors for the **consumption of electricity** (section 1.3); and
- point source emission factors for the extraction of fossil fuels (section 1.4).

The approach to calculating greenhouse gas emissions may depend on the programme or purpose for which they are being used and this should be confirmed, if necessary, prior to estimation.

A summary of energy emission factors that should be used by Greenhouse Challenge members is provided at Appendix 1.

1.1 Stationary Energy Emissions (non transport)

1.1.1 Fuel combustion emissions (excluding natural gas)

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

GHG emissions (t CO_2-e) = Q x EC x EF/1000

Where: Q is the quantity of fuel in tonnes or thousands of litres (sourced from inventory or supplier invoices or production records).

EC is the energy content of fuel in GJ/tonne or GJ/kL (Column A, Table 1 below),

EF is the relevant emission factor. In this case, both the point source emission factor (column B) and the full fuel cycle emissions factor in kg CO_2-e /GJ (Column C) including indirect-emissions and non-CO_2 gases have been reported. For reporting under the **Greenhouse Challenge**, *Full Fuel Cycle* Emission Factors should be used. Division by 1000 converts kg to tonnes.

Emissions are generally expressed in tonnes of CO_2-equivalent (CO_2-e), which includes CO_2, as well as the global warming effect of the relatively small quantities of CH_4 and N_2O emitted. Most of the emissions occur at the point of final fuel combustion (the point source emission factor), but the broadest estimate of total emissions resulting from the use of the fuel includes those emissions associated with the production and transport of the fuel ("full fuel cycle").

Separate calculations should be carried out for each fuel type.

Table 1 Fuel combustion emission factors (Stationary Energy) *

Fuel combusted	Energy content A	Point source emissions factor B	Full fuel cycle emissions factor C
	GJ/t	**kg CO_2-e/GJ**	**kg CO_2-e/GJ**
Solid Fuels			
Black coal – NSW Electricity Generation	•27.0 (washed) 23.2 (unwashed)	90.3	98.1
Black coal – NSW other uses	•27.0 (washed) 23.2 (unwashed)	90.3	97.0
Black coal – Qld Electricity Generation	•27.0 (washed) 21.9 (unwashed)	91.2	93.9
Black coal – Qld other uses	•27.0 (washed) 21.9 (unwashed)	90.3	94.9
Brown coal	10.0	92.0	92.5
Coal used in steel industry	30.0	91.8	112.8
Brown Coal Briquettes	22.1	105.0	115.3
Coke	27.0	119.5	130.9
Wood and wood waste (dry) (CO_2 not counted)	16.2	1.4 (if used in boiler) 14.5 (if used in residential)	1.4 (if used in boiler) 14.5 (if used in residential)
Bagasse as crushed (CO_2 not counted)	9.6	1.4 (if used in boiler)	1.4 (if used in boiler)
Gaseous Fuels			
Coal by-products (gaseous)	18.1 MJ/m^3	37.0	48.4
Natural gas	Refer table 2	Refer table 2	Refer table 2
Town gas	Consumption measured in GJ	59.4	59.4
Landfill and wastewater methane (CO_2 not counted)	37.7 MJ/m^3	5.0	5.0
Liquid Fuels	GJ/kL		
LPG – non transport	49.3 GJ/t	59.4	67.2
Coal by-products (coal tar and BTX)	41.9 GJ/t	81.0	92.4
Naptha	48.2	66.0	73.8
Lighting kerosene	36.6	69.7	77.5
Power kerosene	36.6	69.7	77.5
Heating oil	37.3	69.7	77.5
ADO	38.6	69.7	77.5
Industrial/marine DO	39.6	69.7	77.5
Fuel Oil	40.8	73.6	81.4
Biodiesel			To be developed

*For reporting under the **Greenhouse Challenge and Greenhouse Friendly Certification**, *Full Fuel Cycle* emission factors (Column C) should be used.

Sources: Derived from AGO (2004a); AGO (2004b); George Wilkenfeld (2004); George Wilkenfeld and Associates and Energy Strategies (2002).

Example: Calculation of Emissions Generated from LPG (non-transport)

An island resort located off the coast of Queensland uses 200 tonnes of LPG for non-transport purposes per annum. As a Greenhouse Challenge member, the *Full Fuel Cycle* emission factor should be used. Greenhouse gas direct combustion emissions are calculated as follows:

GHG Emissions = Activity (t) x Energy Content of Fuel (GJ/t) x Emission Factor (kg CO_2-e/GJ) /1000

= (200 x 49.3 x 67.2)/1000 = 660 t CO_2-e

1.1.2 Natural gas

Natural gas is usually supplied at either high or low pressure, depending on the scale of use. Major users are those supplied at high pressure and with an annual usage of more than 100 000 GJ. Estimates of emissions may be calculated using the following formula:

GHG Emissions (t CO_2-e) = Q x EF/1000

Where: Q is the quantity of natural gas consumed and expressed in GJ and sourced from supplier invoices /meters.

EF is the relevant emission factor. In this case, both the Point source emission factor, by state and territory (column A for small users, column C for large users) and the full fuel cycle emissions factor (column B for small users and column D for large users) are provided in kg CO_2-e /GJ. For reporting under the **Greenhouse Challenge**, *Full Fuel Cycle* Emission Factors should be used. Division by 1000 converts kg to tonnes.

Table 2 Emissions from the consumption of natural gas *

	Small user < 100,000 GJ pa		**Large user > 100,000 GJ pa**	
State	**Point source EF (a)**	**Full fuel cycle EF (b)**	**Point source EF (a)**	**Full fuel cycle EF (b)**
	A	B	C	D
	kg CO_2-e/GJ	kg CO_2-e/GJ	kg CO_2-e/GJ	kg CO_2-e/GJ
NSW & ACT	51.7	71.3	51.7	68.0
Victoria	51.9	63.6	51.9	63.4
Queensland	52.6	68.8	52.6	64.2
SA	51.7	73.8	51.7	71.2
WA	52.7	60.7	52.7	60.0
TAS	NA	NA	NA	NA
NT	52.0	53.6	52.0	53.5

* For reporting under the **Greenhouse Challenge and Greenhouse Friendly Certification**, *Full Fuel Cycle* emission factors should be used, (either column B or D depending on the size of the user).

Source: George Wilkenfeld 2004.

Example: Calculation of Emissions Generated from Natural Gas Consumption

A Victorian Hotel uses 9000 GJ of natural gas per annum. Its greenhouse gas emissions (GHG) are calculated as follows:

GHG Emissions = Q x EF / 1000
= 9000 x 63.6 / 1000 = 572 t CO_2-e

1.2 Transport Fuels

Estimates of emissions from the consumption of transport fuels may be estimated with the following formula:

GHG emissions (t CO_2-e) = Q (kL) x EF

OR

GHG emissions (t CO_2-e) = Q (GJ) x EF/1000

Where: Q is the quantity of fuel in thousands of litres or GJ (sourced from inventory or supplier invoices or production records).

EF is the relevant emission factor. Emission factors for combustion of fuels used for transport are reported in Table 3 in both kg CO_2-e per GJ and kg CO_2-e per kL. Both the Point source emission factor (columns B or C) and the full fuel cycle emissions factor in kg CO_2-e /GJ (Columns D or E) including indirect-emissions and non-CO_2 gases have been reported. For reporting under the Greenhouse Challenge, *Point source emission factors* should be used. Division by 1000 converts kg to tonnes.

Table 3 Fuel Combustion emission factors (Transport Fuels) *

Fuel	Energy content	Point source EF		Full fuel cycle EF	
	A	B	C	D	E
	GJ/kL	kg CO_2-e/GJ	t CO_2-e/kL	t CO_2-e/GJ	t CO_2-e/kL
Automotive Gasoline	34.2	73.5	2.5	81.2	2.8
Automotive Diesel Oil	38.6	70.5	2.7	78.2	3.0
Aviation Gasoline	33.1	69.5	2.3	77.2	2.6
Aviation Turbine	36.8	70.4	2.6	78.1	2.9
Industrial diesel fuel	39.6	70.5	2.8	78.2	3.1
Fuel Oil	40.8	74.3	3.0	82.0	3.3
LPG	25.7	60.5	1.6	68.3	1.8
Natural gas (LV)	39.5 (a)	57.2	2.3 (b)	68.6	2.7
Natural Gas (HV)	39.5 (a)	53.8	2.1 (b)	65.2	2.6

*For reporting under the **Greenhouse Challenge**, *Point source emission factors* should be used, (either column B or C depending on the units of the fuel data available). For Greenhouse Friendly Certification, Full Fuel Cycle emission factors should be used.

(a) MJ/m^3 (b) t CO_2-e/m^3

Example: Calculation of emissions generated from transport fuels

A New South Wales freight company consumes 2400 kL of petrol and 2400 kL automotive diesel (transport) per annum. The **direct** GHG emissions are calculated as follows:

Emissions (t CO2-e) = (Q x EF (CO_2-e/kL)

Petrol = 2,400 x 2.5 = 6,000 t CO_2-e

Diesel = 2,400 x 2.7 = 6,480 t CO_2-e

Total GHG emissions = 6,000 + 6,480 =12,480 t CO_2-e

Kilometers traveled

If fleet records show kilometers travelled and not the total quantity of fuel purchased please contact the GC Team to discuss the use of average fuel consumption factors.

1.3 Indirect emissions (electricity end use)

Indirect emission factors for the consumption of electricity are provided in Table 4. **State emissions factors** are used because electricity flows between states are significantly constrained by the capacity of the inter-state interconnectors (or in some cases there are no interconnections). Greenhouse gas emissions associated with the quantity used in tonnes of carbon dioxide equivalent (t CO_2-e) may be calculated with the following equation**:**

GHG emissions (t CO_2-e) = Q x EF (Column A)

Where: Q (Activity) is the electricity used expressed in kWh and

EF (Emission Factor) is the value in Table 4.

OR

GHG emissions (t CO_2-e) = Q x EF/1000 (Column B)

Where: Q (Activity) is the electricity used expressed in GJ

EF (Emission Factor) is the value in Table 4, by location (in GJ (Column B)). It includes CO_2, CH_4 and N_2O emissions from power stations, as well as indirect combustion and fugitive emission from fuel production. The factors take into account average transmission and distribution losses in each state as well as interstate electricity flows. Greenhouse Challenge members should use the full fuel cycle emission factor. Division by 1000 converts kg to tonnes.

Table 4 Emission factors for electricity per kWh delivered, 2002

State	Full Fuel Cycle Emission Factor	
	A	B
	kg CO_2-e/kWh	kg CO_2-e/GJ ($GgCO_2$-e/PJ)
NSW, ACT	1.054	293
VIC	1.392	387
QLD	1.058	294
SA	0.960	267
WA	1.053	293
TAS	0.006	2
NT	0.742	206

Source: George Wilkenfeld (2004).

Example:

A company in New South Wales consumes 100,000 kWh of electricity.

Emissions (t CO_2-e) = (100,000 * 1.054) /1000= 105.4 tonnes.

Box: Emission Factors for the World Resources Institute (WRI)/World Business Council for Sustainable Development (WBCSD) Greenhouse Gas Emissions Reporting Protocol (the WRI/WBCSD GHG Protocol).

The AGO Factors and Methods Workbook seeks to generate a consistent set of emission factors which may be used for a variety of purposes, including for reporting under the WRI/WBCSD GHG Protocol.

The WRI GHG Protocol introduces three ‘scopes’ of emission categories. Emissions from scope 1 and scope 2 are required for the purposes of reporting under the protocol, scope 3 is optional.

Scope 1 emissions are direct emissions, as defined in the introduction, from sources owned or operated by the organisation. ‘Point source emissions factors’ provided in the AGO Factors and Methods Workbook are appropriate for calculating ‘Scope 1’ emissions.

Scope 2 emissions are greenhouse gases released as a result of the generation of electricity, or the production of heat, cooling or steam purchased by the reporting company. The relevant emission factor is reported at Column A in Table 5. The relationship between this emissions factor and the full fuel cycle emissions factor used for reporting under the Greenhouse Challenge and other AGO programmes is also explained in Table 5. The AGO Full Fuel Cycle emissions factor (Column D) is equal to the sum of emissions associated with extraction of the generation fuel (Column B) plus the emissions associated with transmission and distribution losses (Column C) plus the Scope 2 emissions. The factors in Table 5 are expressed in kg of CO_2-e per kWh of delivered electricity.

Scope 3 emissions are other indirect GHG emissions not included in the other ‘scope’ categories. In general, they include the emissions associated with energy lost in transmission & distribution (T&D) system and the extraction, production and transport of fuels consumed in the generation of electricity purchased and consumed by the reporting company. Scope three emissions can also include the following types of emission sources in connection with the companies activities:

- Disposal (end of life) of products sold
- Disposal of waste generated
- Employee business travel
- Employees commuting to and from work
- Extraction, production and transport of purchased fuels consumed
- Extraction, production and transport of other purchased materials or goods
- Generation of purchased electricity that is sold to end-users
- Leased and outsourced activities, and franchises
- Transportation of products, materials, waste
- Use of products manufactured and sold

Table 5 Emission factors: the chain from WRI/GHG GHG Protocol, Scope 2, to full fuel cycle

	'Scope 2' emission factor	Emission factor for fuel extraction	Transmission loss emission factor	Full Fuel Cycle emission factor =A+B+C
	A	B	C	D
	kg CO_2-e/kwh delivered			
NSW	0.894	0.079	0.081	1.054
Vic	1.284	0.002	0.106	1.392
Qld	0.896	0.035	0.127	1.058
SA	0.743	0.112	0.105	0.960
WA	0.958	0.026	0.069	1.053
Tas	0.006	0.000	0.000	0.006
NT	0.671	0.015	0.056	0.742

Source: Derived from George Wilkenfeld 2004.

1.4 Extraction and distribution of coal, gas and petroleum

Coal

Emissions from the production of coal may be estimated from the following formula:

GHG Emissions (tCO_2-e) = Q x EF (CO_2-e)/1000

Where: Q (Activity) is the mass of fuel produced (tonnes).

EF (Emission Factor) is the point source emission factor in kg CO_2-e /tonne in Column C, Table 6 below. Division by 1000 converts kg to tonnes. The CO_2-e estimate (Column C) is the sum of CO_2 (Column A) and 21 times the CH_4 (Column B).

Table 6 Emission factors for the production of coal (fugitive)

	kg emissions/tonne raw coal		
	CO_2	CH_4	CO_2 - e
	A	B	C
COAL	**kg/tonne**	**kg/tonne**	**kg/tonne**
Gassy underground mines – NSW	NA	17.21	361.4
Gassy underground mines - Queensland	NA	17.43	366.0

Less gassy underground mines	NA	0.54	11.3
Open cut mines – NSW	NA	2.17	45.5
Open cut mines – Queensland	NA	0.81	17.1
Open cut mines - Tasmania	NA	0.68	14.2

Source: AGO (2004b).

Petroleum and gas

Emissions from the production of petroleum and gas may be estimated from the following formula:

GHG Emissions (tCO_2-e) = Q x EF (CO_2-e)/1000

Where: Q (Activity) is the mass of fuel produced in tonnes (or energy content measured in PJ).

EF (Emission Factor) is the point source emission factor in kg CO_2-e /PJ in Column C, Table 7 below. The CO_2-e estimate (Column C) is the sum of CO_2 (Column A) and 21 times the CH_4 (Column B).

Table 7 Point source emission factors for the production of oil and gas (fugitive)

PETROLEUM	CO_2	CH_4	CO_2 - e
	A	B	C
	Gg/PJ Throughput	Gg/PJ Throughput	Gg/PJ Throughput
Crude oil production	NA	0.001	0.022
Crude oil transport: domestic	NA	0.0007	0.016
Crude oil refining and storage	0.128	0.001	0.154
NATURAL GAS			
Production and processing	NA	0.001	0.023
Transmission	0.0006	0.011	0.232
Distribution	0.021	0.369	7.761
PETROLEUM AND GAS COMBINED			
Venting at gas processing plant *	2.474	0.064	3.815
Flaring *	0.863	0.011	1.086

Source: AGO (2004b). * These estimates are national average emission factors and should be used in the absence of plant- or company-specific data.

Table 8 Point source emissions factors for flaring of gas at oil refineries

	CO_2	CH_4	CO_2-e
kg/GJ energy flared	47.2	0.12	49.7

Source: AGO (2004b).

2 Industrial processes including refrigerants and solvents

Greenhouse gas emissions from industrial processes other than from combustion of fuels for energy may be estimated by using the emission factors described in Tables 9,10 and 11. These emission factors are national average emissions factors and can be used in the absence of plant- or company specific data.

Table 9 Industrial Processes-Emission Factors and Activity Data

Source	Emission Factor by Gas (t)						Activity Data Required
	CO_2	CH_4	N_2O	PFC	SF_6	CO_2-e	
	A	B	C	D	E	F	
Cement	0.518					0.518	Q= clinker produced (t)
Quicklime production	0.675					0.675	Q= quicklime produced (t)
Dolomitic lime production	0.867					0.867	Q= dolomitic lime produced (t)
Magnesium – use of SF_6 as cover gas					1	23,900	Q= SF_6 used (t)
Soda Ash use	0.415					0.415	Q= soda ash used (t)
Nitric acid production			0.0055			1.705	Q= nitric acid produced (t)
Aluminium production	1.513			(CF_4) 0.108 (C_2F_6) 0.014		2.344	Q= aluminium produced (t)
Aluminium production – use of lime	0.0942					0.0942	Q= lime by-product produced (t)
Iron & Steel – crude steel production		0.00044				0.00924	Q= crude steel (t)

The general methodology employed to estimate emissions associated with each industrial process involves the product of activity level data, eg amount of material produced or consumed, and an associated emission factor per unit of consumption/production according to:

$$E_j = Q_j \times EF_j$$

Where:

E_j is the process emission (t/yr) of CO_2-e from industrial sector *j*

$\mathbf{Q_j}$ is the amount of activity or production of process material in industrial sector *j* (tonnes/yr unless otherwise specified)
$\mathbf{EF_j}$ is the emission factor in t CO_2-e per tonne of production (column F)

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

A company produces 20,000 tonnes of cement clinker per annum. The GHG emissions are calculated as follows:

Emissions (t CO_2-e) = (Q x EF)

Clinker production = 20,000 tonnes

Emission factor (t/t)= 0.518

CO_2-e emissions (t) = 20,000 x 0.518 = 10360 tonnes CO_2-e per annum

Table 10 Industrial Processes-Emission Factors and Activity Data for synthetic gases

Consumption of Halocarbons and SF_6			
Refrigeration and air conditioning	**Default Loss Rates**		**Activity Data Required**
	HFCs	**SF_6**	
domestic refrigeration	0.01		Q = HFC contained in equipment. Both the type of HFC contained in equipment and the quantity of HFC will be shown on the equipment compliance plate. Note: Global warming potentials will need to be applied according to the type of HFC charge. For a list of global warming potentials, see Appendix 3.
domestic window/wall air conditioning	0.02		
domestic split system air conditioning (assuming residual charge vented on retirement)	0.20		
commercial chillers	0.15		
commercial non-chillers	0.15		
transport refrigeration	0.15		
mobile (dependent on whether there is recovery and recycling when serviced and on retirement)	0.13 to 0.29		
gas insulated switchgear and circuit breaker applications		0.01	Q = SF_6 contained in equipment

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

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

Applying the annual leakage rate of 0.15, gives an annual loss of 0.15 x 160 = 24kg of HFC134a.

Multiplying the 24 kg of HFC134a by its global warming potential of 1300 (from Appendix 3), gives a total annual emission of 31,200 kg of CO_2-e.

The use of explosives in mining leads to the release of greenhouse gases. The activity level is the mass of explosive used (in tonnes). Emissions are calculated using the EFs from Table 11 Industrial Processes .

Table 11 Industrial Processes Emission factors for explosive use

Explosive type	Tonne CO_2/tonne product
ANFO	0.1673
Heavy ANFO	0.1778
Emulsion	0.1659

3 Waste to landfill and wastewater treatment

3.1 Introduction

The GHG emissions associated with the disposal of waste can be calculated by the formula, data variables and EFs contained in Tables 12 and 13. Separate calculations should be carried out for each waste type.

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.

Should the methane or part of it be vented to atmosphere that quantity vented would be considered an emission (multiplied by 21 to obtain the CO_2 equivalent emission) as this action would be adding to atmospheric CH_4.

Where waste material is diverted from landfill to recycle or for energy use, no credit for emissions saved can be obtained from the material diverted. The advantage to the organisation is in having less emissions attributed to its activities because less waste is going to land fill. With paper recycling, for example, less energy will be used in processing recycled paper and less virgin wood consumed.

3.2 Municipal Solid Waste

Municipal solid waste that is ultimately disposed of in a landfill produces methane in accordance with the formula (see Table 12):

$$\text{GHG Emissions } (t\ CO_2\text{-e}) = [((Q \times DOC \times DOC_F \times F_1 \times 16/12) - R) \times (1 - OX)] \times 21$$

Table 12: 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 13.
DOC_F	Fraction of degradable organic carbon dissimilated for the waste type produced with a default value of 0.55 for Paper and paper board, Wood and straw and Garden and park waste, and 0.77 for other (non-lignin containing) materials; 0.66 (average of 0.77 and 0.55) for co-mingled waste.
F_1	Carbon fraction of landfill gas which has a default value of 0.50
16/12	Conversion rate of carbon to methane
R	Recovered CH_4 in an inventory year and expressed in tonnes
OX	Oxidation factor (0.1)
21	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 13: Waste – methane conversion factors

Waste types	Default DOC %/fraction	Conversion factor CO_2-e no CH_4 recovered (t=tonnes)
	A	B
Paper and paper board	40% (0.4)	t x 2.8 (DOC_f=0.55)
Textiles	40% (0.4)	t x 3.9 (DOC_f=0.77)
Textiles synthetics	0%	t x 0
Wood and straw	30% (0.3)	t x 2.1 (DOC_f=0.55)
Garden and park	17% (0.17)	t x 1.2 (DOC_f=0.55)
Food	15% (0.15)	t x 1.5 (DOC_f=0.77)
Co-mingled	15% (0.15)	t x 1.2 (DOC_f=0.66)[1]
Medical waste (tissue, fluids, pharmaceuticals)	5% (0.05)	t x 0.5 (DOC_f=0.77)
Concrete/metal/pl astics/glass	0% (0.00)	t x 0 (DOC_f=0.0)

Note: The percentage/fractions represent the quantity of DOC of the various waste types in the mix that may be available for conversion to CO_2.

Note: Organisations that manage their own landfill sites may deduct the amount of methane recovered.

If waste is measured by volume and not by weight conversion factors are available in Appendix 4.

Example: Calculation of Emissions Generated from Solid Waste

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

GHG emissions (t CO_2-e)= Qt x EF (Table 13, Column B)

Food = 140 x 1.5 = 210 tonnes CO_2-e

Paper = 50 x 2.8 = 140 tonnes CO_2-e

Garden = 10 x1.2 = 12 tonnes CO_2-e

Plastic/Glass = 40 x 0.0 = 0 tonnes CO_2-e

Total Waste GHG emissions = 362 t CO_2-e

[1] DOC_f=0.66: derived from average of 0.77 and 0.55 for DOC_f with and without lignin respectively (see IPCC Good Practice Workbook p 5.10)

3.3 Municipal Wastewater Treatment

Total 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 measure the CO_2-e greenhouse gas emissions from treating municipal wastewater. This formula is most relevant to local government authorities.

GHG Emissions (t CO2-e) = $[(((P \times DC_w) \times (1 - F_{sl}) \times EF_w)) + (P \times DC_w \times F_{sl} \times EF_{SL})) - R] \times 21$

The parameters used in the above equation are explained in table 14 together with a listing of the various default values.

Table 14: Municipal Waste variables and default values

Variable	Default values
P (Population)	The population served and measured in 1000 persons and sourced from waste treatment records
DC	The quantity in kilograms of BOD per 1000 persons per year of wastewater. In the event that no waste analysis data is available, a default value of 18,250 kg per 1000 persons per year can be used
F_{sl}	Default fraction of degradable organic component removed as sludge. Should be readily available from internal records of wastewater treatment plants (default 0.29)
EF_w	Default methane emission factor for wastewater with value of 0.22kg CH_4/kg BOD
EF_{sl}	Default methane emission factor for sludge with value of 0.22 kg CH_4/kg DOC (where DOC can be either BOD or COD)
CH_4 - GWP	21 – the Global Warming Potential of CH_4 used to convert the CH_4 emitted from wastewater to CO_2-e
Energy potential CH_4/m^3	33810 kJ
Energy potential CH_4/kg	50312.5 kJ (0.672 kg CH_4 per m^3) (Waste Management Workbook p33)
R	Recovered CH_4 from wastewater in an inventory year and measured/expressed in tonnes
21	Global warming potential used to convert the quantity of methane emitted from the wastewater produced to CO_2-e

Example: Calculation of Emissions Generated from Municipal Wastewater

A local government wastewater treatment plant services a population of 20,000. Based on internal records, the average amount of BOD that is removed as sludge is 0.54. The treatment plant does not recover any methane. Their CO_2-e GHG emissions are calculated as follows:

GHG Emissions (t CO_2-e) $=\{[(\text{Population} \times DC_w \times (1 - F_{sl}) \times EF_w) + (P \times DC_w \times F_{sl} \times EF_{sl})] - R\} \times 21$

GHG emissions (t CO_2-e) $= \{[(P \times DC_w (1 - F_{sl}) \times EF_w) + (P \times DC_w \times F_{sl} \times EF_{sl})] - R\} \times 21$

$= \{[P \times DC_w ((1 - F_{sl}) \times EF_w + F_{sl} \times EF_{sl})] - R\} \times 21$

$= \{[P \times DC_w \times EF_w (1 - EF_{sl} + EF_{sl})] - R\} \times 21$ (where $EF_w = EF_{sl}$)

$= \{(20 \times 18250 \times 0.22 \times 1)\} - 0\} \times 21$

$= 80{,}300$ kg $CH_4 \times 21$

= 1686 t CO_2-e

3.4 Industrial Wastewater Treatment

Total emissions from industrial wastewater are the sum of emissions from wastewater treatment and sludge treatment and depends on the quantity of output produced.

If your organisation operates an industrial wastewater treatment plant then this formula should be used to estimate the CO_2-e GHG emissions. It should be noted that industrial wastewater is expressed in terms of COD. This enables the quantity of degradable carbon to be derived, which is the determinant of CH_4 emitted.

$$E\ (t\ CO_2\text{-e}) = [((W \times COD_w \times (1-F_{sl}) \times EF_w)+(W \times O \times COD_{sl} \times F_{sl} \times EF_{sl}))-R] \times 21$$

If a company does not have any company-specific data on emission factors, a simplified alternative formula for Industrial Wastewater (including sludge) emissions may be used:

$$E\ (t\ CO_2\text{-e}) = [W * COD\ (t/ML) \times 0.22 - R] \times 21.$$

The parameters used in the above equation are explained in table 15 together with a listing of the various default values.

Table 15 Industrial Waste variables and default values

Variable	Default values
W (Wastewater)	Wastewater in m^3 per tonne or ML (mega litres) of wastewater. Sourced from company discharge and production data [m^3 water=1kL]
COD_w	Quantity in kilograms of Chemical Oxygen Demand per cubic metre (or kL) of wastewater sourced from company discharge and production data
F_{sl}	Default fraction of degradable organic component removed as sludge. Should be readily available from internal records of wastewater treatment plants (default 0.29)
EF_W	Methane emission factor for industrial wastewater and has default value of 0.22 kg CH_4/kg BOD or COD
EF_{sl}	The default methane emission factor for industrial wastewater sludge with value of 0.22 kg CH_4/kg DOC (where DOC can be either BOD or COD
COD_{sl}	Quantity in kilograms of Chemical Oxygen Demand per cubic metre of sludge sourced from company discharge and production data
R	is the recovered CH_4 from wastewater year and measured in tonnes
21	Global Warming Potential of CH_4 used to convert the CH_4 emitted from wastewater to CO_2-e

Example 1: Calculation of Emissions Generated from Industrial Wastewater

An industrial wastewater treatment plant produces 26m^3 of wastewater per one tonne of product. Internal records show that the COD (COD_w) has a value of 3.0 kg per m^3 of wastewater. Approximately 5% of the COD is removed as sludge. Consequently, for each tonne of output, methane emissions (with no recovery) is converted to CO_2-e in tonnes from:

GHG Emissions (t CO2-e) = $W \times O \times [((DC_w \times (1-F_{sl}) \times EF_w) + (DC_{sl} \times F_{sl} \times EF_{sl}))-R] \times 21$

$=26 \times 1 \times [((3 \times (1- 0.05) \times 0.22)+ (3 \times 0.05 \times 0.22)) - R] \times 21/1000$

= 17.2 kg of CH_4 per tonne of product

= 0.36 t of CO_2-e per tonne of product

Example 2: Calculation of Emissions Generated from Industrial Wastewater

Company XX treats 312ML wastewater in-house annually. The wastewater passes through a series of treatment tanks.

The COD levels vary through the system and average the following.

Tank		COD mg/L (10^{-3} t/ML)
1	Tank1	11026
2	Anaerobic	3125
3	Anaerobic	1198
4	Aerated (aerobic)	1000
5	Settling Pond	867
6	Storage 1	441
7	Storage 2	367

The wastewater leaves the tank 1 at 11,026mg/L. The anaerobic process reduces the COD from 11,026 to 3125mg/L. The sludge remains in each different treatment pond and is settled in a settling pond. The ponds have not been cleaned out since the plant commenced 10 years ago.

1. The wastewater leaves Tank 1 and enters the anaerobic stage at a concentration of 11026mg /L.
2. The wastewater leaves the anaerobic stage and enters the next anaerobic stage at a concentration of 3125mg /L. This means that 11026-3125 = 7901mg /L degrades anaerobically.
3. The wastewater leaves the anaerobic stage and enters the aerobic stage at a concentration of 1198 mg/L giving 3125-1198 = 1927 that degrades anaerobically. It then decomposes aerobically leaving the pond at a concentration of 1000mg/L. It may be assumed that from this point onwards all COD ultimately degrades anaerobically.
4. This interpretation means that 7901+1927 + 867 = 10695mg /L degrades anaerobically (10.695 t COD/ML).

Therefore, CH_4 produced is: 10.695 x 0.22 x 312 = 734.10 t CH_4 =15,416.20 t CO_2-e.

4 Agriculture

Emissions of methane (CH_4), nitrous oxide (N_2O), oxides of nitrogen (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC) are produced when living and dead biomass is consumed, decays or is burnt. These emissions are modified by human activities including cultivation, addition of fertilizers, deliberate burning and flooding and by the introduction of ruminant animals.

For a comprehensive analysis, refer to *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Agriculture* *http://www.greenhouse.gov.au/agriculture/publications/index.html.*

5 Land-Use Change & Forestry (Vegetation sinks)

5.1 Introduction

If you have planted trees or are planning to plant trees as an option to abate greenhouse gas emissions the amount of carbon taken up (sequestered) in the vegetation will need to be estimated. Predicting and measuring carbon stocks in vegetation is complex. Methods of carbon accounting at the project level vary depending on the size and management of the planting. (It is expected that in early 2005, a practical toolbox for calculating forest and vegetation sinks will become available and which will be consistent with the National Carbon Accounting System).

Greenhouse Challenge Programme members are particularly encouraged to focus on actions that are likely to be consistent with relevant international agreements.

5.2 Estimating carbon sequestration

Carbon accounting for sinks is based on the stock change approach. To determine carbon sequestration the change in carbon stocks over a period of time is calculated using the formula:

$$\Delta C_{\mathrm{i}} = C_i - C_{i-1}$$

Where: ΔC_I = change in carbon stocks in year i

C_I = carbon stocks in year i

C_{I-1} = carbon stocks in the year before year i

Three methods of estimating carbon to different levels of accuracy and cost are described in Table 16 Methods for carbon accounting

The method used should be specified in all reporting.

Table 16 Methods for carbon accounting

Carbon Estimation Method	Type of Planting	Methods (see references section below for details of methods discussed here)
1 – Graphs in “Growing Trees as Greenhouse Sinks” booklet Very broad estimate	Small plantings that will not be harvested (eg shelterbelts and environmental plantings occupying less than about 20 hectares of the property)	Area and age of plantings estimated by the landholder; and Carbon sequestration estimated using the maps and graphs in the Growing Trees as Greenhouse Sinks booklet.
2 – Basic CAMFor model Site specific prediction providing an estimate at low cost	Small or medium-sized commercial plantings that will be harvested (eg farm forestry); or Medium-sized environmental plantings on farms comprising a significant area of the property (eg over 20 hectares).	Area measured using the methods described in the Bush for Greenhouse Field Measurement Procedures, or equivalent; Age of plantings estimated by the landholder; and site specific CAMFor prediction undertaken by the AGO, Third Party Recruiter or member based on information provided by the landholder using standard Field Sheets (see below).

3 – Full Carbon Accounting A higher level of accuracy at medium cost	Plantation estates (eg over 1,000 ha); Large scale environmental planting programmes or groups of plantings; or Any planting where sale of carbon credits is being considered	Level 2 method as described above; and Initial site condition assessment, survival checks and monitoring measurements undertaken as described in the Bush for Greenhouse Field Measurement Procedures, or equivalent Where a forest inventory has been undertaken the results can be converted to carbon stocks

5.3 Calculation Factors

There are many more calculation factors for carbon sinks than can be addressed in this publication. The following method and factors may be used in the relatively common situation where timber inventory results (stem volume) are converted to carbon stocks.

Convert stem volume to stem biomass using a known basic density. Basic density values for a wide range of species are available in NCAS Technical Report No 18 (see references section below). For example, the basic density of Pinus radiata is 440 kg/m^3

Calculate total above ground biomass from stem volume using an expansion factor. NCAS Technical Report No 17 contains some detailed information on expansion factors. Table 16 below contains some default expansion factors for use if no better information is available.

Table 17 Expansion factors

Forest Type	Expansion factor
Native forests	1.4
Native Plantations	1.25
Native Plantations (equation)	$= 1 / [0.9(age/35)^{0.23}]$ (to age 20)
Other species	1.3

Calculate root biomass from above ground biomass using a root to shoot ratio. NCAS Technical Report No 17 contains some of these ratios. The IPCC default root to shoot ratios shown in Table 18can be used if no better information is available.

Table 18 Root to shoot ratios

Forest type	Root to shoot ratio
Conifers (Pines)	0.2
Hardwoods (Eucalypts)	0.25

1. Convert total biomass to carbon stocks by multiplying by 0.5.
2. Convert to CO_2 equivalent by multiplying by 3.67.

5.4 Contact

For more information on carbon accounting for vegetation sinks contact:

Manager
The Greenhouse and Natural Resource Management Team
Australian Greenhouse Office
GPO Box 621
Canberra ACT 2601

Email: gnrm@greenhouse.gov.au

Tel: 02 6274 1358 Fax 02 6274 1326

Table 19 References

Reference and Link	Description
Carbon Accounting Model for Forests (CAMFor) http://www.greenhouse.gov.au/ncas/activities/modelling.html#CAMFor	CAMFor is used to predict carbon sequestration.
NCAS Technical Reports www.greenhouse.gov.au/ncas/publications/index.html	The NCAS technical reports contain scientific information for carbon accounting including some CAMFor inputs
Growing Trees as Greenhouse Sinks Booklet http://www.greenhouse.gov.au/land/vegetation/pubs/abs_landowners.html	Provides background information on greenhouse sinks and a ready reckoner to estimate carbon sequestration potential
Bush for Greenhouse Field Procedures for Carbon Accounting http://www.greenhouse.gov.au/bfg/field-measurement/index.html	Detailed inventory procedures for quantifying carbon in forests. Also includes factors and methods to calculate carbon stocks.
Field Sheets http://www.greenhouse.gov.au/bfg/field-measurement/index.html	The sheets provide a means to record field information used to develop carbon sequestration predictions using the CAMFor model.

Appendix 1 Summary of Energy Emission Factors for Greenhouse Challenge Members

This appendix provides a summary of the energy emission factors that should be used by Greenhouse Challenge members. Emission factors from the main text are reproduced here for the following fuel types:

1.a Electricity

1.b Stationary energy: fuel combustion

1.c Transport

For emission factors for *fugitive emissions* from the production of fossil fuels or emissions from *industrial processes, wastes, agriculture* and *land use change and forestry*, consult the main body of the text.

1.a Electricity

Greenhouse gas emissions in tonnes of carbon dioxide equivalent (t CO_2-e) associated with the consumption of electricity may be calculated with either of the following equations**:**

GHG emissions (t CO_2-e) = Q x EF

Where: Q (Activity) is the electricity used expressed in kWh and

EF (Emission Factor) is the value in Column A, Table 20.

OR

GHG emissions (t CO_2-e) = Q x EF/1000

Where: Q (Activity) is the electricity used expressed in GJ

EF (Emission Factor) is the value in Column B, Table 20.

Table 20 Emission factors for electricity per kWh delivered (or per GJ power delivered)

State	Full Fuel Cycle Emission Factor Use A or B	
	A	B
	kg CO_2-e/kWh	kg CO_2-e/GJ ($GgCO_2$-e/PJ)
NSW, ACT	1.054	293
VIC	1.392	387
QLD	1.058	294
SA	0.960	267
WA	1.053	293
TAS	0.006	2
NT	0.742	206

Example:

A company in Victoria consumes 100,000 kWh of electricity.

Emissions (t CO_2-e) = (100,000 * 1.392)/1000 = 139.2 tonnes.

1.b Stationary Energy

GHG emissions from the combustion of fossil fuels listed in Table 21 may be calculated as follows:

GHG emissions (t CO_2-e) = Q x EC x EF/1000

Where: Q is the quantity of fuel in tonnes or thousands of litres (sourced from inventory or supplier invoices or production records).

EC is the energy content of fuel in either GJ/tonne or GJ/kL (Column A, Table 21 below),

EF is the emission factor (Column B).

Table 21 Fuel combustion emission factors (Stationary Energy)

Fuel combusted	Energy content A	Full fuel cycle emissions factor B
	GJ/t	**kg CO_2-e/GJ**
Solid Fuels		
Black coal – NSW Electricity Generation	•27.0 (washed) 23.2 (unwashed)	98.1
Black coal – NSW other uses	•27.0 (washed) 23.2 (unwashed)	97.0
Black coal – Qld Electricity Generation	•27.0 (washed) 21.9 (unwashed)	93.9
Black coal – Qld other uses	•27.0 (washed) 21.9 (unwashed)	94.9
Brown coal	10.0	92.5
Coal used in steel industry	30.0	112.8
Brown Coal Briquettes	22.1	115.3
Coke	27.0	130.9
Wood and wood waste (dry) (CO_2 not counted)	16.2	1.4 (if used in boiler) 14.5 (if used in residential)
Bagasse as crushed (CO_2 not counted)	9.6	1.4 (if used in boiler)
Gaseous Fuels		
Coal by-products (gaseous)	18.1 MJ/m^3	48.4
Natural gas	Refer table 22	Refer table 22
Town gas	Consumption measured in GJ	59.4
Waste methane (CO_2 not counted)	37.7 MJ/m^3	5.0
Liquid Fuels	GJ/kL	
LPG – non transport	49.3 GJ/t	67.2
Coal by-products (coal tar and BTX)	41.9 GJ/t	92.4
Naptha	48.2	73.8
Lighting kerosene	36.6	77.5
Power kerosene	36.6	77.5
Heating oil	37.3	77.5
ADO	38.6	77.5
Industrial/marine DO	39.6	77.5
Fuel Oil	40.8	81.4
Biodiesel		Estimates to be developed

Example: Calculation of Emissions Generated from LPG (non-transport)

An island resort located off the coast of Queensland uses 200 tonnes of LPG for non-transport purposes per annum. Greenhouse gas emissions are calculated as follows:

GHG Emissions = Activity (t) x Energy Content of Fuel (GJ/t) x Emission Factor (kg CO_2-e/GJ) /1000

= (200 x 49.3 x 67.2)/1000 = 0.66 kt CO_2-e

Natural gas

Natural gas is usually supplied at either high or low pressure, depending on the scale of use. Major users are those supplied at high pressure and with an annual usage of more than 100 000 GJ. Estimates of emissions may be calculated using the following formula:

GHG Emissions (t CO_2-e) = Q x EF/1000

Where: Q is the quantity of natural gas consumed and expressed in GJ and sourced from supplier invoices /meters.

EF is the relevant emission factor, by state and territory. Division by 1000 converts kg to tonnes.

Table 22 Emissions from the consumption of natural gas

	Small user < 100,000 GJ pa	**Large user > 100,000 GJ pa**
State	**Full fuel cycle EF**	**Full fuel cycle EF**
	kg CO_2-e/GJ	kg CO_2-e/GJ
NSW & ACT	71.3	68.0
Victoria	63.6	63.4
Queensland	68.8	64.2
SA	73.8	71.2
WA	60.7	60.0
TAS	NA	NA
NT	53.6	53.5

Example: Calculation of Emissions Generated from Natural Gas Consumption

A Queensland business uses 100,000 GJ of natural gas per annum. Its greenhouse gas emissions (GHG) are calculated as follows:

GHG Emissions = Q x EF / 1000

= 100,000 x 64.2 / 1000 = 6420 t CO_2-e

1.c Transport

Emissions from the consumption of transport fuels may be estimated as follows:

GHG emissions (t CO_2-e) = Q (kL) x EF

Where Q is the quantity of fuel in thousands of litres (sourced from inventory or supplier invoices or production records).

And EF is the emission factor in Column B, Table 23.

OR

GHG emissions (t CO_2-e) = Q (GJ) x EF/1000

Where: Q is the quantity of fuel in GJ and

EF is the relevant emission factor (Column A).

Table 23 Fuel Combustion emission factors (Transport Fuels)

Fuel	Direct EF	
	A	B
	kg CO_2-e/GJ	t CO_2-e/kL
Automotive Gasoline	73.5	2.5
Automotive Diesel Oil	70.5	2.7
Aviation Gasoline	69.5	2.3
Aviation Turbine	70.4	2.6
Industrial diesel fuel	70.5	2.8
Fuel Oil	74.3	3.0
LPG	60.5	1.6
Natural gas (LV)	57.2	2.3 (b)
Natural Gas (HV)	53.8	2.1 (b)

Example: Calculation of emissions generated from transport fuels

A New South Wales freight company consumes 2400 kL of petrol and 2400 kL automotive diesel (transport) per annum. The **direct** GHG emissions are calculated as follows:

Emissions (t CO2-e) = (Q x EF (CO_2-e/kL)

Petrol = 2,400 x 2.5 = 6,000 t CO_2-e

Diesel = 2,400 x 2.7 = 6,480 t CO_2-e

Total GHG emissions = 6,000 + 6,480 =12,480 t CO_2-e

Kilometers traveled

If fleet records show kilometers travelled and not the total quantity of fuel purchased please contact the GC Team to discuss the use of average fuel consumption factors.

Appendix 2 Glossary

Δ	change
ANFO	ammonium nitrate and fuel oil
basic density	dry weight to green weight ratio
BD	basic density (wood)
BOD	biochemical oxygen demand
C	carbon
CAI	current annual increment of trunk timber
CH_4	methane
CO_2-e	carbon dioxide equivalent
COD	chemical oxygen demand
dbh	tree diameter at breast height
DC	degradable organic component(BOD & COD used to measure DC)
COD_{sl}	kg of COD per m^3/sludge
DC_w	kg of BOD/1000 persons
DOC	degradable organic carbon
DOC_F	dissimilated degradable organic component
EC	energy content of fuel
EF	emission factor
EF_{sl}	sludge emission factor
EF_w	waste emission factor
F_l	carbon fraction of landfill gas (default 0.50)
FE	fuel efficiency
F_{sl}	fraction removed as sludge
GC	Greenhouse Challenge Programme
ghg	greenhouse gas
GJ	gigajoule (10^9 joules)
GWP	global warming potential
ha	hectare (10,000 m^2)
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
kL	kilolitre
km	kilometre
kWh	kilowatt hour

L	litre
l	litter
m^3	cubic metre
MJ	megajoule (10^6 joules)
MSW	municipal solid waste
MWh	megawatt hour
moisture%	% water content
N/C	not considered
NGGI	National Greenhouse Gas Inventory
NMVOC	non-methane volatile organic compound
NO_x	Nitrogen oxide
OD:AD	oven-dry to air-dry ratio
OF	oxidation factor
OX	MSW oxidation factor
P	population served
pa	per annum
PJ	petajoule (10^{15} joules)
Q	activity
R	recovered CH_4
S	soil
SF_6	Sulfur hexafluoride
t	Tonne (1000 kg)
TR	trees and roots
V	other vegetation
v	volume
W	m^3 of wastewater/tonne of product
wt	weight
WP	wood products
WP	wood products

Appendix 3 Greenhouse gas global warming potentials

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

Gas	Chemical Formula	IPCC 1996 Global Warming Potential
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydrofluorocarbons HFCs		
HFC-23	CHF_3	11,700
HFC-32	CH_2F_2	650
HFC-41	CH_3F	150
HFC-43-10mee	$C_5H_2F_{10}$	1,300
HFC-125	C_2HF_5	2,800
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1,000
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1,300
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	300
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	3,800
HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	140
HFC-227ea	C_3HF_7	2,900
HFC-236fa	$C_3H_2F_6$	6,300
HFC-245ca	$C_3H_3F_5$	560
Hydrofluoroethers(HFEs)		
HFE-7100	$C_4F_9OCH_3$	500
HFE-7200	$C_4F_9OC_2H_5$	100
Perfluorocarbons PFCs		
Perfluoromethane (tetrafluoromethane)	CF_4	6,500
Perfluoroethane (hexafluoroethane)	C_2F_6	9,200
Perfluoropropane	C_3F_8	7,000
Perfluorobutane	C_4F_{10}	7,000
Perfluorocyclobutane	c-C_4F_8	8,700
Perfluoropentane	C_5F_{12}	7,500
Perfluorohexane	C_6F_{14}	7,400
Sulphur hexafluoride	SF_6	23,900
Indirect gases		
Carbon monoxide	CO	n/a
Nitrogen oxide	NO_x	n/a
Non-methane volatile organic compounds (NMVOCs)	various	n/a

*These GWP factors accord with those specified for calculating emissions under Kyoto accounting provisions

Appendix 4 Units and conversions

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	- (eg 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

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)

eg 423 000 Gg, equivalent to 423 000 kt are equivalent to 423 Mt

Unit of energy Joule

Unit of power (rate of energy usage) Watt

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=3.6x10^6 Joules= 3.6MJ

1 kWh = 3.6 x 10^{-3}GJ

1GJ =278 kWh

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

Municipal Solid Waste Volume to Weight

Material Type	Volume to Weight
Paper	0.09
Textiles	0.14
Wood	0.15
Garden	0.24
Food	0.50
Co-mingled	0.12

Example: conversion of waste volume to weight

If a member has $100m^3$ of co-mingled waste per annum, then the weight of this waste is:

100 x 0.12 = 12 tonnes.

Note: Volume to weight conversions is an inexact science and conversion factors change if materials are compacted.