2.1 Fuel combustion

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☒ Method 3: Direct Measurement

The list of emission stream types for fuel combustion is based on the type of fuel as defined in the 2006 IPCC Guidelines. If the list of fuel types is not relevant, the facility is allowed to input a user-specified fuel type.

Method 1: Calculation Approach

Based on the 2006 IPCC Guidelines[2], Method 1: Calculation Approach uses the following formula:

$$E_g = Q_f \times NCV_f \times \sum\left(EF_{f,g} \times GWP_g\right) \text{— (1)}$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions for GHG (g) i.e. CO_2, CH_4 and N_2O	tonne CO_2e	Calculated
Q_f	Quantity of fuel (f) combusted i.e. total quantity of fuel used for purposes of producing or providing energy	tonne	Reported
NCV_f	Net calorific value of fuel (f)	GJ/tonne	Reported
$EF_{f,g}$	Emission factor for CO_2, CH_4 and N_2O for fuel (f) on a net calorific basis	tonne GHG/GJ	Reported
f	Fuel type (f) being combusted	Nil	Reported
GWP_g	Global warming potential for GHG (g)	Nil	Constant

Q_f, the total quantity of fuel used for purposes of producing or providing energy is also reported in the ECA Energy Use Report (Energy Consumption & Production) for relevant business activities.

If Q_f is measured and reported in terms of (i) Million BTU in HHV (mmBTU) or (ii) Million BTU in LHV (mmBTU) (e.g. Natural Gas), the formula becomes:

$$E_g = Q_f \times F_0 \times \sum\left(EF_{f,g} \times GWP_g\right) \text{ — (2)}$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions for GHG (g) i.e. CO_2, CH_4 and N_2O	tonne CO_2e	Calculated

[2] Refer to the 2006 IPCC Guidelines, Volume 2, Chapter 2 for more details.

Q_f	Quantity of fuel (f) combusted	Million BTU in HHV (mmBTU) or Million BTU in LHV (mm BTU)	Reported
F_0	Conversion factor for mmBTU (HHV or LHV) to GJ	Nil	Constant
$EF_{f,g}$	Emission factor for CO_2, CH_4 and N_2O for fuel (f) on a net calorific basis	tonne GHG/GJ	Reported
f	Fuel type (f) being combusted	Nil	Reported
GWP_f	Global warming potential for GHG (g)	Nil	Constant

The conversion factors for F_0 are as follow:

Source unit	Target unit	Conversion factor, F_0
Million BTU in HHV (mmBTU)	GJ	1.0550559 * 0.9 (for gaseous fuels e.g. natural gas) 1.0550559 * 0.95 (for solid and liquid fuels e.g. coal and oil)
Million BTU in LHV (mmBTU)	GJ	1.0550559
Other source units available in the EDMA system for reporting[3]		
Gigawatt-hour (GWh)	GJ	3600
Million Tonne of Oil Equivalent (Mtoe)	GJ	41868000

According to the 2006 IPCC Guidelines[4], the net calorific value (NCV) i.e. lower heating value (LHV) is about 5% less than the gross calorific value (GCV) i.e. higher heating value (HHV) for solid and liquid fuels, while for gaseous fuels, the NCV is about 10% less.

Default conversion factors i.e. NCV and emission factors (on a net calorific basis) are available for a list of default fuels as defined in the 2006 IPCC Guidelines. Alternatively, the facility can use site-specific conversion factors which have to be substantiated and approved by NEA.

The facility may perform analysis on the fuel to determine its NCV and carbon content. The following formula shows how the CO_2 emission factor can be computed using the fuel carbon content and NCV:

$$EF_{f,CO2} = \frac{C_f}{NCV_f} \times \frac{44}{12}$$

Where: $EF_{f,CO2}$ is the CO_2 emission factor (tonne CO_2/tonne fuel) for the fuel (f)
C_f is the ratio of carbon in the fuel (f) on a tonne carbon/tonne fuel basis
NCV_f is the net calorific value (GJ/tonne fuel) for fuel (f)
$\frac{44}{12}$ is the molecular weight ratio to convert tonnes of carbon to tonnes of CO_2

[3] In the event where activity data is to be reported in these units, the facility may select "Default – convert mmBTU (GCV) to GJ (NCV)" as the data source for "Energy Content" conversion factor in the MP Template in order to automate the uncertainty calculations.
[4] Refer to the 2006 IPCC Guidelines, Volume 2, Chapter 1, page 1.16 for more details.

C_f for a gaseous fuel will be calculated from the formula:

$$C_f = \sum_y \left\{ \frac{mol\%_y \times MW_C \times f_{C,y}}{\sum_y mol\%_y \times MW_y} \right\}$$

Where: C_f is the ratio of carbon in the gaseous fuel (f) on a tonne carbon/tonne fuel basis
$mol\%_y$ is the percentage ratio of each component gas type (y) in 1 mole of fuel (f)
MW_y is the molecular weight of the component gas type (y)
MW_C is the molecular weight of carbon (i.e. 12 g/mol)
f_C, y is the number of carbon atoms in 1 molecule of the component gas type (y)

Figure 1 shows a typical configuration for fuel combustion using natural gas in the MP Template for Method 1: Calculation Approach. In the example, default conversion factors and invoice data are used. The amount of natural gas purchased recorded in invoices is usually specified in terms of mmBTU on a gross calorific value (GCV) basis. Hence, the facility should specify the default conversion from mmBTU (GCV) to GJ (NCV) as the data source under the "Energy Content" conversion factor.

Figure 1 – Fuel combustion using Method 1: Calculation Approach in the MP Template

CA_F1 Emission source: General natural gas use on-site
Emission stream type: Natural Gas

(a) **GHG quantification approach description:**

Natural gas has one delivery point metered by our supplier. Monthly invoice data, specified in mmBTU are used to report the quantity. Default emission factors are used for CO2, CH4 and N2O.

(b) **Additional attachment to elaborate on the GHG quantification approach:** Yes
Document reference/name: GHG emission reporting Basis of Preparation

Activity data
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Invoice	0	1.5%

Overall Activity data uncertainty: 1.50%

Conversion factor: Energy Content
Data source: Default - convert mmBTU (GCV) to GJ (NCV)
Uncertainty: 0.0%

Conversion factor: Carbon dioxide Emission factor
Data source: Default
Uncertainty: 4.0%

Conversion factor: Methane Emission factor
Data source: Default
Uncertainty: 50.0%

Conversion factor: Nitrous oxide Emission factor
Data source: Default
Uncertainty: 50.0%

Uncertainty Assessment
Emission stream uncertainty: 4.3%

Method 1: Calculation Approach for Incineration of Municipal Solid Waste

Based on the 2006 IPCC Guidelines[5], only CO_2 emissions resulting from incineration of carbon in waste of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil) should be counted towards the CO_2 emissions estimate. The CO_2 emissions from combustion of biomass materials (e.g., paper, food, and wood waste) contained in the waste are biogenic emissions and should not be included in the emission estimates.

Most textiles, rubber, liquid solvents and waste oil are either being recycled or constitute a small proportion of the waste (of fossil origin) incinerated. It is assumed that most of our emissions are from the incineration of plastic waste in the municipal waste. CO_2 emissions is calculated based on the total amount of plastic waste incinerated, instead of using the total amount of municipal waste incinerated and the NCV of the municipal waste based on equation (1). The following formula can be used to compute CO_2 emissions based on the plastic fraction of municipal waste that is incinerated.

$$E_{CO2} = Q_f \times EF_0 \text{ — (3)}$$

Parameter ID	Parameter description	Units	Reporting status
E_g	CO_2 emissions based on incineration of the plastic fraction of municipal waste[6]	tonne CO_2e	Calculated
Q_f	Total quantity of fuel (f) i.e. total quantity of waste incinerated	tonne	Reported
EF_0	Alternative composite CO_2 emission factor, taking into account conversion factors such as plastic content, moisture content, fraction of carbon in dry matter, $\frac{44}{12}$ (molecular weight ratio to convert tonnes of carbon to tonnes of CO_2)	Nil	Reported *(based on waste sampling for plastic and moisture content)*
f	Fuel type (f) combusted i.e. municipal waste	Nil	Reported

Consistent with the 2006 IPCC Guidelines, CH_4 emissions are assumed to be very small for large and well-functioning incinerators. N_2O emissions can be estimated by multiplying the quantity of waste incinerated with the IPCC default N_2O emission factor for municipal solid waste.

Method 3: Direct Measurement

The facility can directly measure CO_2 emissions from fuel combustion where the exhaust gas stream from the combustion process is constrained to allow pipeline or exhaust duct measurement. The MP Template assumes that CH_4 and N_2O emissions are not measured directly and instead calculated (using Method 1: Calculation Approach) based on information on the quantity of fuel, the fuel's NCV and the respective CH_4 and N_2O emission factors.

Therefore, upon selecting Method 3: Direct Measurement, the MP Template also automatically configures another emission stream for CH_4 and N_2O emissions using Method 1: Calculation Approach.

[5] Refer to the 2006 IPCC Guidelines, Volume 5, Chapter 5 for more details.

[6] CO_2 emissions from the non-plastic fraction of municipal waste is not required to be reported in the Emissions Report and EDMA system.

Hence, for example, for direct measurement of fuel combustion stream identifier F1, the MP Template will create two emission streams, a Direct Measurement emission stream for CO_2 on Tab **I. Direct – Emission Streams** (DM_F1) and a Calculation Approach emission stream for CH_4 and N_2O on Tab **E. Calc Apch – Emission Streams** (CA_F1).

For Method 3: Direct Measurement, the formula becomes:

$$E_g = E_{CO2} + \left[Q_f \times NCV_f \times \sum\left(EF_{f,g} \times GWP_g\right)\right]$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions for GHG (g) i.e. CO_2, CH_4 and N_2O	tonne CO_2e	Calculated
E_{CO2}	Emissions for CO_2 from direct measurement	tonne CO_2e	Reported
Q_f	Quantity of fuel (f) combusted i.e. total quantity of fuel used for purposes of producing or providing energy	tonne	Reported
NCV_f	Net calorific value for fuel (f)	GJ/tonne	Reported
$EF_{f,g}$	Emission factor for CH_4 and N_2O emissions from fuel (f) on a net calorific basis	tonne GHG/GJ	Reported
f	Fuel type (f) being combusted	Nil	Reported
GWP_g	Global warming potential for GHG (g)	Nil	Constant

CH_4 and N_2O emissions represent less than 1% of GHG emissions from a fuel combustion emission stream i.e. they are insignificant compared to CO_2 emissions. For the purpose of providing the forecast emissions of each emission stream in Tab **J. Summary**, the facility may use the proportion of 9999:1[7] for the relative emissions of CO_2 (using Method 3: Direct Measurement) to CH_4 and N_2O (using Method 1: Calculation Approach) for the combustion of a particular fuel.

If more than one type of fuel is being used for fuel combustion and the facility is using Method 3: Direct Measurement to quantify GHG emissions from combustion of multiple fuels, there will still be only one emission stream form on Tab **I. Direct – Emission Streams** created for fuel combustion. The emission stream form allows for up to four measurement points to be entered.

Nevertheless, individual fuels that are combusted and measured via Method 3: Direct Measurement should still be created on Tab **C. Site Details** in order to create the emission stream forms on Tab **E. Calc Apch – Emission Streams** for CH_4 and N_2O emissions based on Method 1: Calculation Approach.

On Tab **E. Calc Apch – Emission Streams**, the facility can specify measurement of the quantity of each fuel combusted and the source of the conversion factor for CH_4 and N_2O emissions for the fuel type. Given that CH_4 and N_2O emissions are insignificant compared to the CO_2 emissions, the accuracy of

[7] For every 1 tonne of natural gas combusted, the proportion of CO_2 emissions to CH_4 and N_2O emissions in CO_2e terms is 9999:1.

the measurement instrument for the fuel quantity will have minimal impact on the overall uncertainty of the fuel combustion emission stream for a given fuel type.

Figure 2 shows an example of the configuration for fuel combustion in the MP Template for Method 3: Direct Measurement. In the example, two fuel types, municipal waste and natural gas are combusted with the resulting emissions measured through one monitoring stack point.

Figure 3 shows the corresponding Method 1: Calculation Approach emission stream form for CH_4 and N_2O emissions from the combustion of municipal waste. A similar entry would be configured for the natural gas (see Figure 1 for an example). In Figure 3, the energy content of municipal waste is calculated from samples taken from every delivery. Hence, Tier 4 – representative analysis is chosen. However, the sampling of municipal waste still has a high uncertainty due to the difficulty to extract a sample that is fully representative of the entire waste stream. Therefore, the facility has entered a higher site-specific uncertainty value for the energy content analysis on Tab **D. Calc Apch – Metering & Analysis** as shown in Figure 4.

Figure 2 – Fuel combustion using Method 3: Direct Measurement in the MP Template

DM_F1 Emission source: Incineration of solid waste with energy recovery

Emission stream type: F1: Municipal Waste, F2: Natural Gas

(a) **GHG quantification approach description:**

Municipal solid waste is received at the gatehouse where the tracks are weighed on entry and exit to determine the weight of delivery. Each day one delivery is sampled to obtain typical content. The daily samples are aggregated and tested at an off-site laboratory for carbon content.
The incinerator stack is monitoring for flow and CO2 content.

(b) **Additional attachment to elaborate on the GHG quantification approach:** Yes

Document reference/name: GHG emission reporting Basis of Preparation

Options to manage monitoring point entries:

Activity data for monitoring point #1 Gas being measured: Carbon dioxide

Proportion of forecast emissions (CO_2-e) from this monitoring point: 100%

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Stack flow	4 - Accurate Measurement	4.0%
Pitot Tubes		

Temperature correction: Yes Pressure correction: Yes

Overall Activity data uncertainty: 4.00%

Conversion factor: GHG concentration measurement

Data source: Stack CO2 concentration - GHG concentration in gas sample

Frequency of analysis: 4 - Representative

Uncertainty: 3.0%

Emission stream uncertainty: 5.0%

Figure 3 – Fuel combustion using Method 3: Direct Measurement, where Method 1: Calculation Approach is used for quantifying CH_4 and N_2O emissions in the MP Template

CA_F1	Emission source:	Incineration of solid waste with energy recovery (Non-CO2 emissions)	
	Emission stream type:	Municipal Waste	

(a) GHG quantification approach description:

Municipal solid waste is received at the gatehouse where the tracks are weighed on entry and exit to determine the weight of delivery. Each day one delivery is sampled to obtain typical content. The daily samples are aggregated and tested at an off-site laboratory for carbon content.
Default emission factors are used for CH4 and N2O.

(b) Additional attachment to elaborate on the GHG quantification approach: Yes

Document reference/name: GHG emission reporting Basis of Preparation

Activity data

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Weighbridge	4 - Accurate Measurement	1.0%
Weighbridge		

Overall Activity data uncertainty: 1.00%

Conversion factor: Energy Content

Data source: Waste total energy content - Energy Content
Frequency of analysis: 4 - Representative
Uncertainty: 5.0%

Conversion factor: Methane Emission factor

Data source: Default
Uncertainty: 50.0%

Conversion factor: Nitrous oxide Emission factor

Data source: Default
Uncertainty: 50.0%

Uncertainty Assessment

Emission stream uncertainty: **37.4%**

Figure 4 – Specification of waste energy content and site-specific uncertainty

Relevant emission stream(s)	Internal identifier/name	Laboratory name	Conversion factor	Default uncertainty (+/-%)	Site-specific uncertainty (+/-%)	Management procedure name
F1	Waste total energy content	Singapore labs	Energy Content	1.0%	5.0%	SOP - Waste sampling and analysis

Default conversion factors and uncertainty

The Tier 1 default NCV and CO_2, CH_4 and N_2O emission factors for fuel combustion are shown in Table 3 at the end of this section. The NCV and emission factors have been obtained from the 2006 IPCC Guidelines, Volume 2, Chapter 1 Table 1.2 and Chapter 2 Table 2.2 respectively. The default emission factors provided by the 2006 IPCC Guidelines are in the unit of kg GHG/GJ and on a net calorific basis, and hence there is a need to convert the activity data, if measured in other units, to GJ on a net calorific basis using the conversion factors mentioned earlier in sub-section Method 1: Calculation Approach. The uncertainty values for NCV and CO_2 emission factors in Table 2 are adapted from the National Greenhouse and Energy Reporting (NGER) (Measurement) Determination 2008 under the Australian NGER Act. According to the 2006 IPCC Guidelines, emission factors for CH_4 and N_2O are highly uncertain and the 2006 IPCC Guidelines[8] provides a range of uncertainty values. For simplicity, the uncertainty values of all CH_4 and N_2O emission factors are assumed to be 50%.

The 2006 IPCC Guidelines also provides a range – with the upper and lower limits of the IPCC default factors. Tier 1 site-specific conversion factors should still fall within the range of the values for IPCC default factors. Tier 1 site-specific NCV and emission factors are assumed to be more accurate and representative of the facility's processes than the Tier 1 default conversion factors, hence the default

[8] Refer to the 2006 IPCC Guidelines, Volume 2, Chapter 2, page 2.38 for more details.