Greenhouse Gas (GHG) Emissions Measurement and Reporting Guidelines

APPENDIX TO PART II: MONITORING PLAN

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National Environment Agency

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Revision History

Version no.	Revision date	Summary of changes
1	14 February 2018	Initial release on Measurement and Reporting (M&R) requirements supporting the Energy Conservation (Greenhouse Gas Measurement and Reporting) Regulations 2017.
2	15 January 2020	Corrected typographical errors, improved content clarity, and included technical amendments to the following sections: Section 2.1 Fuel Combustion • Method 1: Calculation Approach for Incineration of Municipal Waste, including the Tier 1 default CH_4 and N_2O emission factors for municipal waste, which will be on a g CH_4/tonne municipal waste basis • Corrected the Tier 1 default N_2O emission factor for user-specified fuels (liquid), from 0.0015 to 0.0006 kg N_2O/GJ Section 2.4 Flares • Corrected the default CO_2 emission factors to take into account the flare efficiency, from 2.7 tonne CO_2/tonne flare gas to 2.646 or 2.6865 tonne CO_2/tonne flare gas, depending on the emission stream type. Section 2.6 Fugitive emissions • Provided formulae computing N_2O emissions from either aerobic or anaerobic wastewater treatment, and CO_2 emissions from aerobic wastewater treatment for clarity Section 2.8 Integrated circuit or semiconductor production • Updated the IPCC Tier 2a default conversion factors table and uncertainty values. Factors for F_2 and COF_2 (non-GHGs producing fluorinated compounds by-products) were inadvertently left out.
2.1	29 May 2023	Minor update on the reference link in page 88.
3	15 Dec 2023	Updated to align with Carbon Pricing (Amendment) Act, improved content clarity and included technical amendments to the following sections: - Section 2.9, 2.11, 2.12, 2.13 • Included the 34 newly added HFCs and PFCs to as per Carbon Pricing (Amendment) Act Section 2.3 Ethylene Production • Updated the CO_2 and CH_4 emissions factors and the default uncertainty in table 5 Section 2.6 Fugitive Emissions

Version no.	Revision date	Summary of changes
		• Included an example on 'Emission Stream Type – Other' Section 2.8 Integrated circuit or semiconductor production • Updated the guidelines, emission factors and uncertainty values in Tables 14 and 15 as per 2006 IPCC Guidelines and 2019 Refinement to 2006 IPCC Guidelines Section 2.14 Use of lubricants and paraffin waxes • Made clear the scenarios when emissions from the use of lubricants shall be reported under i) IPPU sector or (ii) Fuel Combustion sector (i.e., for 2-stroke engines). Section 2.15 Use of SF_6 in electrical equipment • Made clear that the SF_6 emissions should include both the top-up quantity and the leakage amount during SF_6 equipment maintenance and servicing

Contents

1. Purpose

This Appendix is to be used in conjunction with the Greenhouse Gas Emissions Measurement and Reporting (GHG M&R) Guidelines Part II: Monitoring Plan. It supports the key M&R requirements and GHG computation approaches as explained in the Guidelines.

Detailed instructions on completing the Emissions Report on the Emissions Data Monitoring and Analysis (EDMA) system are found in the GHG M&R Guidelines Part III: Emissions Report.

Chapter 2 details the applicable emissions quantification methods for common emission sources in Singapore as defined and provided in the Monitoring Plan Template (MP Template). Chapter 3 details the default uncertainty values for the default measurement instruments listed in the MP Template. Chapter 4 contains the list of remaining IPPU emission sources and their emission stream types which are less common in Singapore.

The emissions quantification methods (i.e. Method 1: Calculation Approach, Method 2: Material Balance and Method 3: Direct Measurement) in terms of the formulae[1], configurations in the MP Template, default conversion factors and uncertainty values provided in this Appendix are referenced and adapted from various sources i.e. the 2006 IPCC Guidelines, API Compendium, the National Greenhouse and Energy Reporting (NGER) (Measurement) Determination 2008 under the Australian NGER Act, as well as industry expert judgment and experience.

The configurations in the MP Template (based on the applicable emissions quantification methods for the common emission sources) provided in the form of screenshots in this Appendix are only an indicative guide on how the MP Template could be completed, and are not exemplars of the MP Template. Facilities are advised to fill in the MP Template based on their own emissions sources and emissions quantification methods.

[1] Note that unit conversions are not flagged out in the formulae of this Appendix. Refer to the GHG M&R Guidelines Part III: Emissions Report for such details.

2. Common Emission Sources

Based on the GHG M&R Guidelines Part II: Monitoring Plan and the MP Template, the types of processes or activities resulting in greenhouse gas emissions are broadly categorised into (i) fuel combustion and (ii) industrial processes and product use (IPPU).

This chapter details the applicable emissions quantification methods for the following common emission sources under (i) fuel combustion and (ii) IPPU as defined and provided in the MP Template.

Enhancements from the ECA Energy Use Report (GHG Section)

The types of IPPU emission sources are referenced from the ECA Energy Use Report (EUR) (GHG from non-fuel combustion processes or activities) i.e. IPPU Emission Spreadsheet, which was prepared in accordance with the 2006 IPCC Guidelines. However, the following broad enhancements were made:

i) Classifying "Fugitive emissions from oil and natural gas systems from venting, flaring, oil, and natural gas production and upgrading, natural gas processing, natural gas transmission and storage, transport of oil, oil refining, oil and natural gas distribution" into three emission sources: (i) Flares, (ii) Vents, and (iii) Fugitive emissions;

ii) Addition of new emission source: Coal Gasification;

iii) Merging of "Use of lubricant" and "Use of paraffin wax" into one emission source: Use of lubricants or paraffin waxes;

iv) Renaming of "Use of HFCs and PFCs in fire protection equipment" to: Use of GHGs in fire protection equipment, which includes carbon dioxide (CO_2); and

v) Addition of non-fluorinated compounds such as carbon dioxide (CO_2) and methane (CH_4) into emission source: Integrated circuit or semiconductor production.

For detailed enhancements for each emission source, please refer to the respective sections.

Emission sources and emission stream types

The list of common emission sources and their emission stream types built into the MP Template (and Emissions Report) are tabulated as follow.

Multiple greenhouse gases may be reported within the same emission stream, depending on the type of emission source. However, the emission stream type under 'Any other process or activity resulting in GHG emissions' is able to accommodate one greenhouse gas per emission stream.

Emission source	Emission stream type	Section reference
Fuel Combustion		
User-specified	Table 3 – Tier 1 default fuel combustion conversion factors and uncertainty values	Section 2.1

Emission source	Emission stream type	Section reference
Industrial processes and product use (IPPU)		
Ethylene oxide production	Page 20	Section 2.2
Ethylene production	Page 26	Section 2.3
Flares	Page 33	Section 2.4
Vents	Table 9 – Emission stream types for vents	Section 2.5
Fugitive emissions	Table 11 – Emission stream types for fugitive emissions	Section 2.6
Coal gasification	User-specified	Section 2.7
Integrated circuit or semiconductor production	Page 61	Section 2.8
Thin-film-transistor flat panel display (TFT-FPD) or liquid crystal display (LCD) production	Page 82	Section 2.9
Iron and steel production	Page 86	Section 2.10
Use of GHGs in fire protection equipment	Page 91	Section 2.11
Use of HFCs or PFCs in refrigeration and air-conditioning equipment	Page 93	Section 2.12
Use of HFCs and PFCs in solvents	Page 97	Section 2.13
Use of lubricants or paraffin waxes	Page 100	Section 2.14
Use of SF6 in electrical equipment	Page 105	Section 2.15
Any other process or activity resulting in GHG emissions	User-specified	Section 2.16

<u>Reporting status of parameters</u>

For each emission stream, a reporting status is assigned to each parameter of the formula used to compute emissions. The reporting status indicates whether the parameter is a constant, to be reported or calculated in the EDMA system.

Reporting status	Definition
Calculated	Automatically calculated by the EDMA system (e.g. the final GHG emissions value)
Reported	Parameter is to be reported by the facility in the Emissions Report, and they are usually parameters necessary for the quantification of GHG emissions (e.g. activity data or conversion factors when using Method 1: Calculation Approach, GHG emissions when using Method 3: Direct Measurement)
Constant	Parameter is constant (e.g. global warming potential) and usually not required to be reported in the Emissions Report

Definition of industrial process and fuel combustion emissions

According to international reporting guidelines, it is necessary to separate and allocate emissions from fuel combustion and IPPU accordingly. In both the MP Template and the Emissions Report, each emission stream is assigned an emission stream identifier (e.g. F1, F2 for fuel combustion or P1, P2 for IPPU in Tab **C. Site Details** of the MP Template).

Based on the 2006 IPCC Guidelines[2], the definition below aims to separate the combustion of fuels for producing energy, from the use of hydrocarbons in chemical reactions defining an IPPU process.

Fuel combustion is defined as:

"the intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus."

Examples below may help to illustrate the definition:

If surplus methane or hydrogen from the steam cracking of naphtha is combusted within the petrochemical site for another process, then the emissions are reported as emissions from IPPU. On the other hand, if the gases are passed to a nearby refinery for fuel use, the associated emissions would be reported under fuel combustion.

If waste gases, including CO_2 components, from industrial processes are channelled to heat recovery systems and combusted as fuel, the combustible and non-combustible components are to be segregated and reported separately as emissions from fuel combustion and IPPU respectively.

For IPPU emissions, as far as possible, the reporting of emissions should be allocated to the specific and appropriate IPPU processes defined in the MP Template (i.e. Ethylene production, Ethylene oxide production, Coal gasification etc.). However, any specific IPPU process which has not been pre-defined in the MP Template are to be accounted under the emission source 'Any other process or activity resulting in greenhouse gas emissions'.

[2] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 1, sub-section 1.2.1 on page 1.7 and box 1.1 on page 1.8 for more details.

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 types of fuel as defined in the 2006 IPCC Guidelines. If the list of fuel types is not relevant, the facility should specify a unique fuel type.

Method 1: Calculation Approach

Based on the 2006 IPCC Guidelines[3], 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[4]	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 (in kg GHG/GJ)
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 Million BTU in HHV (mmBTU) (e.g. Natural Gas), the formula becomes:

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

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

[4] To note that even if the NCV may not be used in the calculations (e.g. using the carbon content of the fuel – tCO2/tfuel), the NCV will still need to be reported in the Emissions Report. The NCV number will be auto populated into the ECA Energy Use Report (Energy Consumption & Production).

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	Million BTU in HHV (mmBTU)	Reported
F_0	Conversion factor for mmBTU (HHV) to GJ in LHV 1.05505585 * 0.9 (for gaseous fuels e.g. natural gas) 1.05505585 * 0.95 (for solid and liquid fuels e.g. coal and oil)	GJ/mmBTU	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

According to the 2006 IPCC Guidelines[5], 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/GJ) 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

[5] 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 Waste

Based on the 2006 IPCC Guidelines, municipal waste contains both degradable organic carbon (biogenic) and fossil carbon (non-biogenic). Only CO_2 emissions resulting from incineration of carbon of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil) should be counted towards CO_2 emissions being reported in the Emissions Report. CO_2 emissions from combustion of biomass materials (e.g., paper, food, and wood waste) contained in municipal waste are biogenic emissions and should be calculated and reported as a separate line item in the Emissions Report.

Instead of the default fuel combustion equation (1) which is based on the 2006 IPCC Guidelines, Volume 2: Energy, equation (3) which is based on Volume 5: Waste will be used to determine GHG emissions from municipal waste incineration.

There is no default CO_2 emission factor as the CO_2 emission factor depends on the different waste components and its fossil carbon fraction.

The default CH_4 and N_2O emission factors are referenced from the 2006 IPCC Guidelines, Volume 5, pages 5.20 and 5.21, based on continuous incineration and stoker technology as it is adopted by the incineration plants in Singapore.

$$E_g = Q_f \times \sum\left(EF_g \times GWP_g\right) \text{ — (3)}$$

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 waste incinerated (on a wet weight basis)	tonne	Reported
$EF_{MW,g}$	Emission factor for non-biogenic CO_2; CH_4 and N_2O	tonne GHG/tonne municipal waste	Reported
GWP_g	Global warming potential for GHG (g)	Nil	Constant

The derivation of the net calorific value is still required in the MP Template and the facility should still detail how the energy content factor is derived on Tab **D. Calc Apch – Metering & Analysis** (refer to example in Figure 3 and Figure 4).

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 from fuel combustion cannot be measured directly and are therefore calculated instead (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.

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[6] 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 manually 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

[6] 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[7] 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

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

uncertainty values for Tier 1 site-specific conversion factors are set at half (for NCV and CO_2 emission factor) or a fraction (CH_4 and N_2O emission factors), of that of the default conversion factors.

Given that the MP Template allows the facility to input a specified fuel, the M&R Guidelines have developed default emission factors for CH_4 and N_2O as given in Table 1 below based on the physical states of the user-specified fuel. These factors are an average of the default CH_4 and N_2O emission factors for the various fuels specified in the 2006 IPCC Guidelines. The default uncertainty values for the Tier 1 default CH_4 and N_2O emission factors for user-specified fuels are assumed to be 50%, and for the Tier 1 site-specific CH_4 and N_2O emission factors, the default uncertainty values are assumed to be 30%. However, the default uncertainty values for Tier 1 site-specific NCV and CO_2 emission factors are not provided, the facility is required to enter site-specific uncertainty values (refer to Table 2).

Table 1 – Tier 1 default fuel combustion CH_4 and N_2O emission factors for user-specified fuels and municipal waste

Fuel type	CH_4 emission factor (kg CH_4/GJ)	N_2O emission factor (kg N_2O/GJ)
Solid fuel	0.001	0.0015
Liquid fuel	0.001	0.0006
Gaseous fuel	0.001	0.0001
Emission stream type	**CH_4 emission factor (g CH_4/tonne municipal waste)**	**N_2O emission factor (g N_2O/tonne municipal waste)**
Municipal Waste	0.2	47

Table 2 – Tier 1 default and site-specific uncertainty values for fuel combustion conversion factors for both default and user-specified fuels

Conversion factor	Tier 1 default uncertainty	Tier 1 site-specific uncertainty
Default list of fuels (refer to Table 3)		
CH_4 and N_2O emission factors	50%	30%
CO_2 emission factors	2-26% (Refer to Table 3 below)	1-13% (set at half of the Tier 1 default uncertainty)
Energy content – NCV per tonne	2-50% (Refer to Table 3 below)	1-25% (set at half of the Tier 1 default uncertainty)
User-specified fuels		
CH_4 and N_2O emission factors	50%	30%
CO_2 emission factors & Energy content – NCV per tonne	Not applicable	Not provided, facility to provide

Table 3 – Tier 1 default fuel combustion conversion factors and uncertainty values[8]

Emission stream type	Net calorific value (GJ/tonne)		CO_2 emission factor (kg CO_2/GJ)		CH_4 emission factor (kg CH_4/GJ)	N_2O emission factor (kg N_2O/GJ)
	Factor	Uncertainty	Factor	Uncertainty	Factor	Factor
Anthracite	26.7	28.0%	98.3	5.0%	0.001	0.0015
Aviation Gasoline	44.3	3.0%	70	4.0%	0.003	0.0006
Biodiesel	27.0	50.0%	70.8	N/A	0.003	0.0006
Biogasoline	27.0	50.0%	70.8	N/A	0.003	0.0006
Bitumen	40.2	18.0%	80.7	2.0%	0.003	0.0006
Blast Furnace Gas	2.47	50.0%	260	17.0%	0.001	0.0001
Brown Coal Briquettes	20.7	40.0%	97.5	11.0%	0.001	0.0015
Charcoal	29.5	50.0%	112	N/A	0.2	0.004
Coal Tar	28.0	50.0%	80.7	17.0%	0.001	0.0015
Coke Oven Coke and Lignite Coke	28.2	9.0%	107	11.0%	0.001	0.0015
Coke Oven Gas	38.7	50.0%	44.4	19.0%	0.001	0.0001
Coking Coal	28.2	12.0%	94.6	7.0%	0.001	0.0015
Crude Oil	42.3	6.0%	73.3	3.0%	0.003	0.0006
Ethane	46.4	4.0%	61.6	10.0%	0.001	0.0001
Gas Coke	28.2	50.0%	107	15.0%	0.001	0.0001
Gas/Diesel Oil	43.0	2.0%	74.1	2.0%	0.003	0.0006
Industrial Waste	10.0 [9]	50.0%	143	26.0%	0.03	0.004
Jet Gasoline	44.3	3.0%	70	4.0%	0.003	0.0006
Jet Kerosene	44.1	3.0%	71.5	3.0%	0.003	0.0006
Landfill Gas	50.4	50.0%	54.6	N/A	0.001	0.0001

[8] CO_2 emissions from combustion of biofuels and biomass are non-reckonable emissions. However, the facility is still required to specify an emission stream for combustion of biofuels and biomass as CH_4 and N_2O emissions are reckonable. Uncertainty values for the CO_2 emission factors for biofuels and biomass are listed as non-applicable (N/A) as they are not counted towards the facility's emissions and hence should not affect the uncertainty calculations. The CO_2 emission factors are provided to inform the facility that the EDMA system will compute CO_2 emissions automatically in the Emissions Report using these default CO_2 emission factors, for the purpose of compiling Singapore's national inventory. Do note that these CO_2 emissions are not counted towards and reflected in the facility's overall reckonable emissions on the Emissions Report.

[9] Based on the NCV of municipal waste (non-biomass fraction). No data is provided in the 2006 IPCC Guidelines.

Emission stream type	Net calorific value (GJ/tonne)		CO_2 emission factor (kg CO_2/GJ)		CH_4 emission factor (kg CH_4/GJ)	N_2O emission factor (kg N_2O/GJ)
	Factor	Uncertainty	Factor	Uncertainty	Factor	Factor
Lignite	11.9	50.0%	101	12.0%	0.001	0.0015
Liquefied Petroleum Gas	47.3	8.0%	63.1	3.0%	0.001	0.0001
Lubricants	40.2	11.0%	73.3	2.0%	0.003	0.0006
Motor Gasoline	44.3	3.0%	69.3	4.0%	0.003	0.0006
Municipal Waste [10]	N/A	N/A	N/A	N/A	N/A	N/A
Naphtha	44.5	5.0%	73.3	5.0%	0.003	0.0006
Natural Gas	48.0	4.0%	56.1	4.0%	0.001	0.0001
Natural Gas Liquids	44.2	7.0%	64.2	4.0%	0.003	0.0006
Oil Shale and Tar Sands	8.9	50.0%	107	15.0%	0.001	0.0015
Orimulsion	27.5	18.0%	77	2.0%	0.003	0.0006
Other Biogas	50.4	50.0%	54.6	N/A	0.001	0.0001
Other Bituminous Coal	25.8	28.0%	94.6	5.0%	0.001	0.0015
Other Kerosene	43.8	3.0%	71.9	2.0%	0.003	0.0006
Other Liquid Biofuel	27.4	50.0%	79.6	N/A	0.003	0.0006
Other Petroleum Products	40.2	18.0%	73.3	2.0%	0.003	0.0006
Other Primary Solid Biomass	11.6	50.0%	100	N/A	0.03	0.004
Oxygen Steel Furnace Gas	7.06	50.0%	182	10.0%	0.001	0.0001
Paraffin Waxes	40.2	18.0%	73.3	2.0%	0.003	0.0006
Patent Fuel	20.7	50.0%	97.5	15.0%	0.001	0.0015
Peat	9.76	50.0%	106	N/A	0.001	0.0015

[10] The 2006 IPCC Guidelines specify NCV and CO2 emission factors for the biomass and non-biomass fractions of municipal waste separately.

Emission stream type	Net calorific value (GJ/tonne)		CO_2 emission factor (kg CO_2/GJ)		CH_4 emission factor (kg CH_4/GJ)	N_2O emission factor (kg N_2O/GJ)
	Factor	Uncertainty	Factor	Uncertainty	Factor	Factor
Petroleum Coke	32.5	19.0%	97.5	17.0%	0.003	0.0006
Refinery Feedstock	43.0	18.0%	73.3	2.0%	0.003	0.0006
Refinery Gas	49.5	19.0%	57.6	18.0%	0.001	0.0001
Residual Fuel Oil	40.4	2.0%	77.4	2.0%	0.003	0.0006
Shale Oil	38.1	18.0%	73.3	2.0%	0.003	0.0006
Sludge Gas	50.4	50.0%	54.6	N/A	0.001	0.0001
Sub-bituminous Coal	18.9	28.0%	96.1	5.0%	0.001	0.0015
Sulphite Lyes (Black Liquor)	11.8	50.0%	95.3	N/A	0.003	0.002
Town Gas (Gas Works Gas)	38.7	4.0%	44.4	4.0%	0.001	0.0001
Waste Oils	40.2	11.0%	73.3	2.0%	0.03	0.004
White Spirit and Special Boiling Point Spirit	40.2	18.0%	73.3	2.0%	0.003	0.0006
Wood/Wood Waste	15.6	50.0%	112	N/A	0.03	0.004

2.2 Ethylene oxide production

☒ Method 1: Calculation Approach

☒ Method 2: Material Balance

☐ Method 3: Direct Measurement

There are nine emission stream types based on the 2006 IPCC Guidelines. Three types of abatement options i.e. thermal, other, or no abatement, are included for each of the three processes, i.e. air process, oxygen process and other. According to the 2006 IPCC Guidelines, the selection of process type determines the default CO_2 emission factor, while the abatement options determine the default CH_4 emission factor.

i) Air Process - Thermal abatement

ii) Air Process - Other abatement

iii) Air Process - No abatement

iv) Oxygen Process - Thermal abatement

v) Oxygen Process - Other abatement

vi) Oxygen Process - No abatement

vii) Other - Thermal abatement

viii) Other - Other abatement

ix) Other - No abatement

Method 1: Calculation Approach

The 2006 IPCC Guidelines refer to the following formula:

$$E_g = Q_p \times \left[EF_{p,CO2} + \left(EF_{a,CH4} \times GWP_{CH4}\right)\right]$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions for GHG (g) i.e. CO_2, and CH_4	tonne CO_2e	Calculated
Q_p	Quantity of ethylene oxide produced in process (p)	tonne	Reported
$EF_{p,CO2}$	Emission factor for CO_2 based on process (p)	tonne CO_2/tonne ethylene oxide produced	Reported
p	Process (p) type i.e. Air feed, Oxygen feed or Other	Nil	Reported
$EF_{a,CH4}$	Emission factor for CH_4 based on abatement type (a)	tonne CH_4/tonne ethylene oxide produced	Reported

a	Abatement treatment (a) being Thermal, Other or None	Nil	Reported
GWP_{CH4}	Global warming potential for CH_4	Nil	Constant

According to the 2006 IPCC Guidelines, when using Method 1: Calculation Approach, there is no default CO_2 emission factor for the 'Other' process type and no default CH_4 emission factor for the 'Other abatement' type selections. The default CH_4 emission factor has taken into account CH_4 emissions from the ethylene oxide process vent, ethylene oxide purification process exhaust gas steam and fugitive sources.[11]

Figure 5 shows an example of a configuration for ethylene oxide production in the MP Template for Method 1: Calculation Approach. In the example a Tier 1 site-specific CO_2 emission factor and the default CH_4 emission factor are used. The Tier 1 site-specific CO_2 emission factor has been sourced from the 2006 IPCC Guidelines as an alternative to the default specified by NEA, which assumes a lower Catalyst Selectivity than is used at the facility (refer to next sub-section on conversion factors and uncertainty). The quantity of ethylene oxide produced is measured using a Coriolis flowmeter.

Figure 5 – Ethylene oxide production using Method 1: Calculation Approach in the MP Template

CA_P1 Emission source: Ethylene oxide production
Emission stream type: Oxygen Process - Thermal abatement

(a) GHG quantification approach description:

Ethylene is used as the feedstock with pure oxygen for the production of ethylene oxide. The IPCC default CO2 emission factor assumes a Catalyst Selectivity of 70. However the plant operates at 80. The appropriate IPCC default conversion factor of 0.5 tonne CO2/tonne ethylene oxide production is to be used as a Site default. The default factor for CH4 is selected.

(b) Additional attachment to elaborate on the GHG quantification ap| Yes
Document reference/name: GHG Reporting - Basis of preparation

Activity data
Options to manage activity data entries:
Activity data measurement: FL 001 Ethylene oxide, Coriolis Flowmeter | Tier: 4 - Accurate Measurement | Uncertainty: 1.0%
Overall Activity data uncertainty: 1.00%

Conversion factor: Carbon dioxide Emission factor
Data source: Site-specific
Carbon dioxide Emission Factor: 0.50 Tonne/Tonne | Site-specific uncertainty (+/-%): 5.0%
Justification document reference/name: IPCC Vol 3 Chapter 3, Table 3.20 for Oxygen process, Catalyst Selectivity: 80
Uncertainty: 5.0%

Conversion factor: Methane Emission factor
Data source: Default
Uncertainty: 60.0%

Uncertainty Assessment
Emission stream uncertainty: 5.2%

Method 2: Material Balance

The facility can use Method 2: Material Balance to determine the quantity of carbon converted to CO_2 based on the difference in the quantity of carbon contained in the feedstock, products and waste streams. The formula to be used is shown in Section 3.1.2 of the M&R Guidelines Part II, for example, with ethylene oxide as the primary product, and propylene and butadiene as possible secondary products.

[11] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 3, page 3.78 for more details.

As the CH_4 emission factor is based on the quantity of ethylene oxide produced, details of the production activity data are required. This is likely to have been reported as part of the primary production material stream. However, it could be an alternative measure of production such as that used for official production reporting.

$$E_g = E_{CO2} + \left(Q_p \times EF_{a,CH4} \times GWP_{CH4}\right)$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions for GHG (g) i.e. CO_2 and CH_4	tonne CO_2e	Calculated
E_{CO2}	Emissions for CO_2	tonne CO_2e	Reported
Q_p	Quantity of ethylene oxide produced in process (p)	tonne	Reported
p	Process (p) type i.e. Air feed, Oxygen feed or Other	Nil	Reported
a	Abatement treatment (a) being Thermal, Other or None	Nil	Reported
$EF_{a,CH4}$	Emission factor for CH_4 based on abatement type (a)	tonne CH_4/tonne ethylene oxide produced	Reported
GWP_{CH4}	Global warming potential for CH_4	Nil	Constant

In Tab **G. Mat Bal – Emission Streams** of the MP Template when using Method 2: Material Balance, there is no default CH_4 emission factor for the 'Other abatement' type selections. The emission stream form allows for up to eight material streams to be detailed.

Figure 6 shows an example of a configuration of the 'Air Process – No Abatement' emission stream type. The ethylene feedstock and ethylene oxide primary product are monitored using meters. Ethylene oxide is produced as an aqueous solution and sold for the manufacture of glycol. The majority of the ethylene oxide product is fractionated to form an ethylene oxide gaseous stream for further processing. Refer to Section 5.6.4 of the M&R Guidelines Part II for details on the management of material streams and the data to be provided. Section 5.6.4 also details the estimation of the percentage of carbon contained in each material stream.

For ethylene oxide production, ethylene should be 100% of the feedstock carbon. In the example, 80% of the carbon in the feed is estimated to be contained in the two product streams on a 30%:50% basis. An additional 10% of the carbon is captured as pure CO_2 for sale to third parties. The proportion figures are used to estimate the overall uncertainty of the emission stream.

Figure 6 – Ethylene oxide production using Method 2: Material Balance in the MP Template

MB_P2 — Emission source: Ethylene oxide production
Emission stream type: Air Process - No abatement

(a) GHG quantification approach description:

Ethylene is used as the feedstock with oxygen from air intake for the production of ethylene oxide. Ethylene is the only feedstock. Ethylene oxide as an aqueous solution and gas stream, and a high purity CO2 are the three output streams. No abatement is available for the CH4 emissions with the default factor for CH4 selected.
CO2 is captured during the recovery stage and sold as demand and storage allow. The CO2 material stream represents the quantity of CO2 sold, with

(b) Additional attachment? Yes
Document reference / name: GHG Reporting – Basis of preparation

Options to manage material stream entries:

Proportion of feedstock stream: 100%
Proportion of product/waste Stream: 90%

Activity data for this material stream 1
Material stream type: Feedstock
Feedstock type: Ethylene
Proportion of total Feedstock carbon in this Feedstock material stream: 100%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 001 Ethylene feedstock	4 - Accurate Measurement	0.5%
Electromagnetic Flowmeter		

Overall Activity data uncertainty: 0.50%

Conversion factor: Carbon content
Data source: Ethylene and ethylene oxide purity - Composition - Carbon co
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Activity data for this material stream 2
Material stream type: Production (Primary)
Describe the material: Ethylene oxide product as an aqueous solution to storage
Proportion of total Feedstock carbon in this Product/Waste material stream: 30%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 002 Ethylne oxide (aqueous)	4 - Accurate Measurement	2.0%
Vortex Flow Meter		

Overall Activity data uncertainty: 2.00%

Conversion factor: Carbon content
Data source: Ethylene and ethylene oxide purity - Composition - Carbon co
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Activity data for this material stream 3
Material stream type: Production (Primary)
Describe the material: Ethylene oxide product as a gas following fractionation
Proportion of total Feedstock carbon in this Product/Waste material stream: 50%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 003 Ethylene oxide (gas)	4 - Accurate Measurement	1.0%
Coriolis Flowmeter		

Overall Activity data uncertainty: 1.00%

Conversion factor: Carbon content
Data source: Ethylene and ethylene oxide purity - Composition - Carbon co
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Figure 6 – Ethylene oxide production using Method 2: Material Balance in the MP Template (continued)

Activity data for this material stream 4

Material stream type: Production (Secondary)

Describe the material: High purity CO2 that is soldl to third parties

Proportion of total Feedstock carbon in this Product/Waste material stream: 10%

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Invoice	3 - Invoice	1.5%

Overall Activity data uncertainty: 1.50%

Conversion factor: Carbon content

Data source: CO2 purity - Composition - Carbon content

Frequency of analysis: 3 - Monthly

Uncertainty: 1.5%

Activity data to be used for Reporting to NEA

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:	Active from	Active to	Proportion
FL 002 Ethylne oxide (aqueous) Vortex Flow Meter	4 - Accurate Measurement	2.0%	01-Jan-19		30.00

Activity data measurement:	Tier:	Uncertainty:	Active from	Active to	Proportion
FL 003 Ethylene oxide (gas) Coriolis Flowmeter	4 - Accurate Measurement	1.0%	01-Jan-19		50.00

Overall Activity data uncertainty: 0.98%

Conversion factor: Methane Emission factor

Data source: Default

Uncertainty: 60.0%

Emission stream uncertainty: **15.0%**

Default conversion factors and uncertainty

The Tier 1 default emission factors for ethylene oxide production are shown in Table 4. The CO_2 and CH_4 emission factors have been obtained from the 2006 IPCC Guidelines, Volume 3, Chapter 3, Table 3.20 and Table 3.21 respectively, while the default uncertainty values have been obtained from the 2006 IPCC Guidelines, Volume 3, Chapter 3 Table 3.27.

Based on the 2006 IPCC Guidelines, there is no Tier 1 default CO_2 emission factor for the 'Other' process type and no Tier 1 default CH_4 emission factor for the 'Other abatement' type selections, i.e. listed as not available i.e. N/A in Table 4.

The default CO_2 emission factor for the Air Process assumes a catalyst selectivity of 70%, and the default CO_2 emission factor for the Oxygen Process assumes a catalyst selectivity of 75%.[12] However, a facility may have a catalyst selectivity data different from these respective default catalyst selectivity. Hence, the facility may specify Tier 1 site-specific CO_2 and CH_4 emission factors, citing the 2006 IPCC Guidelines as the reference.

By default, the uncertainty values of Tier 1 site-specific CO_2 and CH_4 emission factors are assumed to be half of Tier 1 default uncertainty values, with 7.5% set as the minimum uncertainty for Tier 1 site-specific CO_2 emission factors.

[12] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 3, page 3.78 for more details.

Table 4 – Tier 1 default ethylene oxide production conversion factors and uncertainty values

Emission stream type	CO_2 emission factor			CH_4 emission factor		
	tonne CO_2 /tonne ethylene oxide produced	Tier 1 default uncertainty	Tier 1 site-specific uncertainty	tonne CH_4 /tonne ethylene oxide produced	Tier 1 default uncertainty	Tier 1 site-specific uncertainty
Air Process - Thermal abatement	0.863	10%	7.5%	0.00079	60%	30%
Air Process - Other abatement	0.863	10%	7.5%	N/A	N/A	30%
Air Process - No abatement	0.863	10%	7.5%	0.00179	60%	30%
Oxygen Process - Thermal abatement	0.663	10%	7.5%	0.00079	60%	30%
Oxygen Process - Other abatement	0.663	10%	7.5%	N/A	N/A	30%
Oxygen Process - No abatement	0.663	10%	7.5%	0.00179	60%	30%
Other - Thermal abatement	N/A	N/A	7.5%	0.00079	60%	30%
Other - Other abatement	N/A	N/A	7.5%	N/A	N/A	30%
Other - No abatement	N/A	N/A	7.5%	0.00179	60%	30%

2.3 Ethylene production

☒ Method 1: Calculation Approach

☒ Method 2: Material Balance

☒ Method 3: Direct Measurement

According to the 2006 IPCC Guidelines, there are six emission stream types for ethylene production which are based on the feedstock-specific emission factors for CO_2 and CH_4.

i) Naphtha

ii) Gas Oil

iii) Ethane

iv) Propane

v) Butane

vi) Other feedstock

<u>Method 1: Calculation Approach</u>

The 2006 IPCC Guidelines[13] refer to the following formula:

$$E_g = Q_f \times \sum (EF_{f,g} \times GWP_g)$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions for GHG (g) i.e. CO_2, and CH_4	tonne CO_2e	Calculated
Q_f	Quantity of ethylene produced using feedstock (f)	tonne	Reported
$EF_{f,g}$	Emission factor for GHG (g) based on feedstock (f)	tonne GHG/tonne ethylene produced	Reported
f	Feedstock type (f)	Nil	Reported
GWP_g	Global warming potential for GHG (g)	Nil	Constant

Figure 7 shows a typical configuration for ethylene production using the feedstock 'Ethane' in the MP Template using Method 1: Calculation Approach. In the example, a Tier 1 site-specific CO_2 emission factor and the default CH_4 emission factor are used. The quantity of ethylene produced is measured using a flowmeter.

[13] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 3, pages 3.74 to 3.75 for more details.

The example assumes that ethane is the only feedstock. If multiple feedstock types are used, a separate emission stream form must be used by creating multiple emission stream types on Tab **C. Site Details**.

Figure 7 – Ethylene production using Method 1: Calculation Approach in the MP Template

CA_P7 Emission source: Ethylene production
Emission stream type: Ethylene produced - Ethane

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

Ethylene is produced from Ethane. Ethylene is measured at the entry to storage tanks. Reconciliation is undertaken daily on the product amounts against tank level and dispatch for reporting official production. The material balance approach was used for 2 months in 2017 with monitoring of ethane and ethylene flow and carbon content to determine a site carbon emission factor. Default CH4 emission factor used.

(b) **Additional attachment?** Yes
Document reference/name: GHG emission reporting Basis of Preparation

Activity data
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 301 Ethylene production	4 - Accurate Measurement	0.5%
Ultrasonic Doppler Flowmeter		

Overall Activity data uncertainty: 0.50%

Conversion factor: Carbon dioxide Emission factor
Data source: Site-specific
Carbon dioxide Emission Factor: 1.20 Tonne/Tonne Site-specific uncertainty (+/-%):
Document reference/name for procedure: Analytics Corp Report: Carbon dioxide emission factor for Ethylene
Uncertainty: 10.0%

Conversion factor: Methane Emission factor
Data source: Default
Uncertainty: 10.0%

Uncertainty Assessment
Emission stream uncertainty: 8.8%

Method 2: Material Balance

The facility can use Method 2: Material Balance to determine the quantity of carbon converted to CO_2 based on the difference in the quantity of carbon contained in the feedstock, products and waste streams. The formula to be used is shown in Section 3.1.2 of the M&R Guidelines Part II, with ethylene as the primary product, and propylene and butadiene as possible secondary products.

As the CH_4 emission factor is based on the quantity of ethylene produced, details of the production activity data are required. This is likely to have been reported as part of the primary production material stream. However, it could be an alternative measure of production such as that used for official production reporting.

$$E_g = E_{CO2} + \left(Q_f \times EF_{f,CH4} \times GWP_{CH4}\right)$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions for GHG (g) i.e. CO_2 and CH_4	tonne CO_2e	Calculated
E_{CO2}	Emissions for CO_2 from material balance	tonne CO_2e	Reported
Q_f	Quantity of ethylene produced using feedstock (f)	tonne	Reported
f	Feedstock type	Nil	Reported

$EF_{f,CH4}$	Emission factor for CH_4 based on feedstock (f)	tonne CH_4/tonne ethylene produced	Reported
GWP_{CH4}	Global warming potential for CH_4	Nil	Constant

In Tab **G. Mat Bal – Emission Streams** of the MP Template using Method 2: Material Balance, there are no default CO_2 and CH_4 emission factors for the 'Other' feedstock' selection (also refer to Table 5). The emission stream form allows for up to eight material streams to be detailed.

Figure 8 shows an example of a configuration for the 'Naphtha' feedstock emission stream type. The Naphtha feedstock, ethylene primary product and propylene as the secondary product are monitored using meters. Refer to Section 5.6.4 of the M&R Guidelines Part II for details on the management of material streams and the data to be provided. Section 5.6.4 also details the estimation of the percentage of carbon contained in each material stream.

For ethylene production, naphtha should be 100% of the feedstock carbon. In the example, 60% of the carbon in the feed is estimated to be contained in the two product streams on a 50%:10% basis. The proportion figures are used to estimate the overall uncertainty of the emission stream.

Figure 8 – Ethylene production using Method 2: Material Balance in the MP Template

MB_P3 — Emission source: Ethylene production
Emission stream type: Ethylene produced - Naphtha

(a) GHG quantification approach description:

Ethylene is produced from Naphtha with propylene as a secondary product. The Naphtha is measured at the entry point to the plant. Ethylene and propylene are measured at the entry to storage tanks. Reconciliation is undertaken daily on the product amounts against tank level and dispatch for reporting official production. The on-site laboratory is used to analyse product by shift for purity and carbon content. Naphtha is analysed by shipment received.

(b) Additional attachment? Yes

Document reference/name: GHG emission reporting Basis of Preparation

Options to manage material stream entries:

Proportion of feedstock stream: 100%
Proportion of product/waste Stream: 60%

Activity data for this material stream 1
Material stream type: Feedstock
Feedstock type: Naphtha
Proportion of total Feedstock carbon in this Feedstock material stream: 100%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 101 Feedstock flow	2 - Measurement	4.0%
Vortex Flow Meter		

Overall Activity data uncertainty: 4.00%

Conversion factor: Carbon content
Data source: Carbon content analysis - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Activity data for this material stream 2
Material stream type: Production (Primary)
Describe the material: Ethlyene product
Proportion of total Feedstock carbon in this Product/Waste material stream: 50%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 201 Ethylene production	4 - Accurate Measurement	0.5%
Ultrasonic Doppler Flowmeter		

Overall Activity data uncertainty: 0.50%

Conversion factor: Carbon content
Data source: Carbon content analysis - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Activity data for this material stream 3
Material stream type: Production (Secondary)
Describe the material: Propylene product
Proportion of total Feedstock carbon in this Product/Waste material stream: 10%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 202 Propylene production	4 - Accurate Measurement	0.5%
Ultrasonic Doppler Flowmeter		

Overall Activity data uncertainty: 0.50%

Conversion factor: Carbon content
Data source: Carbon content analysis - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Activity data to be used for Reporting to NEA
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 201 Ethylene production	4 - Accurate Measurement	0.5%
Ultrasonic Doppler Flowmeter		

Overall Activity data uncertainty: 0.50%

Conversion factor: Methane Emission factor
Data source: Default
Uncertainty: 10.0%

Emission stream uncertainty: **10.4%**

Method 3: Direct Measurement

The facility can directly measure CO_2 emissions based on stack monitoring. The MP Template assumes that unlike CO_2, CH_4 are not directly measured, and therefore the MP Template automatically configures an entry for CH_4 emissions based on Method 1: Calculation Approach in the Direct Measurement emission stream form. Information on the quantity of ethylene produced and the CH_4 emission factor are required. The formula becomes:

$$E_g = E_{CO2} + \left(Q_f \times EF_{f,CH4} \times GWP_{CH4}\right)$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions for GHG (g) i.e. CO_2 and CH_4	tonne CO_2e	Calculated
E_{CO2}	Emissions for CO_2 from direct measurement	tonne CO_2e	Reported
Q_f	Quantity of ethylene produced using feedstock (f)	tonne	Reported
f	Feedstock type	Nil	Reported
$EF_{f,CH4}$	Emission factor for CH_4 based on feedstock (f)	tonne CH_4/tonne ethylene produced	Reported
GWP_{CH4}	Global warming potential for CH_4	Nil	Constant

Figure 9 shows a typical configuration for ethylene production in the MP Template. In the example a site-specific CO_2 conversion factor and the default CH_4 emission factor are used. As the CH_4 emission factor is based on the production quantity of ethylene, details of the production activity data are required. In the example, the quantity of ethylene produced is measured using a flowmeter.

If multiple feedstock types are used, only one emission stream form should be used on Tab **C. Site Details**. The quantification approach description should list the feedstock types.

Figure 9 – Ethylene production using Method 3: Direct Measurement in the MP Template

DM_P1 — Emission source: Ethylene production
Emission stream type: Ethylene produced - Ethane

(a) GHG quantification approach description:

Ethylene is used as the feedstock with oxygen from air intake for the production of ethylene oxide. Ethylene is the only feedstock. Ethylene oxide as an aqueous solution and gas stream, and a high purity CO2 are the three output streams. No abatement is available for the CH4 emissions with the default factor for CH4 selected.
CO2 is captured during the recovery stage and sold as demand and storage allow. Following the recovery stage the flue gas is monitored for flow and CO2 concentration.

(b) Additional attachment? Yes
Document reference/name: GHG 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:
FL-101 Stack flow	4 - Accurate Measurement	1.5%
Venturi Tube		

Temperature correction: Yes — Pressure correction: Yes
Overall Activity data uncertainty: 1.50%

Conversion factor: GHG concentration measurement
Data source: FG - 100 Gas analyser - GHG concentration in gas sample
Frequency of analysis: 4 - Representative
Uncertainty: 3.0%

Activity data for Production
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL - 311 Ethylene production	4 - Accurate Measurement	0.5%
Electromagnetic Flowmeter		

Overall Activity data uncertainty: 0.50%

Conversion factor: Methane — Emission factor
Data source: Default
Uncertainty: 10.0%

Emission stream uncertainty: 3.3%

Default conversion factors and uncertainty

The Tier 1 default CO_2 and CH_4 emission factors for ethylene production are shown in Table 5. The CO_2 and CH_4 emission factors and uncertainty values have been obtained from the 2006 IPCC Guidelines[14]. These default emission factors do not include CO_2 emissions from flaring.

According to the 2006 IPCC Guidelines[15], the emission factors may be used in the event that activity data are available only for the amount of ethylene produced by the steam cracking process. The 2006 IPCC Guidelines states that steam cracking is a multi-product process that leads to ethylene, propylene, butadiene, aromatics, and several other high-value chemicals. In order for IPCC to develop the emission factors for steam cracking, the total CO_2 process emissions of a steam cracker have been divided by the output of ethylene only i.e. ethylene has been chosen as the reference for estimating the total CO_2 emissions from the steam cracking process. Multiplication of the CO_2 emission factors by the ethylene production therefore leads to the total CO_2 emissions resulting not only from the production of ethylene but also from the production of propylene, butadiene, aromatics, and all other chemicals produced by the steam cracking process. The default emission factors provide the total CO_2 emissions from the steam cracking process, not only the CO_2 emissions associated with the production of the ethylene from the steam cracking process as a whole.

[14] Refer to 2006 IPCC Guidelines, Volume 3, Chapter 3, Tables 3.14, 3.16 and 3.27 for more details. The default CO_2 emission factors for Asia are used, regional adjustments to account for differences in the energy efficiency of steam cracking units for Asia (Table 3.15) have been made.
[15] Refer to 2006 IPCC Guidelines, Volume 3, Chapter 3, page 3.75 for more details.

The 2006 IPCC Guidelines also provides default CH_4 emission factors for CH_4 fugitive emissions. Therefore, the default CH_4 emission factors should not be used to estimate CH_4 emissions from steam cracker ethylene plants for which site-specific data for CH_4 fugitive emissions are available.

Assuming that the facility has a reasonably good understanding of the facility's yield from the feedstock, Tier 1 site-specific uncertainty values for CO_2 emission factors are assumed to be about one-third of the IPCC default uncertainty values. 7.5% is set as the minimum uncertainty for Tier 1 default site-specific CH_4 emission factors.

Table 5 – Tier 1 default ethylene production conversion factors and uncertainty values

Emission stream type	CO_2 emission factor			CH_4 emission factor		
	tonne CO_2 /tonne ethylene produced	Tier 1 default uncertainty	Tier 1 site-specific uncertainty	tonne CH_4 /tonne ethylene produced	Tier 1 default uncertainty	Tier 1 site-specific uncertainty
Naphtha	2.25	32%	10%	0.003	10%	7.5%
Gas Oil	2.98	32%	10%	0.003	10%	7.5%
Ethane	1.24	32%	10%	0.006	10%	7.5%
Propane	1.35	32%	10%	0.003	10%	7.5%
Butane	1.35	32%	10%	0.003	10%	7.5%
Other feedstock	2.25	32%	10%	0.003	10%	7.5%

2.4 Flares

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☐ Method 3: Direct Measurement

There are eight emission stream types for flares, taking reference from the API Compendium.[16] This is a change from the list of activities in the Energy Use Report (GHG from non-fuel combustion processes or activities) that catered to a broader set of industry sectors. The emission stream types represent a series of activities that commonly use a flare:

i) Gas Production

ii) Sweet Gas Production

iii) Sour Gas Production

iv) Conventional Oil Production

v) Heavy Oil / Cold Bitumen Production

vi) Thermal Oil Production

vii) Refining

viii) Other (e.g. incineration or combustion of material that does not involve the recovery of energy commodities e.g. heat, steam)

Method 1: Calculation Approach

The calculation approach uses the following formula:

$$E_g = Q_p \times \sum (EF_{p,g,fe} \times GWP_g)$$

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_p	Quantity of flare gas produced by process (p)	tonne	Reported
$EF_{p,CO2,fe}$	Emission factor for CO_2 based on process (p) and flare efficiency (fe)	tonne CO_2/tonne flare gas	Reported
$EF_{p,CH4,fe}$	Emission factor for CH_4 based on process (p) and flare efficiency (fe)	tonne CH_4/tonne flare gas	Reported

[16] *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry* (August 2009), published by the American Petroleum Industry.

$EF_{p,N2O}$	Emission factor for N_2O based on process (p) *Note that $EF_{p,N2O}$ is independent of the flare combustion efficiency	tonne N_2O/tonne flare gas	Reported
p	Process type i.e. emission stream type	Nil	Reported
fe	Flare combustion efficiency	Percentage (%)	Reported
GWP_g	Global warming potential for GHG (g)	Nil	Constant

The calculation of emissions from flaring is similar to the calculation of emissions from fuel combustion, but with the following differences:

i) There is an additional parameter i.e. flare combustion efficiency which affects the computation of flare emissions, with default values of 99.5% for flares at refineries and similar petrochemical facilities and 98% for upstream facilities. In the MP Template, a default flare combustion efficiency is defined for each emission stream type.

ii) According to the API Compendium[17] and 2006 IPCC Guidelines, the flare combustion efficiency is used to calculate CH_4 emissions from non-combusted CH_4 composition of the flare gas. Should there be a site-specific flare efficiency such that the default CH_4 emission factor is no longer appropriate, the site-specific flare efficiency and CH_4 emission factor are to be reported in the Emissions Report.

iii) If the facility's gas stream has a high CO_2 content, the site-specific CO_2 and CH_4 emission factors can be derived from the carbon content of the gas stream including the impact of oxidation, using the following formulae:

$$EF_{f,CO2} = \left[\sum_{y}^{\neq CO2} \left(mol\%_y \times f_{c,y} \times FE \right) + mol\%_{CO2} \right] \times \frac{MW_{CO2}}{\sum_y (mol\%_y \times MW_y)}$$

Where: $EF_{f,CO2}$ is the emission factor for CO_2 for the fuel (f) in tonne CO_2/tonne fuel
$mol\%_y$ is the molar percentage of each component gas type (y) within the fuel
$mol\%_{CO2}$ is the molar percentage of CO_2 within the fuel
MW_y is the molecular weight of the component gas type (y) measured in g/mol
MW_{CO2} is the molecular weight of CO_2 (i.e. 44 g/mol)
$f_{c,y}$ is the number of carbon atoms in 1 molecule of the component gas type (y) (e.g. for CH_4, $f_{c,CH4} = 1$, C_2H_6, $f_{c,C2H6} = 2$)
FE is the combustion efficiency of the flare

$$EF_{f,CH4} = \frac{mol\%_{CH4} \times MW_{CH4}}{\sum_y (mol\%_y \times MW_y)} \times (1 - FE)$$

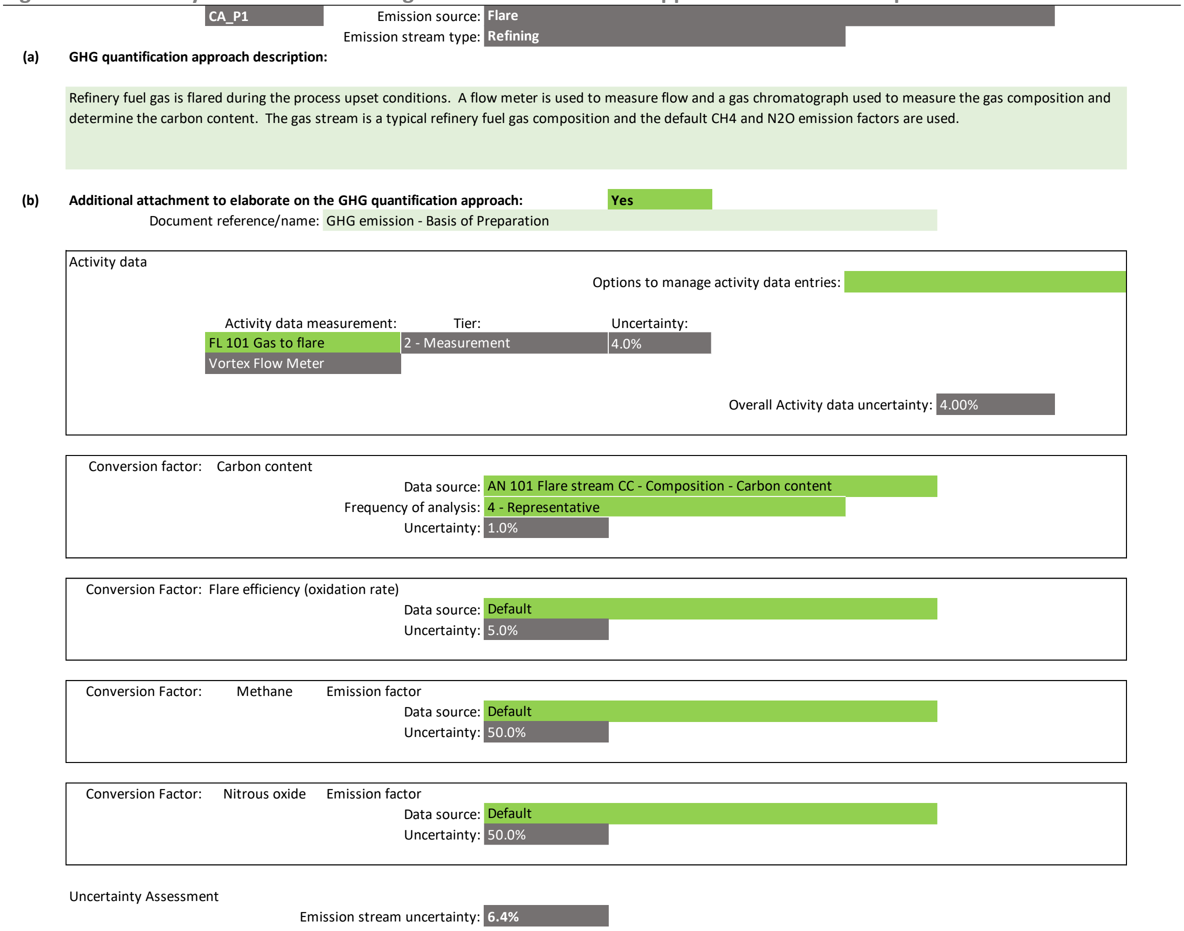
Where: $EF_{f,CH4}$ is the emission factor for CH_4 for the fuel (f) in tonne CH_4/tonne fuel
$mol\%_y$ is the molar percentage of each component gas type (y) within the fuel
$mol\%_{CH4}$ is the molar percentage of CH_4 within the fuel

[17] Refer to API Compendium, Section 4, Chapter 6, page 4-40 for more details.

MW_{CH4} is the molecular weight of CH_4 (i.e. 14 g/mol)
MW_y is the molecular weight of the component gas type (y) measured in g/mol
FE is the combustion efficiency of the flare

Figure 10 shows a typical configuration for refinery flares in the MP Template using Method 1: Calculation Approach. In the example an online analyser is used to derive the carbon content of the feed to the flare, and the default conversion factors for CH_4 and N_2O emissions are used. The quantity of feed gas flared is measured using a flow meter.

Figure 10 – Refinery flare emissions using Method 1: Calculation Approach in the MP Template



Default conversion factors and uncertainty

The Tier 1 default flare efficiency (FE) and CO_2, CH_4 and N_2O emission factors are shown in Table 7.

The default CO_2, CH_4 and N_2O emission factors based on the IPCC recommended values[18] for direct estimation of CO_2, CH_4 and N_2O emissions from reported flared volumes are 2.0, 0.012 and 0.000023 Gg, respectively, per 10^6 m^3 of gas flared for a flaring efficiency (i.e. oxidation factor) of 98% and a generic upstream gas composition as shown in Table 6. A density of 0.745 kg/m^3 has been used to convert the CH_4, CO_2 and N_2O emission factors from a volumetric to mass basis.

[18] Refer to the 2006 IPCC Guidelines, Volume 2, Section 4.2.2.3, Tables 4.2.4 & 4.2.5 footnote 'e'.

Table 6 – Generic gas composition in upstream gas processing operations

Component	Gas processing plant gas composition (volume %)
CH_4	91.9%
Non-methane hydrocarbon	6.84% (Molecular weight is unspecified) *Further assume breakdown of 4.56% ethane and 2.28% propane*
N_2	0.68%
CO_2[19]	0.58%

Table 7 – Tier 1 default flare conversion factors

Emission stream type	Flare efficiency	CO_2 emission factor $EF_{p,CO2}$ (tonne CO_2/tonne flare gas)	CO_2 emission factor $EF_{p,CO2,fe}$ (including flare efficiency) (tonne CO_2/tonne flare gas)	CH_4 emission factor $EF_{p,CH4}$ (tonne CH_4/tonne flare gas)	CH_4 emission factor $EF_{p,CH4,fe}$ (including flare efficiency) (tonne CH_4/tonne flare gas)	N_2O emission factor (tonne N_2O/tonne flare gas)
Gas Production	98%	2.7	2.646	0.8	0.016	0.00003
Sweet Gas Production	98%	2.7	2.646	0.8	0.016	0.00003
Sour Gas Production	98%	2.7	2.646	0.8	0.016	0.00003
Conventional Oil Production	98%	2.7	2.646	0.8	0.016	0.00003
Heavy Oil / Cold Bitumen Production	99.50%	2.7	2.6865	0.8	0.004	0.00003
Thermal Oil Production	99.50%	2.7	2.6865	0.8	0.004	0.00003
Refining	99.50%	2.7	2.6865	0.8	0.004	0.00003
Other	99.50%	2.7	2.6865	0.8	0.004	0.00003

[19] According to the API Compendium, CO_2 present in the stream to the flare is emitted directly as CO_2. Neither the flare combustion efficiency nor the conversion of flare gas carbon to CO_2 apply to the CO_2 already contained in the flared stream.

The Tier 1 default uncertainty values for each parameter are shown in Table 8. The uncertainty value of individual flares is not specified by the 2006 IPCC Guidelines or API Compendium. The carbon content of typical oil and gas sector fuel gas streams may vary by more than 10% between different facilities, while the flare efficiency across the sector may also vary by up to 5%. Therefore, an assumed uncertainty value of 10% for carbon content and 5% for flare efficiency are set to reflect the potential range for these values. The minimum uncertainty for Tier 1 site-specific carbon content is set as 7.5%, while the uncertainty value for Tier 1 site-specific flare efficiency is half of the Tier 1 default uncertainty, i.e. 2.5%.

Table 8 – Tier 1 default and site-specific uncertainty values

Conversion factor	Tier 1 default uncertainty	Tier 1 site-specific uncertainty
Carbon content	10%	7.5%
Flare efficiency	5%	2.5%
CH_4 & N_2O emission factors	50%	30%

2.5 Vents

☒ Method 1: Calculation Approach

☒ Method 2: Material Balance

☒ Method 3: Direct Measurement

There are 19 emission stream types for vents, taking reference from the API Compendium[20]. This is a change from the list of activities in the Energy Use Report (GHG from non-fuel combustion processes or activities) that catered to a broader set of industry sectors. The emission stream types represent a series of activities within the oil and gas sector that result in the release of GHG emissions from vents i.e. process vents. The emission stream types are aligned to the Section 5 of the API Compendium.

As far as possible, the reporting of vented emissions should be allocated to the specific IPPU emission source defined in the MP Template i.e. Ethylene production, Ethylene oxide production, Coal gasification etc. Otherwise, the emissions can be reported under Vents.

The emissions quantification methods available for selection in the MP Template are dependent on the emission stream types. Method 1: Calculation Approach is available for all emission stream types, while Method 2: Material Balance and Method 3: Direct Measurement are applicable for certain emission stream types.

Table 9 tabulates the respective sections and chapters of the API Compendium according to each emission stream type i.e. process vent. Most methods are based on Method 1: Calculation Approach, unless otherwise specified. The general formula for vents is as follow:

$$E_{g,f} = E_{CO2} + (E_{CH4} \times GWP_{CH4})$$

Parameter ID	Parameter description	Units	Reporting status
$E_{g,f}$	Emissions for GHG (g) i.e. CO_2 and CH_4 for vent (f)	tonne CO_2e	Calculated
E_{CO2}	Emissions for CO_2	tonne	Reported (in kg)
E_{CH4}	Emissions for CH_4	tonne	Reported (in kg)
f	Type of vent i.e. emission stream type	Nil	Reported
GWP_{CH4}	Global warming potential for CH_4	Nil	Constant

[20] *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry* (August 2009), published by the American Petroleum Industry.

Table 9 – Emission stream types for vents

Emission stream type	API Compendium references	Description
Process Vents - Dehydration Processes	5.1.1	CH_4 emission factors per m^3 gas processed by glycol dehydrators (table 5-2 and table 5-3) CO_2 emissions based on relative gas concentration (Exhibit 5.1 section 2)
	5.1.3	Engineering approach for desiccant dehydrators (equation 5-1)
	5.1.4	Alternative glycol dehydrator equipment
Process Vents - Dehydrator Kimray Pumps	5.1.2	Additional CH_4 and CO_2 emissions from the use of gas assisted glycol pumps (table 5-4) Ensure no double counting with Dehydration processes
Process Vents - Acid gas removal processes	5.1.5	CH_4 emission factors per m^3 gas processed by acid gas removal units (table 5-5 or API's AMINECalc tool)
Process Vents - Sulphur recovery units	5.1.5	CO_2 emissions from sour gas processing using a material balance approach (equation 5-2 or equation 5-3)
Process Vents – Catalytic cracking	5.2.1	Three approaches are provided for the estimation of CO_2 emissions from coke removal from catalyst. (Figure 5-3 provided a decision tree to select the appropriate approach, being either: • Equation 5-4 • Equation 5-5 • Equation 5-6
Process Vents - Catalytic reforming	5.2.1	
Process Vents - Catalyst regeneration	5.2.1	
	5.2.4	An alternative approach to estimating CO_2 emissions based on weight fraction of coke on spent catalyst (equation 5-10)
Process Vents - Steam methane reforming (hydrogen plants)	5.2.2	Estimation of CO_2 emissions from feedstock based on one of: • Feedstock composition (equation 5-8) • H_2 production and stoichiometric relationship (equation 5-9) • Default emission factors for measured natural gas feedstock and H_2 production (Exhibit 5.8) • Flue rates and exhaust composition (equation 5-6)
	Material balance	Where CO and CO_2 is captured for transfer or re-use elsewhere, a material balance approach can be used
	Direct measurement	CO_2 emissions can be directly measured by exhaust stack monitoring
Process Vents - Delayed coking	5.2.3 Or 5.2.4	Combustion of coke based on carbon content (equation 5-4 and Exhibit 5.9)
Process Vents - Flexi-coking		

Emission stream type	API Compendium references	Description
Process Vents - Asphalt blowing	5.2.5	CH_4 and CO_2 emission factors are provided (table 5-7 and equations 5-12 and 5-13 respectively)
Process Vents - Thermal cracking	5.2.6	CO_2 emissions from coke calcination and coke drum blowdowns (engineering estimate)
	Direct measurement	CO_2 emissions can be directly measured by exhaust stack monitoring
Cold Process Vents	5.3	Physical direct measurement (equation 5-14) or estimation of GHG releases using Method 1: Calculation Approach
Process Vents - Storage tanks	5.4.1, 5.4.3	CH_4 and CO_2 emissions from flashing losses at upstream production operations. Figure 5-5 provided a decision tree to select the appropriate approach, being either: • Direct measurement • API's E&P TANK or other process simulators • Equation 5-16 (Vasquez-Beggs Equation) and equation 5-17 • Equation 5-18, equation 5-19 or equation 5-20 (Correlation equation approach) • Simple emission factors in Table 5-8 or estimate emissions using the flashing loss chart approach (figure 5-6) • Methane flashing loss emission factors (table 5-8) • Methane condensate flashing loss default emission factors • Methane Produced salt water tank flashing loss default emission factors (table 5-10)
	5.4.2	No fugitive emissions are assumed for "weathered" crude and other refined petroleum products as they are assumed to contain no CH_4 or CO_2
Process Vents - Storage tanks and drain vessels	5.4.4	CH_4 and CO_2 emissions from natural gas blanketed tanks (equation 5-15)
Process Vents - Loading / Unloading / Transit	5.5	CH_4 and CO_2 emissions from handling and transfer of live (not weathered) crude oil. Where CH_4 and/or CO_2 is measured in the vented gas use • 5.5.1 Loading loss emissions (table 5-12) • 5.5.2 Ballasting emissions (table 5-13) • 5.5.3 Transit loss emissions (table 5-14)
Process Vents - Pneumatic devices	5.6.1	Calculation approach (equation 5-21) and industry average emission factors for CH_4 and CO_2 emissions from the use of pneumatic and chemical injection devices using hydrocarbon gases (table 5-15)

Emission stream type	API Compendium references	Description
Process Vents - Chemical Injection Pumps	5.6.2	Calculation approach (equation 5-22) and industry average emission factors for CH_4 and CO_2 emissions from the use of pneumatic and chemical injection devices using hydrocarbon gases (table 5-16)
Non-routine activities	5.7	CH_4 and CO_2 emissions from non-routine events Section 5.7.1 details an engineering approach to non-routine releases (equation 5-24 or 5-27) Section 5.7.2 details production segment emission factors for a number of activities such as blowdowns, compressor starts (using fuel gas) (table 5-23 and table 5-24) Section 5.7.3 details gas processing sector factor (table 5-25) Section 5.7.4 details gas transmission sector factors by activity type (table 5-26) Section 5.7.5 details gas distribution sector factors by activity type (table 5-27) Section 5.7.6 refers to table 5-23 for compressor states at refineries where fuel gas is used or other applicable activities

Method 1: Calculation Approach

The API Compendium provides a number of approaches using Method 1: Calculation Approach to compute emissions for the various emission stream types referenced in Table 9. The facility should select the most appropriate approach and indicate in the MP Template, sufficient and appropriate references to the API Compendium e.g. applicable sections, tables, formulae, conversion factors or exhibits.

To provide flexibility for facilities, a generic emission stream form is developed for most emission stream types. Only 'steam methane reforming (hydrogen plants)' emission stream type uses a pre-configured form.

The Appendix does not provide examples of the MP Template configuration for every emission stream type based on the API Compendium estimation approaches. For most types of process vents, the API Compendium provides emission factors to be applied to typical industry production or process flow measurements.

Figure 11 shows a typical configuration for a process vent – catalytic cracking regenerator with the following activity data and conversion factors based on the following equations from the API Compendium.[21] Details of how each activity data value and conversion factor is recorded on Tab **D. Calc Apch – Metering & Analysis** is shown in Figure 12 and Figure 13.

The measuring and reporting process for other process vents can be detailed in a similar way by stating the relevant applicable sections, tables, formulae, conversion factors or exhibits under the GHG emissions quantification approach section and describing each activity data value and conversion factor in Tab **E. Calc Apch – Emission Streams**.

[21] Refer to API Compendium, Section 5, Chapter 2, page 5-20 for more details.

$$E_{CO_2} = \left[K_1 \times Q_r \times \left(P_{CO_2} + P_{CO}\right)\right] \times \frac{44 \text{ mass units } CO_2/\text{mole}}{12 \text{ mass units C/mole}} \times H \qquad \text{(Equation 5-5)}$$

where

E_{CO_2} = emissions of CO_2 (lb/year or kg/year);

K_1 = carbon conversion factor burn term (0.0186 lb-min/hr-dscf-% or 0.2982 kg-min/hr-dscm-, given in Table B-2%);

Q_r = volumetric flow rate of exhaust gas before entering the emission control system, calculated using Equation B-2 (dscf/min or dscm/min);

P_{CO_2} and P_{CO} = percent CO_2 and CO concentrations, respectively, in regenerator exhaust, percent by volume (dry basis); and

H = annual operating time (hrs/yr); 8760 hrs/yr if operating continuously throughout the year.

The term Q_r is derived from API Compendium equation B-2 as:

$$Q_r = \frac{79 \times Q_a + \left(100 - P_{O_{xy}}\right) \times Q_{oxy}}{100 - P_{CO_2} - P_{CO} - P_{O_2}} \qquad \text{(Equation B-2)}$$

Q_a = volumetric flow rate of air to regenerator as determined from control room instrumentation (dscf/min or dscm/min);

Q_{Oxy} = volumetric flow rate of O_2-enriched air to regenerator as determined from control room instrumentation (dscf/min or dscm/min);

P_{Oxy} = O_2 concentration in O_2-enriched air stream inlet to regenerator, percent by volume (dry basis).

The two equations include:

i) Three activity data entries:

   a. Annual operating hours (H)
   b. Volumetric flow rate of air to regenerator (Q_a)
   c. Volumetric flow rate of O_2-enriched air to regenerator (PQ_{Oxy})

ii) Four conversion factors:

   a. Percent CO_2 concentration in regenerator exhaust (P_{CO2})
   b. Percent CO concentration in regenerator exhaust (P_{CO})
   c. Percent O_2 concentration in O_2-enriched air stream to regenerator (P_{Oxy})
   d. Carbon burn rate (K_1)

Figure 11 – Vented emissions from catalytic cracking using Method 1: Calculation Approach in the MP Template

CA_P1 Emission source: Vents
Emission stream type: Process Vents - Catalytic cracking

(a) GHG quantification approach description:

A fluid catalytic cracking unit (FCCU) is operated at the facility. The API Compendium coke burn rate approach is used (Equation 5-5 & equation B-2) to estimate CO2 emissions. The equations require the measurement of two air flow rates that are monitored for control purposes. The FCCU's operating hours are also used and calculated from the plant control system. Three gas analysers measurements for CO2, CO and O2 are used. These are continuously monitored. A fourth conversion factor is a constant value detailed in the API Compendium. This has been recorded as a site default. The uncertainty of the

(b) Additional attachment? **Yes**
Document reference / name: GHG Reporting - Basis of Preparation

Activity data

Activity data measurement:	Tier:	Uncertainty:	Active from	Active to	Proportion
Annual operating hours	4 - Accurate Measurement	1.0%	01-Jan-19		
Availability or Operating hou					

Activity data measurement:	Tier:	Uncertainty:	Active from	Active to	Proportion
FL 101 Air to Regenerator	4 - Accurate Measurement	4.0%	01-Jan-19		
Pitot Tubes					

Activity data measurement:	Tier:	Uncertainty:	Active from	Active to	Proportion
FL 102 O2 Air to Regenerator	4 - Accurate Measurement	4.0%	01-Jan-19		
Pitot Tubes					

Overall Activity data uncertainty: 0.00%

Please provide a description and details for all conversion factors required to calculate this emission stream

Conversion factor 1: Carbon burn rate (K1)
Data source: Site default
Conversion factor 1 and units: 0.2982 kg-min/hr-dscm
Document reference/name for procedure: API Compendium table B-2 and Equation 5-5 section 5.2.1
Uncertainty: Please provide: 5.0%

Conversion factor 2: Percent CO2 concentration in regenerator exhaust
Data source: CN - 201 CO2 concentration - GHG concentration in gas sample
Frequency of analysis: 4 - Representative
Uncertainty: 3.0%

Conversion factor 3: Percent CO concentration in regenerator exhaust
Data source: CN - 202 CO concentration - GHG concentration in gas sample
Frequency of analysis: 4 - Representative
Uncertainty: 3.0%

Conversion factor 4: Percent O2 concentration in O2-enriched air stream to regenerator
Data source: CN - 203 O2 concentration - GHG concentration in gas sample
Frequency of analysis: 4 - Representative
Uncertainty: 3.0%

Uncertainty Assessment
Emission stream uncertainty: **10.0%**

Figure 12 – Specifying the activity data for an FCCU in the MP Template for Vented emissions

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument or technique	Tier	Default uncertainty (+/-%)	Site-specific uncertainty (+/-%)	Management procedure name
P1	Annual operating hours	Availability or Operating hours	4 - Accurate Measurement	1.0%		SoP - FCCU unit management
P1	FL 101 Air to Regenerator	Pitot Tubes	4 - Accurate Measurement	4.0%		SoP - FCCU unit management
P1	FL 102 O2 Air to Regenerator	Pitot Tubes	4 - Accurate Measurement	4.0%		SoP - FCCU unit management

Figure 13 – Specifying the conversion factors for an FCCU in the MP Template for Vented emissions

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument	Conversion factor	Default uncertainty (+/-%)	Site-specific uncertainty (+/-%)	Management procedure name
P1	CN - 201 CO2 concentration	Flue Gas Analyser	GHG concentration in gas sample	3.0%		SoP - FCCU unit management
P1	CN - 202 CO concentration	Flue Gas Analyser	GHG concentration in gas sample	3.0%		SoP - FCCU unit management
P1	CN - 203 O2 concentration	Flue Gas Analyser	GHG concentration in gas sample	3.0%		SoP - FCCU unit management

** The site-specific uncertainty detailed in Figure 11 would need to be assessed from site data.*

Emissions from the 'process vent – steam methane reforming (hydrogen plants)' emission stream type can be estimated using all three emissions quantification methods. There are 2 options under Method 1: Calculation Approach according to the API Compendium[22] and these 2 options have been built into the MP Template:

i) **Feedstock use** i.e. quantity of feedstock used, assuming all carbon in the feedstock is combusted to CO_2. This is equivalent to equation 5-8 in the API Compendium.

ii) **Hydrogen production** i.e. the quantity of hydrogen produced, based on the stoichiometric relationship between CH_4 (in feedstock) and H_2 (produced). This is equivalent to equation 5-9 in the API Compendium.

As detailed in Figure 14 and Figure 15 below, the selection of the more appropriate option is based on the available data.

Where the quantity of feedstock used is known and it can be assumed that all feedstock carbon is combusted, then the feedstock option is appropriate and has lower uncertainty. Figure 14 shows a typical configuration for a process vent – steam methane reforming (hydrogen plants) using Method 1: Calculation Approach. The emission stream form in Tab **E. Calc Apch – Emission Streams** contains an 'Activity data to be use' dropdown, and in the example the 'feedstock use' approach is selected. In the example, the facility specifies the measurement of the quantity of the feedstock and the source of the conversion factor, i.e. carbon content emission factor. In the example, the facility uses a Tier 1 site-specific conversion factor for the carbon content emission factor of natural gas, referenced from the 2006 IPCC Guidelines 2006 IPCC Guidelines, Volume 2; Chapters 1 Table 1.2 (for the NCV in GJ/tonne) and Table 1.3 (for the carbon content in kg/GJ).

Where the quantity of feedstock is not directly measured, however the total facility's use of feedstock including additional heating/combustion within the hydrogen plant is measured/invoiced, the theoretical quantity of feedstock needed can be assessed and reported as hydrogen production. This quantity can then be deducted from the facility's total use of the feedstock with the remainder reported as fuel combustion. In this case, two activity data entries will be recorded, one for the total quantity of feedstock used/purchased and one for the quantity of feedstock used for heating/combustion.

Figure 15 shows the hydrogen production approach.

[22] Refer to API Compendium, Section 5, Chapter 2, pages 5-17 to 5-30 for more details.

Figure 14 – Vented emissions from steam methane reforming (hydrogen plants) using Method 1: Calculation Approach in the MP Template based on the amount of feedstock used

CA_P1	Emission source:	Vents
	Emission stream type:	Process Vents - Steam methane reforming (hydrogen plants)
	Activity data to be used:	Feedstock use

(a) GHG quantification approach description:

Hydrogen is produced from natural gas feedstock. PSA purge gas is a low-GJ fuel gas consisting mostly of CO2, CO, and CH4, and some H2. The purge gas is then routed to the reformer furnace and combusted to CO2.
The quantity of natural gas used is to be used with the IPCC default carbon content (IPCC 2006 Guidelines, Volume 2, Chapter 1, Table 1.2 & 1.3) to calculate CO2 emissions from the feedstock. Additional reformer heating is supplied from a second natural gas stream, refer to CA_F1 for details.

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

Document reference/name: GHG Reporting - Basis of preparation

Activity data (feedstock quantity):

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 001 Natural gas flow	4 - Accurate Measurement	2.0%
Vortex Flow Meter		

Overall Activity data uncertainty: 2.00%

Conversion factor: Carbon content Emission factor

Data source:	Site-specific
Carbon content Emission factor:	0.734 tonne/tonne; Site-specific uncertainty (+/-%):
Justification document reference/name:	IPCC Vol 2, Chapter 1, 15.3 kg C/GJ (Table 1.3) x 0.048 GJ/tonne (Table 1.2)
Uncertainty:	2.8%

Uncertainty Assessment

Emission stream uncertainty: 3.5%

Figure 15 – Vented emissions from steam methane reforming (hydrogen plants) using Method 1: Calculation Approach in the MP Template based on amount of hydrogen produced

CA_P2	Emission source:	Vents
	Emission stream type:	Process Vents - Steam methane reforming (hydrogen plants)
	Activity data to be used:	Hydrogen production

(a) GHG quantification approach description:

Hydrogen is produced from natural gas feedstock. PSA purge gas is a low-GJ fuel gas consisting mostly of CO2, CO, and CH4, and some H2. The purge gas is then routed to the reformer furnace and combusted to CO2. The quantity of natural gas used as feedstock and additional reformer heating is not individually monitored. The quantity of natural gas feedstock and resulting CO2 emissions are calculated from the H2 production and the stoichiometric relationship to methane. The remaining natural gas used is apportioned to fuel combustion, refer to CA_F1 for details.

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

Document reference/name: GHG Reporting - Basis of preparation

Activity data (hydrogen production quantity):

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 001 Natural gas flow	4 - Accurate Measurement	2.0%
Vortex Flow Meter		

Overall Activity data uncertainty: 2.00%

Conversion factor: Carbon dioxide Emission factor

Data source:	Site-specific
Carbon dioxide Emission factor:	0.260 tonne/tonne; Site-specific uncertainty (+/-%):
Justification document reference/name:	Based on supplier Natural gas composition CH4 = 85%, C2H6 = 8%, C4H10= 3%
Uncertainty:	7.5%

Uncertainty Assessment

Emission stream uncertainty: 7.8%

Method 2: Material Balance

The facility can use Method 2: Material Balance to determine the quantity of carbon converted to CO_2 based on the difference in the quantity of carbon contained in the feedstock, products and waste streams. For vents, the applicable emission stream type is ‘process vent – steam methane reforming (hydrogen plants)’, where CO_2 or other by-products are captured and stored or sold.

Method 2: Material Balance copies the Feedstock option under Method 1: Calculation Approach, but with the total carbon input estimated from the quantity of feedstock. If the quantity of feedstock is not physically measured, the quantity of Hydrogen produced could be used to generate an engineering estimate of the quantity of feedstock required.

Figure 16 shows a typical configuration for a process vent – steam methane reforming (hydrogen plants) using Method 2: Material Balance. The natural gas feedstock and secondary products CO and CO_2 are monitored using flowmeters. Refer to Section 5.6.4 of the M&R Guidelines Part II for details on the management of material streams and the data to be provided. Section 5.6.4 also details the estimation of the percentage of carbon contained in each material stream.

In the example, natural gas should be 100% of the feedstock carbon, where 70% of the feedstock carbon in the feed is estimated to be contained in the two secondary product streams on a 40%:30% basis. The proportion figures are used to estimate the overall uncertainty of the emission stream.

Figure 16 – Vented emissions from steam methane reforming (hydrogen plants) using Method 2: Material Balance in the MP Template

MB_P1	Emission source:	Vents
	Emission stream type:	Process Vents - Steam methane reforming (hydrogen plants)

(a) GHG quantification approach description:

Hydrogen is produced from natural gas feedstock. Process purge gases are obtained providing CO, CO2 (high purity) streams and a low GJ stream containing CO, CO2, CH4 and H2 that is combusted in the reformer. The high purity CO2 stream and CO streams are filtered and stored for sale to third parties. The purity of the CO and CO2 streams are monitored monthly for QA control. The default carbon content of natural gas is used. Additional reformer heating is supplied from a second natural gas stream, refer to CA_F1 for details.

(b) Additional attachment? Yes

Document reference/name: GHG Reporting - Basis of preparation

Options to manage material stream entries:

Proportion of feedstock stream: 100%
Proportion of product/waste Stream: 70%

Activity data for this material stream 1
Material stream type: Feedstock
Feedstock type: Natural Gas
Proportion of total Feedstock carbon in this Feedstock material stream: 100%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 001 Natural gas feed	4 - Accurate Measurement	1.0%
Coriolis Flowmeter		

Overall Activity data uncertainty: 1.00%

Conversion factor: Carbon content
Data source: Default
Uncertainty: 5.7%

Activity data for this material stream 2
Material stream type: Production (Secondary)
Describe the material: CO fuel stream sales
Proportion of total Feedstock carbon in this Product/Waste material stream: 40%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 004 CO sales	4 - Accurate Measurement	2.0%
Vortex Flow Meter		

Overall Activity data uncertainty: 2.00%

Conversion factor: Carbon content
Data source: CO Sales gas purity - Composition - Carbon content
Frequency of analysis: 3 - Analysis done once every year or more frequent
Uncertainty: 2.0%

Activity data for this material stream 3
Material stream type: Production (Secondary)
Describe the material: High purity CO2 sales gas
Proportion of total Feedstock carbon in this Product/Waste material stream: 30%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 005 CO2 sales	4 - Accurate Measurement	2.0%
Vortex Flow Meter		

Overall Activity data uncertainty: 2.00%

Conversion factor: Carbon content
Data source: Site-specific
Carbon content: 0.273 tonne/tonne Site-specific uncertainty (+/-%):
Benchmark/justification document reference/name: CO2 transfer agreement quality specification
Uncertainty: 10.0%

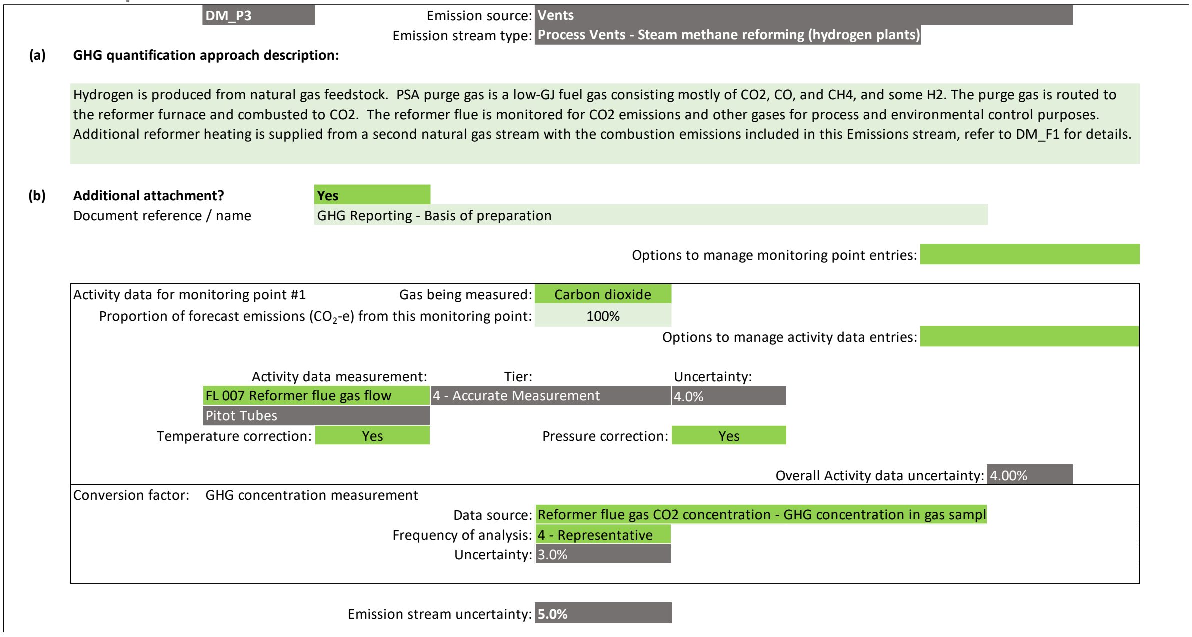
Emission stream uncertainty: **22.0%**

Method 3: Direct Measurement

Method 3: Direct Measurement may be applicable if an exhaust stack or ducting that allows measurement of the exhaust gas flow rate and GHG concentration has been installed.

Figure 17 shows a typical configuration for the process vent - steam methane reforming (hydrogen plants) using Method 3: Direct Measurement.

Figure 17 – Vented emissions from steam methane reforming (hydrogen plants) using Method 3: Direct Measurement in the MP Template


DM_P3
Emission source: Vents
Emission stream type: Process Vents - Steam methane reforming (hydrogen plants)

(a) GHG quantification approach description:

Hydrogen is produced from natural gas feedstock. PSA purge gas is a low-GJ fuel gas consisting mostly of CO2, CO, and CH4, and some H2. The purge gas is routed to the reformer furnace and combusted to CO2. The reformer flue is monitored for CO2 emissions and other gases for process and environmental control purposes. Additional reformer heating is supplied from a second natural gas stream with the combustion emissions included in this Emissions stream, refer to DM_F1 for details.

(b) Additional attachment? Yes
Document reference / name: GHG 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:
FL 007 Reformer flue gas 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: Reformer flue gas CO2 concentration - GHG concentration in gas sampl
Frequency of analysis: 4 - Representative
Uncertainty: 3.0%

Emission stream uncertainty: 5.0%

Default conversion factors and uncertainty

There are no Tier 1 default conversion factors, and Tier 1 default and site-specific uncertainty values for most emission stream types using Method 1: Calculation Approach. Refer to Table 10 at the end of this section for more information.

The facility is not required to report the conversion factors used to estimate emissions in the Emissions Report. However, they must be specified in the MP Template as a Tier 1 site-specific conversion factor or an analysis process used during the reporting period. The generic emission stream form used in the MP Template does not cater for the selection of the API Compendium emission factors, however, any reference made to the API Compendium emission factors should be stated in the MP submission.

With regard to Method 1: Calculation Approach, Tier 1 site-specific conversion factors to be used for vented emissions could be derived from the API Compendium. Table 9 details the applicable sections within the API Compendium for each emission stream. These sections detail the formula and options for Tier 1 default site-specific conversion factors. As for Tier 1 site-specific conversion factors, Section 5 of the API Compendium has uncertainty values for emission factors, where available. The API and IPIECA[23] have developed an uncertainty guideline[24]. The uncertainty guideline details methods to calculate uncertainty of various emission sources in the oil and gas sector.

With regard to Method 2: Material Balance, the facility can refer to the default carbon content values in the 2006 IPCC Guidelines[25] for determining the carbon content of the feedstock, or provide Tier 1 site-specific carbon content values. The site-specific default uncertainty is assumed to be half of the default value, but the facility can provide a site-specific uncertainty value. For user-specified fuels i.e.

[23] IPIECA is the global oil and gas industry association for environmental and social issues.
[24] *Addressing Uncertainty in Oil & Natural Gas Industry Greenhouse Gas Inventories: Technical Considerations and Calculation Methods* (February 2015), published by the API and the IPIECA, available at http://www.api.org/~/media/Files/EHS/climate-change/Addressing_Uncertainty.pdf
[25] Refer to 2006 IPCC Guidelines, Volume 1, Chapter 1, Tables 1.2 and 1.3 for more details.

feedstock, there is no Tier 1 default carbon content and no site-specific uncertainty value. No default carbon content factors are available for product or waste streams.

Table 10 – Tier 1 default and site-specific uncertainty values for vents conversion factors

Conversion factor	Tier 1 default uncertainty	Tier 1 site-specific uncertainty
Method 1: Calculation Approach		
Emission stream type: Process vent – steam methane reforming (hydrogen plants)		
Carbon content emission factor (activity data based on feedstock use)	Not applicable	2.8% (typical for most feedstocks)
CO_2 emission factor (activity data based on hydrogen production)	Not applicable	7.5% (reflects possible variability of different feedstocks)
All remaining emission stream types		
Generic, to be specified by facility	Not applicable	Not provided, facility to provide, e.g. based on the uncertainty guideline
Method 2: Material Balance		
Emission stream type: Process vent – steam methane reforming (hydrogen plants); Sulphur recovery units		
Carbon content conversion factor for material stream type: feedstock	Only for default list of fuels as shown in Table 3. Uncertainty is calculated by taking the square root of the sums of the squares of the uncertainties of NCV and CO_2 EF of the fuel i.e. SQRT [SUMSQ(NCV, CO_2 EF)]. For user-specified fuels: not applicable	For default list of fuels: the site-specific uncertainty is halved of the default uncertainty. For user-specified fuels: not provided, facility to provide.
Carbon content conversion factor for material stream type: production (primary)	Not applicable	5% (reflects possible product quality)
Carbon content conversion factor for material stream type: production (secondary)	Not applicable	10% (reflects possible secondary product quality, twice primary products)
Carbon content conversion factor for material stream type: waste material	Not applicable	20% (reflects possible waste stream variability, twice secondary products)
Method 3: Direct Measurement		
Emission stream type: Process vent – steam methane reforming (hydrogen plants); thermal cracking; cold process vents; storage tanks and drain vessels		
GHG concentration measurement	Not applicable	10% (reflects uncertainty of measurement and variability of process performance)

2.6 Fugitive emissions

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☐ Method 3: Direct Measurement

There are three emission stream types for fugitive emissions, taking reference from Section 6 of the API Compendium i.e. (i) equipment leaks and (ii) wastewater management – which are related to the oil and natural gas industry operations as well as a last emission stream type i.e. (iii) other – for any other type of fugitive emissions[26]. This is a change from the list of activities in the Energy Use Report (GHG from non-fuel combustion processes or activities) that catered to a broader set of industry sectors.

The only available emissions quantification method in the MP Template is Method 1: Calculation Approach, which are based on industry methods in the API Compendium.

Table 11 – Emission stream types for fugitive emissions

Emission stream type	API Compendium references	Description
Equipment leaks	6.1	Three options are available for general equipment leaks: • Facility-level • Equipment-level • Component-level Types of GHG emissions: CO_2, CH_4
Wastewater management	6.2.1	Wastewater treatment • Aerobic wastewater treatment • Anaerobic wastewater treatment Types of GHG emissions: • Aerobic treatment for oil and natural gas-based organic material in wastewater: CO_2 and N_2O, CH_4 (only for poorly maintained aerobic treatment plants) • Anaerobic treatment: CH_4 and N_2O
Other	N/A	N/A

The API Compendium includes methods for the estimation of fluorinated fugitive emissions from air-conditioning and refrigeration equipment and SF_6 emissions from electrical equipment. These emission streams are not classified under fugitive emissions, and the facility should refer to the applicable IPPU emission source (refer to sections 2.12 and 2.15 respectively).

[26] One example of the 'Emission Stream Type – Other' is the fugitive emissions from composting or aerobic digestion of food waste from food digesters, which will emit both CH_4 and N_2O emissions (as per IPCC Chap 5 Vol 4).

Method 1: Calculation Approach

The API Compendium provide a number of approaches to estimating fugitive emissions. The facility should select the most appropriate approach and provide in the MP Template the references to the applicable sections, tables, formulae, conversion factors or exhibits from the API Compendium.

To provide flexibility, a generic emission stream form is developed for all fugitive emission stream types. The generic emission stream form requires the facility to specify the GHG types to be reported. This is usually CH_4, potentially CO_2 and/or N_2O for wastewater treatment plants.

$$E_{g,p} = E_{CO2} + (E_{CH4} \times GWP_{CH4}) + (E_{N2O} \times GWP_{N2O})$$

Parameter ID	Parameter description	Units	Reporting status
$E_{g,f}$	Emissions for GHG (g) i.e. CO_2, CH_4 and N_2O for fugitive type (p)	tonne CO_2e	Calculated
E_{CO2}, E_{CH4}, E_{N2O}	Emissions for CO_2, CH_4 and N_2O	tonne	Reported (in kg)
p	Type of fugitive emission i.e. emission stream type	Nil	Reported
GWP_g	Global warming potential for CH_4 and N_2O	Nil	Constant

The generic emission stream form provides two conversion factors for the facility to specify how the site-specific conversion factors will be calculated, including an option to use a Tier 1 site-specific conversion factor e.g. emission factors based on the API Compendium.

The API Compendium provides estimates of uncertainty for some emission factors. Generally, they are high due to the expected variability between facilities and equipment types. Therefore, the generic emission stream form in the MP Template does not automatically calculate the emission stream uncertainty, but the facility is required to provide an estimate of the overall emission stream uncertainty. As fugitive emissions are generally minor compared to major combustion or other process emissions, a conservatively high estimate is unlikely to have a material impact on the facility's overall uncertainty as calculated on Tab **J. Summary**.

Figure 18 shows a typical configuration for fugitive CH_4 and CO_2 emissions from equipment leaks arising from the distribution of natural gas based on the API Compendium's facility-level average emission factor approach.

The API Compendium[27] provides three fugitive emission factors for gas distribution namely CH_4 and CO_2 emission factors for pipeline leaks, and CO_2 emission factor from oxidation of CH_4 (as the CH_4 emitted from underground pipeline leaks is oxidised to form CO_2). As the API Compendium assumes a fixed gas composition of CH_4 and CO_2, in the example, the facility derives the on-site gas composition through gas chromatography, and adjust the CH_4 and CO_2 emissions accordingly.

[27] Refer to API Compendium, Section 6, Chapter 1, page 6-8 for more details.

Given that the emission factors are based on pipeline length and in order to estimate the activity data i.e. pipeline length, the facility uses an engineering estimate that is based on historical design records for early installations and their GIS for recent installations.

The API Compendium provides uncertainty estimates for gas distribution of between 62.7% for CH_4 leaks and 76.6% for CO_2 from oxidation. These uncertainty values are significantly higher than the uncertainty from pipeline length (5%) and the use of gas chromatography for correcting the API Compendium CH_4 and CO_2 emission factor (1%). With the application of the global warming potential for CH_4 to the CH_4 emission factor, it is over 21 times as high as the CO_2 emission factors making it the dominant emission factor. The application of equations A and B as detailed in section 4.3.4 of the main Guideline. Equation A is applied to the uncertainty of the pipeline length (5%), concentration change (1%) and emission factor for each of the three emission calculations. Equation B is then applied to the result of each emission calculation with the relative emission factor to calculate the overall uncertainty of the emission stream. As shown in Figure 18, this was calculated as 62%[28], slightly less than the uncertainty of the dominant CH_4 emission factor.

Figure 18 – Fugitive emissions for natural gas distribution using facility-level emission factor for Method 1: Calculation Approach in the MP Template

CA_P1 — Emission source: **Fugitive emissions**
Emission stream type: **Equipment leaks**

GHG quantification approach description:

The API Compendium facility-level emission factors are to be used to estimate CH4 and CO2 emissions from the distribution of natural gas. The API Compendium provides three emission factors for: CH4 leaks, CO2 leaks and CO2 from oxidation of CH4 as the gas rises to the surface. The emission factors are based on pipeline length, which is derived from our geographic information system (GIS) and historical design records for early installations. The composition of our natural gas is monitored and used to adjust the default emission factors. Uncertainty is dominated by the uncertainty of the CH4 emission factor and estimated to be 62%.

Additional attachment to elaborate on the GHG quantification approach: **Yes**
Document reference/name: GHG Reporting - Basis of Preparation

Activity data

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Pipeline length	1 - Engineering estimate	5.0%
Engineering estimate		

Overall Activity data uncertainty: 5.00%

Emission coverage

	Gas #1	Gas #2	Gas #3
Which greenhouse gases are to be estimated:	Methane	Carbon dioxide	

Conversion factor: Methane — Concentration
Data source: Natural gas composition - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Conversion factor: Carbon dioxide — Concentration
Data source: Natural gas composition - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Uncertainty Assessment
Please provide an estimate of the emissions stream uncertainty: **62%**

28 $$\frac{\sqrt{\left(\left(\sqrt{5\%^2+62.7\%^2+1\%^2}\right)\times 1.002\times 21\right)^2+\left(\left(\sqrt{5\%^2+76.6\%^2+1\%^2}\right)\times 0.3484\right)^2+\left(\left(\sqrt{5\%^2+74.4\%^2+1\%^2}\right)\times 0.06636\right)^2}}{\sum 1.002\times 21+0.3484+0.06636}$$

Default conversion factors and uncertainty

The facility is not required to specify the conversion factors used to estimate emissions or composition details of the fugitive gases in the Emissions Report. Any Tier 1 site-specific conversion factors to be used for fugitive emissions should be derived from the API Compendium or any other international or industry guideline.

For equipment leaks using the facility-level average emission factors approach in the API Compendium, when the CO_2 or CH_4 composition of the gas for fugitive sources is different from the API Compendium default (see Table 6-2), the site-specific CO_2 or CH_4 concentration must be specified in the MP Template as a Tier 1 site-specific conversion factor or an analysis process used during the reporting period. The generic emission stream form used in the MP Template does not cater for the selection of the API Compendium emission factors, however, the reference API Compendium emission factors should be stated in the MP submission.[29] For equipment leaks, the API Compendium provides the following types of emission factors for different industry sectors:

i) Facility-Level Average Fugitive Emission Factors, Table 6-2;

ii) Equipment-Level Average Fugitive Emission Factors, Tables 6-3 to 6-11; and

iii) Component-Level Average Fugitive Emission Factors, Tables 6-12 to 6-22.

The 2006 IPCC Guidelines, Volume 2, Chapter 4, Table 4.2.4 provides some alternative facility-level emission factors. Note that emission factors marked as being flaring and venting as the 'Emission source' are not applicable within this emission stream.

For wastewater management, the relevant equations in the API Compendium are equations 6-11, 6-12, 6-13 and 6-14.

CH_4 emissions from either aerobic or anaerobic wastewater treatment	Equation 6-11
N_2O emissions from either aerobic or anaerobic wastewater treatment	Equation 6-12
CO_2 emissions from aerobic wastewater treatment	Equation 6-13
CH_4 emissions from anaerobic wastewater treatment	Equation 6-14

The API Compendium equation 6-11 is based on the 2006 IPCC Guidelines on wastewater treatment and discharge.[30] The relevant Methane Conversion Factors (MCF) are found in Tables 6-23 and 6-24 and these factors are referenced from the 2006 IPCC Guidelines[31]. The API Compendium also makes reference to the 2006 IPCC Guidelines, which provide default Chemical Oxygen Demand (COD) factors and the default wastewater generation rates, as tabulated in Table 12.

[29] Refer to API Compendium, Section 6, Chapter 1, pages 6-11 to 6-13 for more details.

[30] Refer to the 2006 IPCC Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, Section 6.2.3 on industrial wastewater for more details.

[31] Refer to the 2006 IPCC Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.8 in page 6-21 for more details.

Table 12 - Default Chemical Oxygen Demand (COD) factors and wastewater generation rates

Industry type	Waste water generation rate, W (m^3/ton)	Range for W (m^3/ton)	Chemical Oxygen Demand (COD) (kg/m^3)	Range for COD (kg/m^3)
Petroleum Refineries	0.6	0.3 - 1.2	1	0.4 - 1.6
Organic Chemicals	67	0 - 400	3	0.7 - 5

The API Compendium equation 6-12 can be simplified to the following:

$$E_{N2O}\left(\frac{tonne}{year}\right) = Q\left(\frac{m^3}{year}\right) \times N\left(\frac{kg\ N}{m^3}\right) \times EF_{N2O}\frac{kgN_2O - N}{kg\ N} \times \frac{44}{28} \times 0.001\ \frac{tonne}{kg}$$

Where: Q = volume of wastewater treated

N = average concentration of N in effluent, $[N]_{out}$. Instead, ($[N]_{in}$ – $[N]_{out}$] is more accurate. However, if $[N]_{out}$ is not measured, $[N]_{in}$ can be used but this will lead to an overestimation of N_2O emissions.

EF_{N2O} = emission factor from discharged wastewater, 0.005 kg N_2O-N / kg N

44/28 = nitrogen to N_2O conversion factor

The API Compendium equation 6-13 can be simplified to following

$$E_{CO2} = Q\left(\frac{m^3}{year}\right) \times \frac{[BOD_5]}{0.7}\left(\frac{mg}{L}\right) \times \frac{44}{32} \times 1000\frac{L}{m^3} \times 10^{-9}\left(\frac{tonne}{mg}\right)$$

Where: Q = wastewater flow rate

$BOD_5/0.7$ = approximation of the ultimate BOD i.e. total BOD initially present at the inlet before treatment. Alternatively, you could (i) replace $BOD_5/0.7$ with (BOD_{inlet} – BOD_{outlet}), or (ii) replace $BOD_5/0.7$ with just BOD_{inlet} if you assume BOD_{outlet} is 0.

44/32 = oxygen to CO_2 conversion factor

Figure 19 shows an example of wastewater treatment for a well-maintained aerobic treatment plant using BOD measurement. In the example, the wastewater results from fossil fuel hydrocarbon sources. Wastewater treatment CO_2 emissions from fossil fuel hydrocarbon sources and from non-fossil fuel sources[32] are both to be included in the facility's MP Template. A separate emission stream should be created within the MP Template to separate the two.

As this is a well-maintained aerobic treatment plant, the default Methane Conversion Factor (MCF) is zero and no CH_4 emissions are generated. However, as suggested in table 6-23 of the API

[32] CO_2 emissions from non-fossil fuel sources will not be counted towards the facility's threshold. Refer to Table 2 in the GHG M&R Guidelines Part I.

Compendium, an overloaded aerobic plant may generate CH_4 emissions, and in this situation, 'Methane' should also be selected for reporting and a MCF conversion factor should be recorded.

N_2O emissions are also generated from wastewater treatment. The nitrogen content of the wastewater flow needs to be determined. The API Compendium equation 6-12 is used.

In the example the overall uncertainty of the wastewater treatment was assessed as 29.4%[33]. This is highly variable and dependent on the N_2 concentration. In the example N_2O emissions are lower than the CO_2 emissions reducing the impact of the high uncertainty of the default value used in the example for the emission factor for N_2O from discharged wastewater. The API Compendium quotes a value of 0.005 kg N_2O-N/kg N, based on the IPCC default[34]. The IPCC does not quote an uncertainty for this default value, however a range of 0.005 to 0.25 kg N_2O-N/kg N is used. In the example an uncertainty of 100% was assumed.

Figure 19 – Wastewater treatment (Fugitive emissions) using Method 1: Calculation Approach in the MP Template

CA_P1 — Emission source: **Fugitive emissions**
Emission stream type: **Wastewater management**

(a) GHG quantification approach description:

Wastewater is treated on-site using a well managed Aerobic treatment plant. No sludge is removed. The wastewater treated is primarily from hydrocarbon sources. The API Compendium equation 6-13 is used to estimate CO2 emissions. The actual wastewater flow is measured using a rotary flow meter. The BOD5 is measured annually to track performance of the plant.
N2O emissions are estimated using equation 6-12. Ammonia-Nitrogen levels of the biogenic wastewater were assessed as 50 mg/L from study undertaken in 2014.

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

Activity data
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Wastewater to treatment	2 - Measurement	6.0%
Rotary Meter		

Overall Activity data uncertainty: 6.00%

Emission coverage

	Gas #1	Gas #2	Gas #3
Which greenhouse gases are to be estimated:	Carbon dioxide	Nitrous oxide	

Conversion factor: COD or BOD5
Data source: BOD5 of wasterwater plant - Biochemical oxidation (BOD5)
Frequency of analysis: 3 - Analysis done once every year or more frequent
Uncertainty: 30.0%

Conversion factor: Not Appliable
Data source:
Uncertainty: -

Conversion factor: Nitrogen concentration of wastewater flow
Data source: Site-specific
Nitrogen concentration of wastewater flow: 5 mg/L — Site-specific uncertainty (+/-%): 10.0%
Justification document reference/name: Wasterwater study report (2014)
Uncertainty: 10.0%

Uncertainty Assessment
Please provide an estimate of the emissions stream uncertainty: **28.8%**

33 $\frac{\sqrt{\left(\left(\sqrt{6\%^2+30\%^2}\right)\times 100/0.7\times\frac{44}{32}\right)^2+\left(\left(\sqrt{6\%^2+10\%^2+100\%^2}\right)\times 5\times 0.005\times\frac{44}{28}\times 310\right)^2}}{\sum 100/0.7\times 44/32+50\times 0.005\times\frac{44}{28}\times 310}$, assuming BOD5 is 100 mg/L and N_2 concentration is 5 mg/L and the uncertainty of the default emission factor for N_2O from discharged wastewater (Equation 6-12) is 100%.

34 Refer to the 2006 IPCC Guidelines, Volume 5, Chapter 6: Wastewater Treatment and Discharge, section 6.3.1.2 for more details.

The emission stream form for anaerobic wastewater treatment would be very similar, and equation 6-14 in the API Compendium could be used. The API Compendium assumes that negligible CO_2 would be released, hence CH_4 should be selected instead of CO_2. The MCF conversion factor will be displayed in the emission stream form. MCF is equivalent to F_{AD} for equation 6-14.

Section 6 of the API Compendium has uncertainty values for emission factors, where available. The API and IPIECA[35] have developed an uncertainty guideline[36]. The uncertainty guideline details methods to calculate uncertainty of various emission sources in the oil and gas sector.

[35] IPIECA is the global oil and gas industry association for environmental and social issues.

[36] *Addressing Uncertainty in Oil & Natural Gas Industry Greenhouse Gas Inventories: Technical Considerations and Calculation Methods* (February 2015), published by the API and the IPIECA, available at http://www.api.org/~/media/Files/EHS/climate-change/Addressing_Uncertainty.pdf

2.7 Coal gasification

☒ Method 1: Calculation Approach

☒ Method 2: Material Balance

☐ Method 3: Direct Measurement

There are no emission stream types specified for coal gasification. The facility is to provide brief description of the emission stream type (e.g. process, type of feedstock).

Coal gasification is not a standard IPCC activity or process, and is described by the IPCC as an uncommon processing method for production of some chemicals including methanol. Facilities using coal gasification for the production of chemicals covered by existing IPCC activities or processes should continue to categorise the emission source/stream based those IPCC emission sources. This emission source is intended to cover CO_2 emissions arising from the production of H_2, CO and syngas.

Method 1: Calculation Approach

The calculation approach uses the following formula:

$$E_{CO2} = Q_f \times EF_{f,CO2}$$

Parameter ID	Parameter description	Units	Reporting status
E_{CO2}	Emissions of CO_2	tonne CO_2e	Calculated
Q_f	Quantity of feedstock (f)	tonne	Reported
$EF_{f,CO2}$	Emission factor for CO_2 based on feedstock (f)	tonne CO_2/tonne feedstock	Reported
f	Feedstock type (f)	Nil	Reported

In the absence of an IPCC method and accompanying default emission factors, the facility may wish to provide a Tier 1 site-specific conversion factor or describe an appropriate analysis technique for the calculation of CO_2 emissions based on the carbon content of the feedstock. For second and subsequent feedstocks, another emission stream would have to be created in Tab **C. Site details**.

However, given that carbon will be contained in the product streams that are sold or used as a feedstock to other processes, Method 2: Material Balance is likely to be more applicable.

Method 2: Material Balance

The facility can use Method 2: Material Balance to determine the quantity of carbon converted to CO_2 based on the difference in the quantity of carbon contained in the feedstock, products and waste streams.

The material balance approach uses the following formula to calculate the CO_2 emissions and CO_2 emission factor:

$$E_{CO2} = [\sum_f (QF_f \times CCF_f) - \left\{\sum_j (QP_j \times CCP_j) + \sum_k (QS_k \times CCS_k) + \sum_l (QW_l \times CCW_l)\right\}] \times \frac{44}{12}$$

$$EF_{f,CO2} = \frac{E_{f,CO2}}{QF_f}$$

Feedstocks may include primary and secondary feedstocks and products may include high purity CO and syngas stream containing CO, CO_2, H_2 and other gases.

Parameter ID	Parameter description	Units	Reporting status
E_{CO2}	Emissions of CO_2	tonne CO_2e	Reported
QF_f	Annual quantity of feedstock (f) consumed for the production of products	tonne	Reported
CCF_f	Carbon content of feedstock (f)	% or ratio	Not reported
QP_j	Annual quantity of primary product (j), produced	tonne	Not reported
CCP_j	Carbon content of primary product (j)	% or ratio	Not reported
QS_k	Annual quantity of secondary product (k) produced	tonne	Not reported
CCS_k	Carbon content of secondary product (k)	% or ratio	Not reported
QW_l	Annual quantity of waste stream (l) resulting from the production process	tonne	Not reported
CCW_l	Carbon content of waste stream (l)	% or ratio	Not reported
$EF_{f,CO2}$	Calculated emission factor for feedstock (f)	tonne CO_2/ tonne feedstock	Calculated
f	Feedstock type (f)	Nil	Reported

Where multiple feedstocks are used under a Method 2: Material Balance emission stream, the facility will be required to report the measured CO_2 emissions allocated to each feedstock in the Emissions Report. If feedstocks are used at alternative time periods, the CO_2 emissions can be tracked by each time period and its associated feedstock. If multiple feedstocks are used simultaneously, the percentage of carbon lost can be assumed to apply equally to each feedstock.

Figure 20 shows a typical configuration for coal gasification in the MP Template. In the example, two types of feedstock are recorded, with coal predicted to provide 80% of the carbon contained in the feedstock and biomass providing the remaining 20%. The carbon content of each feedstock is obtained from product quality documentation provided with each shipment (i.e. Tier 4 representative analysis). The quantity of each carbon-containing product (i.e. CO and syngas streams) are detailed, including the measurement of flow and carbon content. H_2 flow is not recorded as it does not contain carbon. The predicted percentage of carbon from the feedstocks contained in each product stream is recorded.

For Method 2: Material Balance, given that CO_2 emissions are calculated based on the unaccounted carbon, and since 20% of the feedstock is biogenic in the example in Figure 20, the calculated CO_2 emissions should be reduced by 20% accordingly in proportion for subsequent emissions reporting.

As the majority of carbon is captured in the products streams (95% in the example), the estimated quantity of CO_2 emissions will be small leading to a high uncertainty due to the relatively high absolute uncertainty of carbon in the feedstock and product streams.

Figure 20 – Coal gasification using Method 2: Material Balance in the MP Template

MB_P2 Emission source: Coal Gasification
Emission stream type: Production of H2, CO and syngas for sale

(a) GHG quantification approach description:

Sub-bituminous coal and palm kernels are used as feedstocks to the gasification plant. The plant produced syngas that is separated into high purity H2, CO streams and a residual syngas stream that are sold. A small proportion of syngas is vented, with all CO released assumed to oxidise to CO2. The feedstocks are weighted as delivered to the process, with supplier product specifications on deliver used to estimate carbon content. The three sales gas pipelines are metered including gas chromatograph for gas composition and carbon content. The proportion of feedstock carbon from biomass will be excluded from the reported CO2 emissions.

(b) Additional attachment? **Yes**
Document reference/name: GHG Reporting - Basis of preparation

Options to manage material stream entries:

Proportion of feedstock stream: 100%
Proportion of product/waste Stream: 95%

Activity data for this material stream 1
Material stream type: Feedstock
Feedstock type: Sub-bituminous Coal
Proportion of total Feedstock carbon in this Feedstock material stream: 80%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FD 101 Coal feedstock Weighing Conveyor Belt	4 - Accurate Measurement	1.0%

Overall Activity data uncertainty: 1.00%

Conversion factor: Carbon content
Data source: Coal carbon composition - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Activity data for this material stream 2
Material stream type: Feedstock
Other Primary Solid
Feedstock type: Biomass
Proportion of total Feedstock carbon in this Feedstock material stream: 20%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FD 201 Palm kernel feedstock Weighing Conveyor Belt	4 - Accurate Measurement	1.0%

Overall Activity data uncertainty: 1.00%

Conversion factor: Carbon content
Data source: Palm kernel carbon composition - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Activity data for this material stream 3
Material stream type: Production (Secondary)
Describe the material: High purity carbon monoxide sales
Proportion of total Feedstock carbon in this Product/Waste material stream: 85%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 005 CO2 sales Vortex Flow Meter	4 - Accurate Measurement	2.0%

Overall Activity data uncertainty: 2.00%

Conversion factor: Carbon content
Data source: CO Sales gas purity - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Activity data for this material stream 4
Material stream type: Production (Secondary)
Describe the material: Syngas sales
Proportion of total Feedstock carbon in this Product/Waste material stream: 10%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
FL 303 Syngas sales Vortex Flow Meter	4 - Accurate Measurement	2.0%

Overall Activity data uncertainty: 2.00%

Conversion factor: Carbon content
Data source: gas analysers - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Emission stream uncertainty: **44.8%**

Default conversion factors and uncertainty

For Method 1: Calculation Approach, there is no Tier 1 default CO_2 emission factor for coal gasification in the 2006 IPCC Guidelines. The default uncertainty value for any Tier 1 site-specific CO_2 emission factor is also assumed to be 10%, but the facility can provide a site-specific uncertainty value.

With regard to Method 2: Material Balance, the facility can refer to the default carbon content values in the 2006 IPCC Guidelines[37] for determining the carbon content of the feedstock, or provide Tier 1 site-specific carbon content values. The Tier 1 site-specific uncertainty is assumed to be half of the Tier 1 default uncertainty value, but the facility can provide a site-specific uncertainty value. For user-specified fuels i.e. feedstock, there is no Tier 1 default carbon content and no Tier 1 site-specific uncertainty value. No default carbon content factors are available for product or waste streams. Also see Table 13.

Table 13 – Tier 1 default and site-specific uncertainty values for coal gasification conversion factors

Conversion factor	Tier 1 default uncertainty	Tier 1 site-specific uncertainty
Method 1: Calculation Approach		
CO_2 emission factor	Not applicable	10% (assumes significant variation in feedstocks)
Method 2: Material Balance		
Carbon content conversion factor for material stream type: feedstock	Only for default list of fuels as shown in Table 3. Uncertainty is calculated by taking the square root of the sums of the squares of the uncertainties of NCV and CO_2 EF of the fuel i.e. SQRT [SUMSQ(NCV, CO_2 EF)] For user-specified fuels: not applicable	For default list of fuels: the site-specific uncertainty is halved of the default uncertainty. For user-specified fuels: not provided, facility to provide
Carbon content conversion factor for material stream type: production (primary)	Not applicable	5% (reflects possible product quality)
Carbon content conversion factor for material stream type: production (secondary)	Not applicable	10% (reflects possible secondary product quality, twice primary products)
Carbon content conversion factor for material stream type: waste material	Not applicable	20% (reflects possible waste stream variability, twice secondary products)

[37] Refer to 2006 IPCC Guidelines, Volume 1, Chapter 1, Tables 1.2 and 1.3 for more details.

2.8 Integrated circuit or semiconductor production

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☒ Method 3: Direct Measurement

From 1 Jan 2024 onwards, facilities can report the GHG emissions using the default emission factors in 2006 IPCC Guidelines or 2019 Refinement to 2006 IPCC Guidelines. There is no change to the emissions quantification methodology and formula.

There are six emission stream types based on the 2006 IPCC Guidelines and six emission streams types based on the 2019 Refinement to 2006 IPCC Guidelines. They are listed as below in the MP Template.

i) Plasma etching thin film

ii) Cleaning chemical vapour deposition (CVD) tool chambers

iii) Furnace (diffusion)

iv) Nitride removal (etching)

v) Cleaning of low k CVD reactors

vi) Other

vii) Etching and Wafer Cleaning (EWC) (2019 Refinement)

viii) Remote Plasma Cleaning (RPC) (2019 Refinement)

ix) In-situ Plasma Cleaning (IPC) (2019 Refinement)

x) In-situ Thermal Cleaning (ITC) (2019 Refinement)

xi) Thin Film Deposition (TFD) (2019 Refinement)

xii) Other (2019 Refinement)

Method 1: Calculation Approach

The GHG M&R requirements refer to the following IPCC Tier 2a formula in the 2006 IPCC Guidelines[38]:

$$E_g = FC_{g,used} \times \{(1 - C_g) \times [1 - (A_g \times D_g)] \times GWP_g + B_{b,g} \times [1 - (A_{b,g} \times D_{b,g})] \times GWP_{b,g}\}$$

I.e. $E_g = FC_{g,used} \times \{(1 - C_g) \times [1 - (A_g \times D_g)] \times GWP_g + (B_{b,g} \times GWP_{b,g})\}$

where $A_{b,g} \times D_{b,g} = 0$ by default

[38] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 6 for more details.

The above formula applies to metered consumption (using quantity of gas fed into the process and measured by a meter). For non-metered consumption (using quantity of gas purchased for use in the process), $FC_{g,used}$ is determined using the following formula:

$$\text{where } FC_{g,used} = FC_{g,purchased} \times (1 - h)$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions of fluorinated compound (g)	tonne CO_2e	Calculated
$FC_{g,used}$	Quantity of fluorinated compound (g) fed into the process	tonne	Reported in kg (metered), or Not reported (non-metered)
$FC_{g,purch}$	Quantity of fluorinated compound (g) purchased	tonne	Reported in kg (non-metered), or Not reported (metered)
h	Fraction of gas remaining in gas cylinder (heel) after use	Fraction	Constant[39]
1 - C_g	Emission factor for fluorinated compound (g); with C_g being the use rate of fluorinated compound (g) i.e. fraction destroyed or transformed in the process	Fraction	Constant
A_g & $A_{b,g}$	Fraction of fluorinated compound (g) or by-product (b) volume used with emission control technology *Note that $A_{b,g} \times D_{b,g} = 0$ by default	Fraction	Reported ($A_{b,g}$is not reported)
D_g & $D_{b,g}$	Fraction of fluorinated compound (g) or by-product (b) destroyed by the emission control technology *Note that $A_{b,g} \times D_{b,g} = 0$ by default	Fraction	Reported ($D_{b,g}$is not reported)
$B_{b,g}$	Rate of creation of by-product fluorinated compound (b) from fluorinated compound (g) in the process	Fraction	Reported
g	Type of fluorinated compound (g) fed into the process	Nil	Reported
p	Process type i.e. emission stream type	Nil	Reported
GWP_g & $GWP_{b,g}$	Global warming potential for fluorinated compound (g) or by-product (b)	Nil	Constant

According to the 2006 IPCC Guidelines, the Tier 2a method is based on type of process gas and does not distinguish between processes or process types (*etching* versus *cleaning*), individual processes or tools. The Tier 2a method uses facility-specific data on the proportion of gas used in processes with and without emission control technology, and uses default values for the other parameters. The Tier 2b method, on the other hand, uses facility-specific data on the proportion of gas used in *etching* versus *cleaning* and the proportion of gas used in processes with emission control technology, but

[39] Although the heel fraction in the Emissions Report is assumed to be 10%, if the facility is aware of the actual heel fraction, the facility is able to use it in the emissions quantification methodology too. Refer to the M&R Guidelines Part III Section 3.8 for more information.

relies on default values for some or all of the other parameters. According to the 2019 Refinement to 2006 IPCC Guidelines, the Tier 2a method is based on type of process gases (similar with Tier 2a in IPCC guidelines), the Tier 2b method is based on the type of process gases and wafer size, while the Tier 2c method is based on type of process-gas, wafer size as well as the processes/tools.

Emissions from integrated circuit or semiconductor production will be derived based on the following rules:

i) The emission stream types in the MP Template are configured based on the process types, rather than the type of gas used and the use of abatement. An emission stream must be created for each fluorinated compound (or other non-fluorinated GHG used) for each applicable process.

   a. After defining the emission stream in Tab **C. Site Details**, the type of gas used should be selected in Tab **E. Calc Apch – Emission Streams**. Taking into account local industry practices, non-fluorinated GHGs such as CO_2, CH_4 and N_2O are built into the MP Template. The formula still applies but there are no default conversion factors for the use of these non-fluorinated GHGs. Site-default conversion factors would have to be used.

   b. In the MP Template, there is no default conversion factor for the 'fraction of gas used with abatement'. The facility should provide a site-specific conversion factor.

ii) The M&R requirements adopt Tier 2 default emission factors (under IPCC) as the Tier 1 default emission factors (under M&R).

   a. The facility has the discretion to apply 2006 IPCC Guidelines or 2019 Refinement to IPCC Guidelines, then apply Tiers 2a, 2b, 2c emission factors by selecting the "default" option, or apply emission factors from other sources such as US EPA or site-specific emission factors by selecting 'site-default' option under the 'data source' field for the relevant conversion factors. The facility shall not pick and choose the Guidelines or tier for different emission streams.

iii) For both Tiers 2a and 2b methods, the 2006 IPCC Guidelines does not provide the default values for $D_{b,g}$, fraction of by-product that is destroyed by the emission control technology.[40] The GHG M&R requirements assume that the default conversion factor for $D_{b,g}$ is zero. Hence, the GHG M&R requirements refer to the formula for by-product emissions:

$$E_{b,g} = FC_{g,used} \times B_{b,g} \times GWP_{b,g}$$

   a. Should there be a non-zero site-specific value for $D_{b,g}$, the facility should not select the 'default' option under 'data source' for the conversion factor 'rate of by-product gas production' (which represents $B_{b,g}$) in the MP Template, and select the appropriate 'data source', whether is it a Tier 1 site-specific factor or a factor that is derived from metering and analysis.

[40] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 6, page 6.7 for more details.

iv) For Tiers 2a, 2b, 2c methods in 2019 Refinement to 2006 IPCC Guidelines, the default Dg in Table 6.19 can be used, provided that the facility can provide supporting evidence showing that the default Dg are achievable by the installed abatement equipment.

v) For non-metered consumption, the default value for the fraction of gas remaining in the shipping container (heel) is 0.10 based on the 2006 IPCC Guidelines i.e. $(1 - h) = 0.9$. This is a default option i.e. 'invoice with default heel' that is built into the MP Template under 'activity data measurement' in Tab **E. Calc Apch – Emission Streams**.

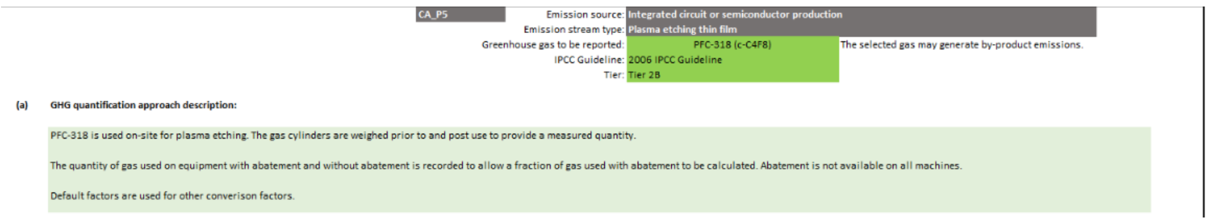
  a. When the actual heels are monitored by a facility, the facility shall create an activity data in Tab D "invoice with actual heel" and then select the activity data in Tab E for the applicable emissions streams. The facility shall also key in the actual heel in the emissions report to report its emissions more accurately.

Figure 21 shows a typical configuration for the plasma etching thin film process with PFC-318 specified as the type of GHG used. According to the 2006 IPCC Guidelines, this GHG may generate fluorinated by-product emissions and a note will be shown below the GHG selection cell, and conversion factors for by-product production will be required for emissions computation.

In the example, the quantity of GHG used is assessed by measuring the quantity of fluorinated compound in the cylinder prior to and after use. Alternatively, the facility may determine the quantity contained in the cylinder based on invoices or other records by following v) above

The default conversion factors for 'fraction of gas destroyed or transformed in the process', 'fraction of gas destroyed by emission control technology' and 'rate of by-product gas production' are selected in the example. The 'fraction of gas used with emission control technology' is directly calculated by recording the use of the PFC gas on equipment with and without emission control technology available.

Figure 21 – Integrated circuit or semiconductor production using Method 1: Calculation Approach in the MP Template


CA_P5

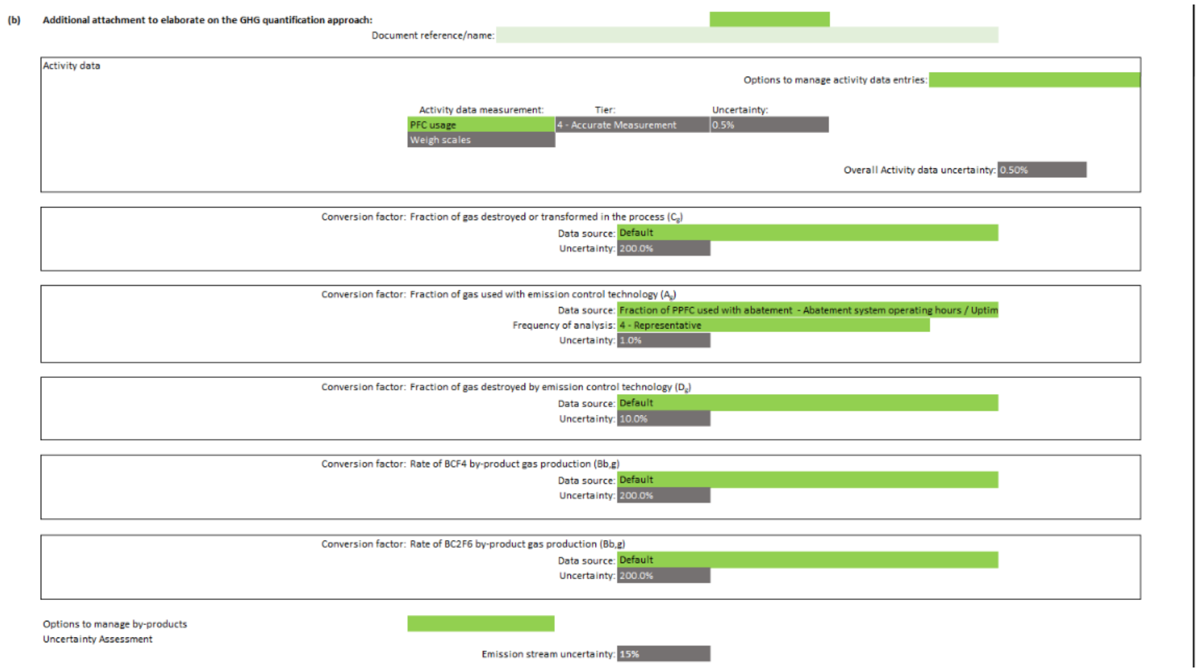
Emission source: Integrated circuit or semiconductor production
Emission stream type: Plasma etching thin film
Greenhouse gas to be reported: PFC-318 (c-C4F8) — The selected gas may generate by-product emissions.
IPCC Guideline: 2006 IPCC Guideline
Tier: Tier 2B

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

PFC-318 is used on-site for plasma etching. The gas cylinders are weighed prior to and post use to provide a measured quantity.

The quantity of gas used on equipment with abatement and without abatement is recorded to allow a fraction of gas used with abatement to be calculated. Abatement is not available on all machines.

Default factors are used for other converison factors.



(b) **Additional attachment to elaborate on the GHG quantification approach:**
Document reference/name:

Activity data
Options to manage activity data entries:
Activity data measurement: | Tier: | Uncertainty:
PFC usage | 4 - Accurate Measurement | 0.5%
Weigh scales
Overall Activity data uncertainty: 0.50%

Conversion factor: Fraction of gas destroyed or transformed in the process (C_g)
Data source: Default
Uncertainty: 200.0%

Conversion factor: Fraction of gas used with emission control technology (A_g)
Data source: Fraction of PPFC used with abatement - Abatement system operating hours / Uptim
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Conversion factor: Fraction of gas destroyed by emission control technology (D_g)
Data source: Default
Uncertainty: 10.0%

Conversion factor: Rate of BCF4 by-product gas production (Bb,g)
Data source: Default
Uncertainty: 200.0%

Conversion factor: Rate of BC2F6 by-product gas production (Bb,g)
Data source: Default
Uncertainty: 200.0%

Options to manage by-products
Uncertainty Assessment
Emission stream uncertainty: 15%

The overall uncertainty of the emission stream under integrated circuit or semiconductor production can vary significantly. This results from the structure of the emissions calculation and relatively high uncertainty of each step. In particular, the high uncertainty of the ‘fraction of gas destroyed or transformed in the process’, given the broad range of IPCC default emission factors (from 10% to 98%) and high uncertainty of the abatement effectiveness, can result in a high uncertainty for the gas released even though the actual emissions can be low due to abatement. Therefore, even though abatement helps reduce overall emissions, there is an uncertainty value tied to the default abatement conversion factor which can increase the overall uncertainty of the emission stream.

Figure 22 shows an example of how the quantity of fluorinated gas use can be reported on Tab **D. Calc Apch – Metering & Analysis**. In the example, weigh scales are used to weigh each gas cylinder before use and either after each use or prior to disposal or recycle.

Figure 22 – Specifying the measurement of fluorinated gas use in the MP Template for Integrated circuit or semiconductor production

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument or technique	Tier	Default uncertainty (+/-%)	Site-specific uncertainty (+/-%)	Management procedure name	Remove row options
P5	PFC usage	Weigh scales	4 - Accurate Measurement	0.5%		SoP- Management and use of PFC gases	

The analysis of the fraction of the fluorinated gas used with abatement can be reported on Tab **D. Calc Apch – Metering & Analysis** as shown in Figure 23. In the example, the activity data i.e. fluorinated gas use is tracked with respect to the availability of abatement for the equipment used. The quantity of the fluorinated gas used with abatement is compared to the total quantity of the fluorinated gas used to derive the fraction conversion factor. The uncertainty of the calculation is assumed to be zero. The statistical uncertainty of the measurement of the fluorinated gas use is already captured in the overall uncertainty equation as shown in Figure 21.

Figure 23 – Specifying the calculation of abatement fraction in the MP Template for Integrated circuit or semiconductor production

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument	Conversion factor	Default uncertainty (+/-%)	Site-specific uncertainty (+/-%)	Management procedure name	Remove row options
P5	Fraction of PPFC used with abatement	Abatement control system timer	Abatement system operating hours / Uptime of abatement system	1.0%		SoP- Management and use of PFC gases	

Method 3: Direct Measurement

The MP Template and Emissions Report allow the facility to directly measure and report the release of GHGs from the electronics industry should such techniques be devised. At present this is not practiced in Singapore. Refer to the direct measurement sections in other emission sources for more information.

Default conversion factors and uncertainty

Facilities have the flexibility in deciding whether to adopt 2006 IPCC Guidelines or 2019 Refinement to 2006 IPCC Guidelines. However, facilities are encouraged to use the most accurate tier possible to quantify its emissions, e.g. if gas usage are tracked at process-level, 2006 IPCC Guidelines tier 2b or 2019 Refinement tier 2c should be used.

The IPCC default conversion factors for (i) $1 - C_g$ i.e. emission factor for fluorinated compound fed into the process; (ii) B_{CF4}, B_{C2F6} and B_{C3F8} i.e. rate of creation of by-product fluorinated compounds from fluorinated compound in the process; and (iii) D_g, fraction of fluorinated compound that is destroyed by the emission control technology, are tabulated in Table 14 as follow[41].

In Table 14, the treatment of the gases are as follow:

i) Greenhouse Gases with GWP: The fluorinated compound fed into the process, and the by-product emissions will be needed to be accounted for in the MP and ER.

ii) Greenhouse Gases without GWP: As these fluorinated compounds fed into the process do not have a GWP in the IPCC assessment reports, the fluorinated compound fed into the process will not be needed to be accounted for in the MP and ER. Only the by-product emissions will be needed to be accounted for in the MP and ER.

iii) Non-GHG producing FC by-products: The fluorinated compound fed into the process is not a GHG, but it produces fluorinated by-products. Only the by-product emissions will be needed to be accounted for in the MP and ER.

For other types of GHGs, there are no default conversion factors for (i) $1 - C_g$ i.e. emission factor for fluorinated compound fed into the process; and (ii) D_g, fraction of fluorinated compound that is destroyed by the emission control technology. In addition, B_{CF4}, B_{C2F6} and B_{C3F8} i.e. rate of creation of by-product fluorinated compounds from fluorinated compound in the process, is assumed to be zero.

For non-metered consumption, the default uncertainty value for the fraction of gas remaining in the shipping container (heel) i.e. 'invoice with default heel' is 1.8%.

[41] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 6, Tables 6.3 and 6.6 and 2019 Refinement to IPCC Guidelines, Volume 3, Chapter 5, Tables 6.7, 6.9 to 6.11 and 6.17 for more details.

Based on the 2006 IPCC Guidelines and 2019 Refinement to 2006 IPCC guidelines, the default uncertainty values for the default conversion factors are tabulated in Table 15.

Table 14 (A) – 2006 IPCC Guidelines Default Integrated Circuit or Semiconductor Production Conversion Factors Tier 2A and 2B [42]

TIER 2 DEFAULT EMISSION FACTORS FOR FC EMISSIONS FROM SEMICONDUCTOR MANUFACTURING														
	Greenhouse Gases with TAR GWP									Greenhouse Gases without TAR GWP			Non-GHGs Producing FC By-products‡	
Process Gas (i)	CF_4	C_2F_6	CHF_3	CH_2F_2	C_3F_8	$c\text{-}C_4F_8$	NF_3 Remote	NF_3	SF_6	C_4F_6	C_5F_8	C_4F_8O	F_2	COF_2
Tier 2a														
1-Ui	0.9	0.6	0.4	0.1	0.4	0.1	0.02	0.2	0.2	0.1	0.1	0.1	NA	NA
B_{CF4}	NA	0.2	0.07	0.08	0.1	0.1	0.02†	0.09	NA	0.3	0.1	0.1	0.02†	0.02†
B_{C2F6}	NA	NA	NA	NA	NA	0.1	NA	NA	NA	0.2	0.04	NA	NA	NA
B_{C3F8}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.04	NA	NA
Tier 2b														
Etch 1-Ui	0.7*	0.4*	0.4*	0.06*	NA	0.2*	NA	0.2	0.2	0.1	0.2	NA	NA	NA
CVD 1-Ui	0.9	0.6	NA	NA	0.4	0.1	0.02	0.2	NA	NA	0.1	0.1	NA	NA
Etch B_{CF4}	NA	0.4*	0.07*	0.08*	NA	0.2	NA	NA	NA	0.3*	0.2	NA	NA	NA
Etch B_{C2F6}	NA	NA	NA	NA	NA	0.2	NA	NA	NA	0.2*	0.2	NA	NA	NA
CVD B_{CF4}	NA	0.1	NA	NA	0.1	0.1	0.02†	0.1†	NA	NA	0.1	0.1	0.02†	0.02†
CVD B_{C2F6}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CVD B_{C3F8}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.04	NA	NA

Notes: NA denotes not applicable based on currently available information

‡ The default emission factors for F_2 and COF_2 may be applied to cleaning low-k CVD reactors with ClF_3.

* Estimate includes multi-gas etch processes

† Estimate reflects presence of low-k, carbide and multi-gas etch processes that may contain a C-containing FC additive

[42] Refer to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.3 for more details.

Table 14 (B) – 2019 Refinement to IPCC Guidelines Default Integrated Circuit or Semiconductor Production Tier 2A Conversion Factors

Tier 2A Default Conversion Factors[43]																			
Process Gas	CF_4	C_2F_6	C_3F_8	C_3F_8 Remote	C_4F_6	c-C_4F_8	C_4F_8O	C_5F_8	CHF_3	CH_2F_2	CH_3F	C_2HF_5	NF_3 Remote	NF_3	SF_6	N_2O TFD	N_2O other	COF_2	F_2
(1-Ui)	0.73	0.55	0.4	0.063	0.15	0.13	0.14	0.085	0.47	0.2	0.35	0.064	0.02	0.18	0.55	0.78	1.0	NM	NM
B_{CF4}	NA	0.19	0.2	NA	0.06	0.099	0.13	0.053	0.082	0.061	0.028	0.077	0.034	0.067	0.12	NA	NA	NM	NM
B_{C2F6}	0.043	NA	0.000018	NA	0.063	0.02	0.045	0.047	0.045	0.044	0.01	0.024	NA	0.014	0.095	NA	NA	NM	NM
B_{C3F8}	NA	NA	NA	NA	NA	NA	NA	0.000055	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F6}	0.00060	NA	NA	NA	NA	0.0015	NA	NA	0.000032	NA	0.0011	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F8}	0.0014	NA	NA	NA	0.0051	NA	NA	NA	0.00021	0.071	0.0065	NA	NA	NA	NA	NA	NA	NA	NA
B_{C5F8}	0.00045	NA	NA	NA	NA	0.0035	NA	NA	0.00079	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{CH3F}	0.0021	NA	0*	NA	0.00064	0.0004	NA	NA	0.0043	0.0043	NA	NA	NA	0.0022	0.0009	NA	NA	NA	NA
B_{CH2F2}	0.0057	NA	NA	NA	0.00003	0.00026	NA	NA	0.00082	NA	0.0021	NA	NA	0.00023	0.0000021	NA	NA	NA	NA
B_{CHF3}	0.040	0.002	0.0000012	NA	0.018	0.022	NA	0.0053	NA	0.057	0.015	NA	NA	0.0068	0.0014	NA	NA	NA	NA

[43] Refer to the 2019 Refinement to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.7 for more details.

Table 14 (C) – 2019 Refinement to IPCC Guidelines Default Integrated Circuit or Semiconductor Production Tier 2B Conversion Factors

Tier 2B Default Conversion Factors[44]																			
Process Gas	CF_4	C_2F_6	C_3F_8	C_3F_8 Remote	C_4F_6	c-C_4F_8	C_4F_8O	C_5F_8	CHF_3	CH_2F_2	CH_3F	C_2HF_5	NF_3 Remote	NF_3	SF_6	N_2O TFD	N_2O other	COF_2	F_2
≤200 mm wafer size																			
(1-Ui)	0.79	0.55	0.4	NA	0.12	0.12	0.14	0.072	0.51	0.13	0.7	0.064	0.028	0.18	0.58	1.0	1.0	NM	NM
B_{CF4}	NA	0.19	0.2	NA	0.1	0.11	0.13	NA	0.085	0.079	NA	0.077	0.015	0.11	0.13	NA	NA	NM	NM
B_{C2F6}	0.03	NA	NA	NA	0.11	0.019	0.045	0.014	0.035	0.025	0.0034	0.024	NA	0.0059	0.11	NA	NA	NM	NM
B_{C3F8}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{C5F8}	0.00077	NA	NA	NA	NA	0.00043	NA	NA	0.0012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{CHF3}	0.059	0.002	NA	NA	0.066	0.02	NA	0.0039	NA	0.049	NA	NA	NA	NA	0.0011	NA	NA	NA	NA
300 mm wafer size																			
(1-Ui)	0.65	0.8	0.3	0.063	0.15	0.18	NA	0.1	0.38	0.2	0.32	NA	0.018	0.18	0.29	0.5	1.0	NM	NM
B_{CF4}	NA	0.21	0.21	NA	0.059	0.046	NA	0.11	0.075	0.06	0.031	NA	0.038	0.04	0.034	NA	NA	NM	NM
B_{C2F6}	0.061	NA	0.18	NA	0.062	0.028	NA	0.083	0.067	0.044	0.011	NA	NA	0.02	0.041	NA	NA	NM	NM
B_{C3F8}	NA	NA	NA	NA	NA	NA	NA	0.00012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F6}	0.0015	NA	NA	NA	NA	0.008	NA	NA	0.0001	NA	0.0012	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F8}	0.0033	NA	NA	NA	0.0051	NA	NA	NA	0.00067	0.072	0.007	NA	NA	NA	NA	NA	NA	NA	NA
B_{CH3F}	0.0053	NA	0.00073	NA	0.00065	0.0022	NA	NA	0.037	0.0044	NA	NA	NA	0.0036	0.0082	NA	NA	NA	NA
B_{CH2F2}	0.014	NA	NA	NA	0.00003	0.0014	NA	NA	0.0026	NA	0.0023	NA	NA	0.00039	0.00002	NA	NA	NA	NA
B_{CHF3}	0.013	NA	0.012	NA	0.017	0.03	NA	0.0069	NA	0.057	0.016	NA	NA	0.011	0.0039	NA	NA	NA	NA

[44] Refer to the 2019 Refinement to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.9 for more details.

Table 14 (D) – 2019 Refinement to IPCC Guidelines Default Integrated Circuit or Semiconductor Production Tier 2C Conversion Factors (≤200 MM)

Tier 2C (≤200 MM) Default Conversion Factors[45]																	
Process Gas	CF_4	C_2F_6	C_3F_8	C_4F_6	c-C_4F_8	C_4F_8O	C_5F_8	CHF_3	CH_2F_2	CH_3F	C_2HF_5	NF_3	SF_6	N_2O TFD	N_2O other	COF_2	F_2
Etching or Wafer Cleaning (EWC)																	
(1-Ui)	0.73	0.72	NA	0.12	0.14	NM	0.0722	0.51	0.13	0.7	0.064	0.19	0.55	NA	NA	NM	NM
B_{CF4}	NA	0.1	NA	0.13	0.11	NM	NA	0.085	0.079	NA	0.077	0.004	0.13	NA	NA	NM	NM
B_{C2F6}	0.046	NA	NA	0.11	0.037	NM	0.014	0.035	0.025	0.0034	0.024	0.025	0.11	NA	NA	NM	NM
B_{C5F8}	0.0012	NA	NA	NA	0.0086	NA	NA	0.0012	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{CHF3}	0.09	0.047	NA	0.066	0.04	NA	0.0039	NA	0.049	NA	NA	NA	0.0012	NA	NA	NA	NA
Remote Plasma Cleaning (RPC)																	
(1-Ui)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.028	NA	NA	NA	NA	NA
B_{CF4}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.015	NA	NA	NA	NA	NA
In-situ Plasma Cleaning (IPC)																	
(1-Ui)	0.92	0.55	0.4	NA	0.1	0.14	NA	NA	NA	NA	NA	0.18	NM	NA	NA	NM	NA
B_{CF4}	NA	0.21	0.2	NA	0.11	0.13	NA	NA	NA	NA	NA	0.14	NM	NA	NA	NM	NA
B_{C2F6}	NA	NA	NA	NA	NA	0.045	NA	NA	NA	NA	NA	NA	NM	NA	NA	NM	NA
Thin Film Deposition (TFD)																	
(1-Ui)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0	NA	NA	NA
Other																	
(1-Ui)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0	NA	NA

[45] Refer to the 2019 Refinement to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.10 for more details.

Table 14 (E) – 2019 Refinement to IPCC Guidelines Default Integrated Circuit or Semiconductor Production Tier 2C Conversion Factors (≤300 MM)

Tier 2C (300 MM) Default Conversion Factors [46]															
Process Gas	**CF_4**	**C_2F_6**	**C_3F_8**	**C_4F_6**	**c-C_4F_8**	**C_5F_8**	**CHF_3**	**CH_2F_2**	**CH_3F**	**NF_3**	**SF_6**	**N_2O TFD**	**N_2O other**	**COF_2**	**F_2**
Etching and Wafer Cleaning (EWC)															
(1-Ui)	0.65	0.8	0.3	0.15	0.18	0.1	0.38	0.2	0.32	0.16	0.29	NA	NA	NM	NM
B_{CF4}	NA	0.21	0.21	0.059	0.046	0.11	0.075	0.06	0.031	0.045	0.034	NA	NA	NM	NM
B_{C2F6}	0.061	NA	0.18	0.062	0.028	0.083	0.067	0.044	0.011	0.045	0.041	NA	NA	NM	NM
B_{C3F8}	NA	NA	NA	NA	NA	0.00012	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F6}	0.0015	NA	NA	NA	0.0083	NA	0.0001	NA	0.0012	NA	NA	NA	NA	NA	NA
B_{C4F8}	0.0033	NA	NA	0.0051	NA	NA	0.00067	0.072	0.007	NA	NA	NA	NA	NA	NA
B_{CH3F}	0.0053	NA	0.00073	0.00065	0.0022	NA	0.037	0.0044	NA	0.008	0.0082	NA	NA	NA	NA
B_{CH2F2}	0.014	NA	NA	0.00003	0.0014	NA	0.0026	NA	0.0023	0.00086	0.00002	NA	NA	NA	NA
B_{CHF3}	0.013	NA	0.012	0.017	0.03	0.0069	NA	0.057	0.0016	0.025	0.0039	NA	NA	NA	NA
Remote Plasma Cleaning (RPC)															
(1-Ui)	NA	NA	0.063	NA	NA	NA	NA	NA	NA	0.018	NA	NA	NA	NA	NA
B_{CF4}	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.038	NA	NA	NA	NA	NA
In-situ Plasma Cleaning (IPC)															
(1-Ui)	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.2	NA	NA	NA	NA	NA
B_{CF4}	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.037	NA	NA	NA	NA	NA
In-situ Thermal Cleaning (ITC)															
(1-Ui)	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.28	NA	NA	NA	NA	NA
B_{CF4}	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01	NA	NA	NA	NA	NA
TFD															
(1-Ui)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.5	NA	NA	NA
Other															
(1-Ui)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0	NA	1.0

[46] Refer to the 2019 Refinement to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.11 for more details.

Table 15 (A)– 2006 IPCC Guidelines Default Uncertainty Values for Integrated Circuit or Semiconductor Production Conversion Factors [47]

Conversion factor	Tier2A/2B default uncertainty (%)													
	Greenhouse gases with GWP									Greenhouse Gases without GWP			Non-GHG Producing FC By-products	
	CF_4	C_2F_6	CHF_3	CH_2F_2	C_3F_8	c-C_4F_8	NF_3 Remote	NF_3	SF_6	C_4F_6	C_5F_8	C_4F_8O	F_2	COF_2
Tier 2A														
$1 - C_g$	15	30	100	400	20	80	400	70	300	300	80	40	NA	NA
B_{CF4}	NA	90	300	200	60	100	200	200	NA	200	100	80	200	200
B_{C2F6}	NA	NA	NA	NA	NA	200	NA	NA	NA	200	200	NA	NA	NA
B_{C3F8}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	40	NA	NA
D_g [48]	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Tier 2B														
$Etch\ 1 - C_g$	60	100	100	700	NA	200	NA	300	300	300	200	NA	NA	NA
$CVD\ 1 - C_g$	10	30	NA	NA	0.4	30	400	70	NA	NA	30	40	NA	NA
$Etch\ B_{CF4}$	NA	200	300	200	NA	200	NA	NA	NA	200	200	NA	NA	NA
$Etch\ B_{C2F6}$	NA	NA	NA	NA	NA	200	NA	NA	NA	200	200	NA	NA	NA
$CVD\ B_{CF4}$	NA	80	NA	NA	60	60	200	200	NA	NA	60	80	80	200
$CVD\ B_{C2F6}$	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
$CVD\ B_{C3F8}$	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	40	40	NA
Dg [49]	10	10	10	10	10	10	10	10	10	10	10	10	10	10

[47] Refer to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.9 for more details.
[48] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 6, pages 6.21 and 6.22 for more details.
[49] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 6, pages 6.21 and 6.22 for more details.

Table 15 (B)– 2019 Refinement to 2006 IPCC Guidelines Default Uncertainty Values for Integrated Circuit or Semiconductor Production Conversion Factors (Tier 2A)

Tier 2A default uncertainties (%)[50]																			
Process Gas	CF_4	C_2F_6	C_3F_8	C_3F_8 Remote	C_4F_6	c-C_4F_8	C_4F_8O	C_5F_8	CHF_3	CH_2F_2	CH_3F	C_2HF_5	NF_3 Remote	NF_3	SF_6	N_2O TFD	N_2O other	COF_2	F_2
$(1-U_i)$	60	40	200	200	200	140	200	180	120	200	140	100	400	200	140	120	200	200	200
B_{CF4}	NA	120	200	NA	400	200	200	160	200	200	200	100	600	400	400	NA	NA	200	200
B_{C2F6}	400	NA	200	NA	400	160	200	200	400	200	200	140	NA	400	200	NA	NA	200	200
B_{C3F8}	NA	NA	NA	NA	NA	NA	NA	200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F6}	200	NA	NA	NA	NA	200	NA	NA	400	NA	40	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F8}	400	NA	NA	NA	400	NA	NA	NA	400	200	200	NA	NA	NA	NA	NA	NA	NA	NA
B_{C5F8}	200	NA	NA	NA	NA	200	NA	NA	400	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{CH3F}	200	NA	200	NA	400	200	NA	NA	400	200	NA	NA	NA	400	400	NA	NA	NA	NA
B_{CH2F2}	200	NA	NA	NA	400	200	NA	NA	400	NA	200	NA	NA	400	400	NA	NA	NA	NA
B_{CHF3}	200	200	200	NA	400	200	NA	400	NA	180	200	NA	NA	400	400	NA	NA	NA	NA

[50] The uncertainties are obtained from the 2019 Refinement to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.19. **When IPCC default uncertainty values are not available, the uncertainty values are provided as follows 1) use the highest default uncertainty value in each column when available; 2) use the upper limit 200% based on 2006 GLs, paragraph 6.3.1 when the entire column is empty.**

Table 15 (C)– 2019 Refinement to 2006 IPCC Guidelines Default Uncertainty Values for Integrated Circuit or Semiconductor Production Conversion Factors (Tier 2B)

Tier 2B default uncertainties (%)[51]																			
Process Gas	**CF_4**	**C_2F_6**	**C_3F_8**	**C_3F_8 Remote**	**C_4F_6**	**c-C_4F_8**	**C_4F_8O**	**C_5F_8**	**CHF_3**	**CH_2F_2**	**CH_3F**	**C_2HF_5**	**NF_3 Remote**	**NF_3**	**SF_6**	**N_2O TFD**	**N_2O other**	**COF_2**	**F_2**
≤200 mm wafer size																			
(1-U_i)	400	40	200	NA	200	200	200	200	100	160	200	100	200	150	200	200	200	NA	NA
B_{CF4}	NA	120	200	NA	200	200	200	NA	80	140	NA	100	180	150	200	NA	NA	NA	NA
B_{C2F6}	400	NA	NA	NA	400	200	200	200	200	120	200	140	NA	150	200	NA	NA	NA	NA
B_{C3F8}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{C5F8}	400	NA	NA	NA	NA	200	NA	NA	200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{CHF3}	120	120	NA	NA	400	200	NA	200	NA	160	NA	NA	NA	NA	200	NA	NA	NA	NA
300 mm wafer size																			
(1-U_i)	60	200	200	200	200	140	NA	180	120	200	140	NA	400	200	140	120	200	NA	NA
B_{CF4}	NA	200	200	NA	400	200	NA	160	200	200	200	NA	600	400	400	NA	NA	NA	NA
B_{C2F6}	200	NA	200	NA	400	160	NA	200	400	200	200	NA	NA	400	200	NA	NA	NA	NA
B_{C3F8}	NA	NA	NA	NA	NA	NA	NA	200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F6}	400	NA	NA	NA	NA	200	NA	NA	400	NA	40	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F8}	400	NA	NA	NA	400	NA	NA	NA	400	200	200	NA	NA	NA	NA	NA	NA	NA	NA
BCH_3F	200	NA	200	NA	400	200	NA	NA	400	200	NA	NA	NA	400	400	NA	NA	NA	NA
BCH_2F_2	400	NA	NA	NA	400	200	NA	NA	400	NA	200	NA	NA	400	400	NA	NA	NA	NA
$BCHF_3$	200	NA	200	NA	400	200	NA	400	NA	180	200	NA	NA	400	400	NA	NA	NA	NA

[51] Refer to the 2019 Refinement to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.19. For missing uncertainties, a conservative approach is adopted to obtain the uncertainty values (i.e. to adopt the highest uncertainty of any emissions factor for a particular gas, or 200% when uncertainty is not available for any emission factor of a gas)

Table 15 (D) – 2019 Refinement to 2006 IPCC Guidelines Default Uncertainty Values for Integrated Circuit or Semiconductor Production Conversion Factors (Tier 2C) (≤200 MM)

Tier 2C (≤200 MM) default uncertainty (%)[52]																	
Process Gas	**CF_4**	**C_2F_6**	**C_3F_8**	**C_4F_6**	**c-C_4F_8**	**C_4F_8O**	**C_5F_8**	**CHF_3**	**CH_2F_2**	**CH_3F**	**C_2HF_5**	**NF_3**	**SF_6**	**N_2O TFD**	**N_2O other**	**COF_2**	**F_2**
Etching or Wafer Cleaning (EWC)																	
(1-U_i)	40	60	NA	200	140	NA	200	100	160	200	100	140	100	NA	NA	NA	NA
B_{CF4}	NA	180	NA	200	200	NA	NA	80	140	NA	100	140	100	NA	NA	NA	NA
B_{C2F6}	400	NA	NA	400	400	NA	200	200	120	200	140	140	100	NA	NA	NA	NA
B_{C5F8}	400	NA	NA	NA	400	NA	NA	200	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{CHF3}	120	180	NA	400	400	NA	200	NA	160	NA	NA	NA	100	NA	NA	NA	NA
Remote Plasma Cleaning (RPC)																	
(1-U_i)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	NA	NA	NA	NA	NA
B_{CF4}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	180	NA	NA	NA	NA	NA
In-situ Plasma Cleaning (IPC)																	
(1-U_i)	200	40	200	NA	200	200	NA	NA	NA	NA	NA	180	NA	NA	NA	NA	NA
B_{CF4}	NA	120	200	NA	200	200	NA	NA	NA	NA	NA	180	NA	NA	NA	NA	NA
B_{C2F6}	NA	NA	NA	NA	NA	200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thin Film Deposition (TFD)																	
(1-U_i)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	NA	NA	NA
Other																	
(1-U_i)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	NA	NA

[52] Refer to the 2019 Refinement to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.20.

Table 15 (E)– 2019 Refinement to 2006 IPCC Guidelines Default Uncertainty Values for Integrated Circuit or Semiconductor Production Conversion Factors (Tier 2C) (300 MM)

Tier 2C (300 MM) default uncertainty (%)[53]														
Process Gas	**CF_4**	**C_2F_6**	**C_3F_8**	**C_4F_6**	**c-C_4F_8**	**C_5F_8**	**CHF_3**	**CH_2F_2**	**CH_3F**	**NF_3**	**SF_6**	**N_2O TFD**	**N_2O other**	**COF_2**	**F_2**
Etching and Wafer Cleaning (EWC)															
(1-U_i)	60	200	200	200	140	180	120	200	140	180	140	NA	NA	NM	NM
B_{CF4}	NA	200	200	400	200	160	200	200	200	200	400	NA	NA	NM	NM
B_{C2F6}	200	NA	200	400	160	200	400	200	200	200	200	NA	NA	NM	NM
B_{C3F8}	NA	NA	NA	NA	NA	400	NA	NA	NA	NA	NA	NA	NA	NA	NA
B_{C4F6}	400	NA	NA	NA	200	NA	400	NA	40	NA	NA	NA	NA	NA	NA
B_{C4F8}	400	NA	NA	400	NA	NA	400	200	200	NA	NA	NA	NA	NA	NA
B_{CH3F}	200	NA	200	400	200	NA	400	200	NA	200	400	NA	NA	NA	NA
B_{CH2F2}	400	NA	NA	400	200	NA	400	NA	200	200	400	NA	NA	NA	NA
B_{CHF3}	200	NA	200	400	200	400	NA	180	200	200	400	NA	NA	NA	NA
Remote Plasma Cleaning (RPC)															
(1-U_i)	NA	NA	200	NA	NA	NA	NA	NA	NA	400	NA	NA	NA	NA	NA
B_{CF4}	NA	NA	NA	NA	NA	NA	NA	NA	NA	600	NA	NA	NA	NA	NA
In-situ Plasma Cleaning (IPC)															
(1-U_i)	NA	NA	NA	NA	NA	NA	NA	NA	NA	100	NA	NA	NA	NA	NA
B_{CF4}	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	NA	NA	NA	NA	NA
In-situ Thermal Cleaning (ITC)															
(1-U_i)	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	NA	NA	NA	NA	NA
B_{CF4}	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	NA	NA	NA	NA	NA
TFD															
(1-U_i)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	120	NA	NA	NA
Other															
(1-U_i)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	NA	200

[53] Refer to the 2019 Refinement to 2006 IPCC Guidelines, Volume 3, Chapter 6, Table 6.21.

The default uncertainty value for site-specific conversion factor: fraction of gas used with emission control technology, is assumed to be 7.5%. For other conversion factors i.e. (i) C_g i.e. emission factor for fluorinated compound fed into the process; (ii) D_g, fraction of fluorinated compound that is destroyed by the emission control technology; and (iii) B_{CF4}, B_{C2F6} and B_{C3F8} i.e. rate of creation of by-product fluorinated compounds from fluorinated compound in the process, the site-specific uncertainty values are assumed to be half of that of the default uncertainty values specified in the table above.

For other types of GHG fed into the process where no default value is specified for $1 - C_g$ i.e. fraction destroyed or transformed in the process, the site-specific uncertainty value for C_g is 25% and D_g is 5%. The uncertainty of a site-specific value for C_g could vary significantly from the assumed value, depending on the actual value of C_g. The uncertainty value selected therefore provides a moderate level of uncertainty. However, the facility is encouraged to provide a more accurate site-specific uncertainty value where possible. For such other types of GHGs that are fed into the process, the MP Template assumes that there are no by-product GHG emissions generated.

2.9 Thin-film-transistor (TFT) flat panel display (TFT-FPD) or liquid crystal display (LCD) production

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☒ Method 3: Direct Measurement

There are four emission stream types based on the 2006 IPCC Guidelines for thin-film-transistor flat panel display (TFT-FPD) or liquid crystal display (LCD) production. This is based on the gas-specific emission factors namely PFC-14 (i.e. CF_4), NF_3 and SF_6. The last emission stream type is catered to other GHGs where default emission factors are not available.

i) PFC-14

ii) NF_3

iii) SF_6

iv) Other GHGs i.e. HFCs and other PFCs:

1. HFC-23 (CHF_3)
2. HFC-32 (CH_2F_2)
3. HFC-41 (CH_3F)
4. HFC-125 (CHF_2CF_3)
5. HFC-134 (CHF_2CHF_2)
6. HFC-134a (CH_2FCF_3)
7. HFC-143 (CH_2FCHF_2)
8. HFC-143a (CH_3CF_3)
9. HFC-152 (CH_2FCH_2F)
10. HFC-152a (CH_3CHF_2)
11. HFC-161 (CH_3CH_2F)
12. HFC-227ea (CF_3CHFCF_3)
13. HFC-236cb ($CH_2FCF_2CF_3$)
14. HFC-236ea (CHF_2CHFCF_3)
15. HFC-236fa ($CF_3CH_2CF_3$)
16. HFC-245ca ($CH_2FCF_2CHF_2$)
17. HFC-245fa ($CHF_2CH_2CF_3$)
18. HFC-365mfc ($CH_3CF_2CH_2CF_3$)
19. HFC-43-10mee ($CF_3CHFCHFCF_2CF_3$)
20. HFC-227ca ($CF_3CF_2CHF_2$)
21. HFC-245cb ($CF_3CF_2CH_3$)
22. HFC-245ea ($CHF_2CHFCHF_2$)
23. HFC-245eb ($CH_2FCHFCF_3$)
24. HFC-263fb ($CH_3CH_2CF_3$)
25. HFC-272ca ($CH_3CF_2CH_3$)
26. HFC-329p ($CHF_2CF_2CF_2CF$)
27. HFC-1132a ($CH_2{=}CF_2$)
28. HFC-1141 ($CH_2{=}CHF$)
29. (Z)-HFC-1225ye ($CF_3CF{=}CHF(Z)$)
30. (E)-HFC-1225ye ($CF_3CF{=}CHF(E)$)
31. (Z)-HFC-1234ze ($CF_3CH{=}CHF(Z)$)
32. HFC-1234yf ($CF_3CF{=}CH_2$)
33. (E)-HFC-1234ze (trans-$CF_3CH{=}CHF$)
34. (Z)-HFC-1336 ($CF_3CH{=}CHCF_3(Z)$)
35. HFC-1243zf ($CF_3CH{=}CH_2$)
36. HFC-1345zfc ($C_2F_5CH{=}CH_2$)
37. 3,3,4,4,5,5,6,6,6-Nonafluorohex-1-ene ($C_4F_9CH{=}CH_2$)
38. 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooct-1-ene ($C_6F_{13}CH{=}CH_2$)
39. 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-Heptadecafluorodec-1-ene ($C_8F_{17}CH{=}CH_2$)
40. PFC-116 (C_2F_6)
41. PFC-218 (C_3F_8)
42. PFC-318 (c-C_4F_8)
43. PFC-3-1-10 (C_4F_{10})
44. PFC-4-1-12 (C_5F_{12})
45. PFC-5-1-14 (C_6F_{14})
46. PFC-c216 (c-C_3F_6)
47. Perfluorocyclopentene (c-C_5F_8)
48. PFC-61-16 (n-C_7F_{16})

49. PFC-71-18 (C_8F_{18})
50. PFC-91-18 ($C_{10}F_{18}$)
51. Perfluorodecalin (cis) (Z-$C_{10}F_{18}$)
52. Perfluorodecalin (trans) (E-$C_{10}F_{18}$)
53. PFC-1114 (CF_2=CF_2)
54. PFC-1216 (CF_3CF=CF_2)
55. Perfluorobuta-1,3-diene (CF_2=$CFCF$=CF_2)
56. Perfluorobut-1-ene (CF_3CF_2CF=CF_2)
57. Perfluorobut-2-ene (CF_3CF=$CFCF_3$)

Method 1: Calculation Approach

The GHG M&R requirements refer to the following IPCC Tier 1 formula in the 2006 IPCC Guidelines[54]:

$$E_g = C_u \times C_d \times EF_g \times GWP_g$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions of fluorinated compound (g)	tonne CO_2e	Calculated
C_u	Fraction of annual plant production capacity utilised i.e. annual capacity utilisation	Nil	Reported
C_d	Annual manufacturing design capacity, expressed in terms of m^2 substrate processed	Giga or 10^9 square metres of substrate processed, Gm^2	Reported
EF_g	Emission factor for fluorinated compound (g) expressed as annual mass emissions per square metre of substrate area processed	g/m^2 substrate processed	Reported
g	Type of GHG (g)	Nil	Reported
GWP_g	Global warming potential for fluorinated compound (g)	Nil	Constant

The calculation of emissions relies on a fixed set of factors:

i) a gas-specific emission factor EF_g, expressed as an average emission per unit of substrate area (e.g. TFT-FPD panel) consumed during manufacture;

ii) annual capacity utilisation (C_u, a fraction) where in most cases the facility will measure the quantity of TFT-FPD or LCD material manufactured to determine the percentage of plant production utilised; and

iii) annual manufacturing design capacity C_d, in units of giga square meters (Gm^2)) of substrate processes. The product $C_u \times C_d$ is an estimate of the quantity of substrate consumed during TFT-FPD or LCD manufacture.

[54] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 6 for more details. Note that depending on the units of the various parameters, the actual computation formula may involve unit conversion. Refer to the M&R Guidelines Part III Section 3.9 for more information.

Figure 24 shows a typical configuration for TFT-FPD or LCD production in the MP Template for Method 1: Calculation Approach. In the example, the default NF_3 emission factor is used while C_u, 'fraction of annual plant production capacity utilised' and the activity data C_d, annual manufacturing design capacity, is determined via the facility's internal monitoring system.

Figure 24 – TFT-FPD or LCD production using Method 1: Calculation Approach in the MP Template

CA_P1 Emission source: TFT-FPD or LCD production
Emission stream type: NF3

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

NF3 is used during the manufacture of flat panel display units. The design capacity is calculated from forecast demand for each unit size and the plant capacity to meet demand. Utilisation is a plant performance metric of production of each unit type against forecast capacity. Each metric is determined from the foreacst and recorded count of each unit type and physical size specification. The default emission factor for the average quantity of NF3 used for that material.

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

Activity data
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Plant design capacity (m2)	1 - Engineering estimate	0.0%
Engineering estimate		

Overall Activity data uncertainty: 0.00%

Conversion factor: NF3 Emission Factor
Data source: Default
Uncertainty: 50.0%

Conversion factor: Fraction of Annual Plant Production Capacity Utilised
Data source: Plant Utilisation - Ratio to design capacity
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Uncertainty Assessment
Emission stream uncertainty: **50.0%**

The method uses design capacity and utilisation to calculate actual production of substrate material, as tracked by an internal monitoring system. The uncertainty of the actual production value will be calculated by the MP Template as the aggregation of the uncertainty of these two values. For ease of populating the site-specific uncertainty, the facility can set the uncertainty of the design capacity as 0% and the uncertainty of the utilisation to that of the internal monitoring system. For commercially purchased materials this may be around 1.5% based on the default assumption for invoice data uncertainty. In the example 1.0% was used due to the high cost of the product.

The measurement approach for the design capacity and actual utilisation as estimated from the internal monitoring system must be specified on Tab **D. Calc Apch – Metering & Analysis** as shown in Figure 25 and Figure 26.

Figure 25 – Specifying an engineering estimate in the MP Template

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument or technique	Tier	Default uncertainty (+/-%)	Site-specific uncertainty (+/-%)	Management procedure name
P1	Plant design capacity (m2)	Engineering estimate	1 - Engineering estimate	10.0%	0.0%	SoP - Manufacturing Operations

Figure 26 – Specifying a production count in the MP Template

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument	Conversion factor	Default uncertainty (+/-%)	Site-specific uncertainty (+/-%)	Management procedure name
P1	Plant Utilisation	Production count by unit m2	Ratio to design capacity		1.0%	SoP - Manufacturing Operations

Method 3: Direct Measurement

The MP Template and Emissions Report allow the facility to directly measure and report the release of GHGs from the electronics industry should such techniques be devised. Refer to the direct measurement sections in other emission sources for more information.

Default conversion factors and uncertainty

The default emission factors for TFT-FPD or LCD production are shown in Table 15, based on the 2006 IPCC Guidelines, Volume 3, Chapter 6 Table 6.2. The 2006 IPCC Guidelines state that the uncertainty values of these emission factors is not known but probably large due to the variability of technology across the global sector, hence the Tier 1 default uncertainty values are assumed to be at 50%. The Tier 1 site-specific uncertainty values are assumed to be one-fifth of the default uncertainty values. The significant reduction in uncertainty for site-specific emission factors assumes that the facility has a stable level of technology.

Table 15 – Tier 1 default TFT-FPD or LCD production conversion factors and uncertainty values

Emission stream type	Fluorinated compound/square metres of substrate processed (g/m^2)	Tier 1 default uncertainty	Tier 1 site-specific Uncertainty
PFC-14 (CF_4)	0.5	50%	10%
NF_3	0.9	50%	10%
SF_6	4	50%	10%
Other GHGs	N/A	N/A	10%

The default uncertainty value for Tier 1 default site-specific conversion factor for C_u, fraction of annual plant production capacity utilised, is assumed to be 7.5%.

2.10 Iron and steel production

☒ Method 1: Calculation Approach

☒ Method 2: Material Balance

☐ Method 3: Direct Measurement

There are ten emission stream types for iron and steel production based on the 2006 IPCC Guidelines. This is based on the numerous stages or process options in iron and steel making.

i) Sinter Production

ii) Coke Oven

iii) Iron Production

iv) Direct Reduced Iron Production

v) Pellet Production

vi) Basic Oxygen Furnace (BOF)

vii) Electric Arc Furnace (EAF)

viii) Open Hearth Furnace (OHF)

ix) Global Average Factor (default)

x) Other

Method 1: Calculation Approach

The GHG M&R requirements refer to the following IPCC Tier 1 formula in the 2006 IPCC Guidelines[55]:

$$E_g = Q_p \times \sum (EF_{p,g} \times GWP_g)$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions for GHG (g) i.e. CO_2, and CH_4	tonne CO_2e	Calculated
Q_p	Quantity of Tonne coke, crude steel, pig iron, DRI, sinter or pellet produced using process or steelmaking method (p)	tonne	Reported
$EF_{p,g}$	Emission factor for GHG (g) and process or steelmaking method (p)	tonne or kg GHG/tonne production	Reported
p	Process or steelmaking method	Nil	Reported

[55] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 4, pages 4.9 to 4.31 for more details.

Parameter ID	Parameter description	Units	Reporting status
GWP_g	Global warming potential for GHG (g)	Nil	Constant

Figure 27 shows a typical configuration for iron and steel production using an electric arc furnace (EAF). In the example a Tier 1 site-specific CO_2 emission factor (and site-specific uncertainty value) is used for the CO_2 emissions. As no default CH_4 conversion factor is available for EAFs and CH_4 emissions are assumed to be negligible, a Tier 1 site-specific CH_4 emission factor of zero has been recorded. The quantity of steel production is measured using weigh scales.

Figure 27 – Iron and steel production using Method 1: Calculation Approach in the MP Template

CA_P1 Emission source: Iron and steel production
Emission stream type: Electric Arc Furnace (EAF)

(a) GHG quantification approach description:

An electric arc furnace is used to re-process scrap steel. Steel production is measured as the weight of steel ingots for sale. A site-default CO2 emission factor is used based on a historical material balance analysis. CH4 emissions are assumed to be zero.

(b) Additional attachment? Yes
Document reference/name: GHG reporting - Basis of Preparation

Activity data

Activity data measurement:	Tier:	Uncertainty:
Steell production	2 - Measurement	1.0%
Weigh scales		

Overall Activity data uncertainty: 1.00%

Conversion factor: Carbon dioxide Emission factor
Data source: Site-specific
Carbon dioxide Emission Factor: 0.0943 Tonne/Tonne Site-specific uncertainty (+/-%): 2.0%
Benchmark/justification document reference/name: GHG Emissions from EAF operation - 2013 study
Uncertainty: 2.0%

Conversion factor: Methane Emission factor
Data source: Site-specific
Methane Emission Factor: 0.000 Tonne/Tonne Site-specific uncertainty (+/-%): 0.0%
Benchmark/justification document reference/name: GHG Emissions from EAF operation - 2013 study
Uncertainty: 0.0%

Uncertainty Assessment
Emission stream uncertainty: 2.2%

Method 2: Material Balance

Corporations can use Method 2: Material Balance to determine the quantity of carbon converted to CO_2 based on the difference in the quantity of carbon contained in the feedstock, products and waste streams. The formula to be used is shown in Section 3.1.2 of the M&R Guidelines Part II, for example, with iron or steel as the primary product.

Figure 28 shows a configuration of the 'electric arc furnace (EAF)' emission stream type, where there are three input (feedstock) streams and two output streams. The emission stream form allows for up to eight material streams to be detailed. Refer to Section 5.6.4 of the M&R Guidelines Part II for details on the management of material streams and the data to be provided. Section 5.6.4 also details the estimation of the percentage of carbon contained in each material stream.

Iron and steel production has a comparatively high number of input streams. The percentage of carbon from each input stream must be estimated to correctly determine the overall uncertainty of the emission stream. The aggregated percentage for the input streams should be 100% as shown in Figure 28. The aggregated percentage for the output streams should not add to 100%, but rather the percentage of carbon contained in these measured output streams. The remaining carbon is assumed to be released as CO_2.

As detailed in the section on Method 1: Calculation Approach, only three emission stream types have Tier 1 default CH_4 emission factors according to the 2006 IPCC Guidelines. As the CH_4 emission factor is based on the production quantity of the primary product i.e. steel, details of the production activity data are required. This is likely to be a repeat of the primary production material stream.

As no default CH_4 conversion factor is available for EAFs and CH_4 emissions are assumed to be negligible, a Tier 1 site-specific CH_4 emission factor of zero has been recorded.

Figure 28 – Iron and steel production using Method 2: Material Balance in the MP Template

MB_P2 Emission source: Iron and steel production
Emission stream type: Electric Arc Furnace (EAF)

(a) GHG quantification approach description:

An electric arc furnace is used to re-process scrap steel. Steel production is measured as the weight of steel ingots for sale. Steel production prior to ingot production can be recycled to the furnace. Scrap steel and charging coke are measured on a conveyor system as it is feed to the furnace charger. Carbon anodes are measured on delivery to the facility, with each batch recorded with an average weight. The carbon content of steel ingots is assessed as part of the production quality control procedures. IPCC defaults are used for the carbon content of coke and carbon anodes.

(b) Additional attachment? Yes
Document reference/name: GHG reporting - Basis of Preparation

Options to manage material stream entries:

Proportion of feedstock stream: 100%
Proportion of product/waste Stream: 5%

Activity data for this material stream 1
Material stream type: Feedstock
Feedstock type: Steel
Proportion of total Feedstock carbon in this Feedstock material stream: 5%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Scrap steel use	2 - Measurement	2.0%
Weighing Conveyor Belt		

Overall Activity data uncertainty: 2.00%

Conversion factor: Carbon content
Data source: Default
Uncertainty: 10.0%

Activity data for this material stream 2
Material stream type: Feedstock
Feedstock type: EAF Carbon Electrodes
Proportion of total Feedstock carbon in this Feedstock material stream: 80%
Options to manage activity data entries:

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

Overall Activity data uncertainty: 1.00%

Conversion factor: Carbon content
Data source: Default
Uncertainty: 10.0%

Figure 28 – Iron and steel production using Method 2: Material Balance in the MP Template (Continued)

Activity data for this material stream 3
Material stream type: Feedstock
Feedstock type: EAF Charge Carbon
Proportion of total Feedstock carbon in this Feedstock material stream: 15%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Charging coke use	2 - Measurement	2.0%
Weighing Conveyor Belt		

Overall Activity data uncertainty: 2.00%

Conversion factor: Carbon content
Data source: Default
Uncertainty: 10.0%

Activity data for this material stream 4
Material stream type: Production (Primary)
Describe the material: Steel ingots
Proportion of total Feedstock carbon in this Product/Waste material stream: 5%
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Steel ingot production	4 - Accurate Measurement	0.5%
Weigh scales		

Overall Activity data uncertainty: 0.50%

Conversion factor: Carbon content
Data source: Steel ingot and slag carbon content - Composition - Carbon content
Frequency of analysis: 4 - Representative
Uncertainty: 1.0%

Activity data to be used for Reporting to NEA
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Steel ingot production	4 - Accurate Measurement	0.5%
Weigh scales		

Overall Activity data uncertainty: 0.50%

Conversion factor: Methane Emission factor
Data source: Site-specific
Emission factor: 0.000 Tonne/Tonne Site-specific uncertainty (+/-%): 0.0%
Benchmark/justification document reference/name: GHG Emissions from EAF operation - 2013 study
Uncertainty: 0.0%

Emission stream uncertainty: **8.6%**

Default conversion factors and uncertainty

The Tier 1 default CO_2 and CH_4 emission factors for iron and steel production are shown in Table 16. The emission factors and uncertainty values have been obtained from the 2006 IPCC Guidelines.[56]

The 2006 IPCC Guidelines provides default CH_4 emission factors only for (i) Sinter Production, (ii) Coke Oven and (iii) Direct Reduced Iron Production. CH_4 emissions are likely from any process involving heating of carbon containing products such as iron making, however the uncertainty is high. The facility should use any available data to estimate if CH_4 emissions can be quantified.[57]

Tier 1 site-specific uncertainty values for CO_2 and CH_4 emission factors are assumed to be half of that of the IPCC default uncertainty values, with 7.5% as the minimum uncertainty for Tier 1 site-specific CO_2 and CH_4 emission factors.

[56] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 4, Tables 4.1 and 4.4 for more details.
[57] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 4, pages 4.23 to 4.26 for more details.

Table 16 – Tier 1 default iron and steel production conversion factors and uncertainty values

Emission stream type	CO_2 emission factor			CH_4 emission factor		
	Default (tonne CO_2/ tonne production)	Tier 1 default uncertainty	Tier 1 site-specific uncertainty	Default (kg CH_4/ tonne production)	Tier 1 default uncertainty	Tier 1 site-specific uncertainty
Sinter Production	0.20	25%	7.5%	0.070	25%	7.5%
Coke Oven	0.56	25%	7.5%	0.0001	25%	7.5%
Iron Production	1.35	25%	7.5%	N/A	N/A	7.5%
Direct Reduced Iron Production	0.70	25%	7.5%	0.048	25%	7.5%
Pellet Production	0.03	25%	7.5%	N/A	N/A	7.5%
Basic Oxygen Furnace (BOF)	1.46	25%	7.5%	N/A	N/A	7.5%
Electric Arc Furnace (EAF)	0.08	25%	7.5%	N/A	N/A	7.5%
Open Hearth Furnace (OHF)	1.72	25%	7.5%	N/A	N/A	7.5%
Global Average Factor (default)	1.06	25%	7.5%	N/A	N/A	7.5%
Other	N/A	N/A	7.5%	N/A	N/A	7.5%

2.11 Use of GHGs in fire protection equipment

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☐ Method 3: Direct Measurement

The facility is required to specify the GHG used in the fire protection equipment as the emission stream typ.

1) Carbon dioxide (CO_2)
2) HFC-23 (CHF_3)
3) HFC-32 (CH_2F_2)
4) HFC-41 (CH_3F)
5) HFC-125 (CHF_2CF_3)
6) HFC-134 (CHF_2CHF_2)
7) HFC-134a (CH_2FCF_3)
8) HFC-143 (CH_2FCHF_2)
9) HFC-143a (CH_3CF_3)
10) HFC-152 (CH_2FCH_2F)
11) HFC-152a (CH_3CHF_2)
12) HFC-161 (CH_3CH_2F)
13) HFC-227ea (CF_3CHFCF_3)
14) HFC-236cb ($CH_2FCF_2CF_3$)
15) HFC-236ea (CHF_2CHFCF_3)
16) HFC-236fa ($CF_3CH_2CF_3$)
17) HFC-245ca ($CH_2FCF_2CHF_2$)
18) HFC-245fa ($CHF_2CH_2CF_3$)
19) HFC-365mfc ($CH_3CF_2CH_2CF_3$)
20) HFC-43-10mee ($CF_3CHFCHFCF_2CF_3$)
21) HFC-43-10mee ($CF_3CHFCHFCF_2CF_3$)
22) HFC-227ca ($CF_3CF_2CHF_2$)
23) HFC-245cb ($CF_3CF_2CH_3$)
24) HFC-245ea ($CHF_2CHFCHF_2$)
25) HFC-245eb ($CH_2FCHFCF_3$)
26) HFC-263fb ($CH_3CH_2CF_3$)
27) HFC-272ca ($CH_3CF_2CH_3$)
28) HFC-329p ($CHF_2CF_2CF_2CF_3$)
29) HFC-1132a ($CH_2=CF_2$)
30) HFC-1141 ($CH_2=CHF$)
31) (Z)-HFC-1225ye ($CF_3CF=CHF$(Z))
32) (E)-HFC-1225ye ($CF_3CF=CHF$(E))
33) (Z)-HFC-1234ze ($CF_3CH=CHF$(Z))
34) HFC-1234yf ($CF_3CF=CH_2$)
35) (E)-HFC-1234ze (trans-$CF_3CH=CHF$)
36) (Z)-HFC-1336 ($CF_3CH=CHCF_3$(Z))
37) HFC-1243zf ($CF_3CH=CH_2$)
38) HFC-1345zfc ($C_2F_5CH=CH_2$)
39) 3,3,4,4,5,5,6,6,6-Nonafluorohex-1-ene ($C_4F_9CH=CH_2$)
40) 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooct-1-ene ($C_6F_{13}CH=CH_2$)
41) 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-Heptadecafluorodec-1-ene ($C_8F_{17}CH=CH_2$)
42) PFC-14 (CF_4)
43) PFC-116 (C_2F_6)
44) PFC-218 (C_3F_8)
45) PFC-318 (c-C_4F_8)
46) PFC-3-1-10 (C_4F_{10})
47) PFC-4-1-12 (C_5F_{12})
48) PFC-5-1-14 (C_6F_{14})
49) PFC-c216 (c-C_3F_6)
50) Perfluorocyclopentene (c-C_5F_8)
51) PFC-61-16 (n-C_7F_{16})
52) PFC-71-18 (C_8F_{18})
53) PFC-91-18 ($C_{10}F_{18}$)
54) Perfluorodecalin (cis) (Z-$C_{10}F_{18}$)
55) Perfluorodecalin (trans) (E-$C_{10}F_{18}$)
56) PFC-1114 ($CF_2=CF_2$)
57) PFC-1216 ($CF_3CF=CF_2$)
58) Perfluorobuta-1,3-diene ($CF_2=CFCF=CF_2$)
59) Perfluorobut-1-ene ($CF_3CF_2CF=CF_2$)
60) Perfluorobut-2-ene ($CF_3CF=CFCF_3$)

Method 1: Calculation Approach

Based on the 2006 IPCC Guidelines[58], Method 1: Calculation Approach uses the following formula:

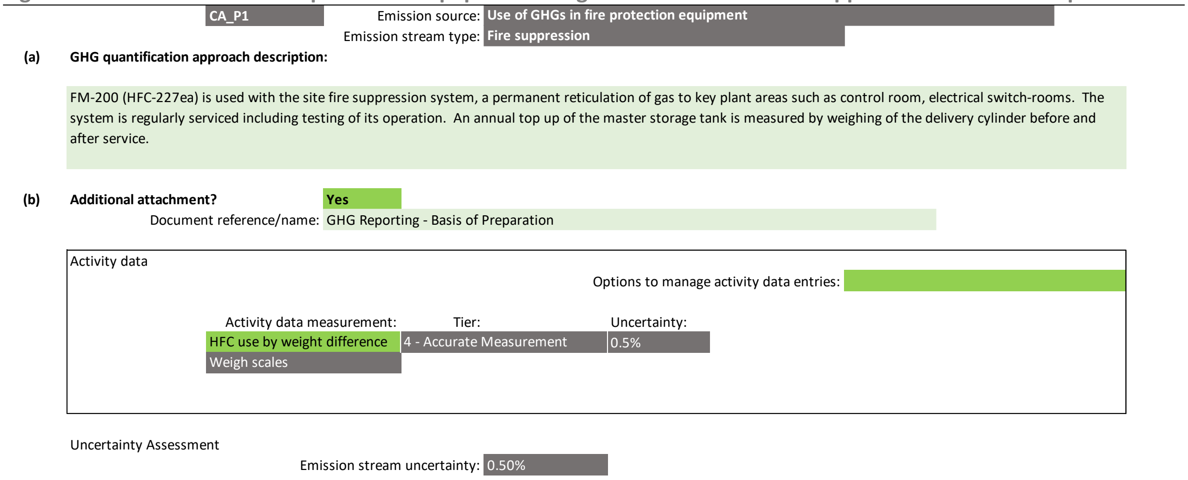
$$E_g = \left(QU_g + QD_g\right) \times GWP_g$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions of GHG (g) i.e. HFCs, PFCs or CO_2	tonne CO_2e	Calculated
QU_g	Amount of the GHG (g) in the equipment used	tonne	Reported (in kg)
QD_g	Amount of the GHG (g) in the equipment disposed of	tonne	Reported (in kg)
g	Type of GHG	Nil	Reported
GWP_g	Global warming potential for GHG (g)	Nil	Constant

The facility is required to report the amount of GHGs in the fire protection equipment that is used, and the amount of GHGs in the equipment disposed of. If an automatic fire suppression system is used for an entire room or other physical spaces, the quantity of GHGs used could be calculated from the top up of any permanent tanks used.

Figure 29 shows a typical configuration for the use of HFCs in fire protection equipment in the MP Template. In the example, the amount of HFCs used is derived by weighing the storage tank of the fire suppression system before and after use. There is no fire protection equipment disposed of.

Figure 29 – Use of GHGs in fire protection equipment using Method 1: Calculation Approach in the MP Template


CA_P1 Emission source: Use of GHGs in fire protection equipment
Emission stream type: Fire suppression

(a) GHG quantification approach description:

FM-200 (HFC-227ea) is used with the site fire suppression system, a permanent reticulation of gas to key plant areas such as control room, electrical switch-rooms. The system is regularly serviced including testing of its operation. An annual top up of the master storage tank is measured by weighing of the delivery cylinder before and after service.

(b) Additional attachment? Yes
Document reference/name: GHG Reporting - Basis of Preparation

Activity data
Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
HFC use by weight difference	4 - Accurate Measurement	0.5%
Weigh scales		

Uncertainty Assessment
Emission stream uncertainty: 0.50%

Default conversion factors and uncertainty

No conversion factor is required for this emission source type. The default uncertainty values would depend on the activity data tier selected and the measurement instrument involved.

[58] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 7, pages 7.61 to 7.65 for more details.

2.12 Use of HFCs or PFCs in refrigeration and air-conditioning equipment

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☐ Method 3: Direct Measurement

The facility is required to specify the following GHG or refrigerant blend used in the refrigeration and air-conditioning equipment as the emission stream type. If a refrigerant blend contains gases which are not GHGs, these gases need not be reported. Where possible, the facility should create separate emission streams for emissions arising from (i) manufacturing (e.g. cooling of processes/cleanrooms) and (ii) non-manufacturing purposes (e.g. general cooling for office buildings).

1) R-401A (13% HFC-152a)
2) R-401B (11% HFC-152a)
3) R-401C (15% HFC-152a)
4) R-402A (60% HFC-125)
5) R-402B (38% HFC-125)
6) R-403A (20% PFC-218)
7) R-403B (39% PFC-218)
8) R-404A (44% HFC-125; 52% HFC 143a; 4% HFC-134a)
9) R-405A (7% HFC-152a; 42.5% PFC-318)
10) R-407A (20% HFC-32; 40% HFC-125; 40% HFC-134a)
11) R-407B (10% HFC-32; 70% HFC-125; 20% HFC-134a)
12) R-407C (23% HFC-32; 25% HFC-125; 52% HFC-134a)
13) R-407D (15% HFC-32; 15% HFC-125; 70% HFC-134a)
14) R-407E (25% HFC-32; 15% HFC-125; 60% HFC-134a)
15) R-408A (7% HFC-125; 46% HFC-143a)
16) R-410A (50% HFC-32; 50% HFC-125)
17) R-410B (45% HFC-32; 55% HFC-125)
18) R-411A (11% HFC-152a)
19) R-411B (3% HFC-152a)
20) R-411C (1.5% HFC-152a)
21) R-412A (5% PFC-218)
22) R-413A (9% PFC-218; 88% HFC-134a)
23) R-415A (18% HFC-152a)
24) R-415B (75% HFC-152a)
25) R-416A (59% HFC-134a)
26) R-417A (46.6% HFC-125; 50% HFC-134a)
27) R-418A (2.5% HFC-152a)
28) R-419A (77% HFC-125; 19% HFC-134a)
29) R-420A (88% HFC-134a)
30) R-421A (58% HFC-125; 42% HFC-134a)
31) R-421B (85% HFC-125; 15% HFC-134a)
32) R-422A (85.1% HFC-125; 11.5% HFC-134a)
69) HFC-23 (CHF_3)
70) HFC-32 (CH_2F_2)
71) HFC-41 (CH_3F)
72) HFC-125 (CHF_2CF_3)
73) HFC-134 (CHF_2CHF_2)
74) HFC-134a (CH_2FCF_3)
75) HFC-143 (CH_2FCHF_2)
76) HFC-143a (CH_3CF_3)
77) HFC-152 (CH_2FCH_2F)
78) HFC-152a (CH_3CHF_2)
79) HFC-161 (CH_3CH_2F)
80) HFC-227ea (CF_3CHFCF_3)
81) HFC-236cb ($CH_2FCF_2CF_3$)
82) HFC-236ea (CHF_2CHFCF_3)
83) HFC-236fa ($CF_3CH_2CF_3$)
84) HFC-245ca ($CH_2FCF_2CHF_2$)
85) HFC-245fa ($CHF_2CH_2CF_3$)
86) HFC-365mfc ($CH_3CF_2CH_2CF_3$)
87) HFC-43-10mee ($CF_3CHFCHFCF_2CF_3$)
88) HFC-227ea (CF_3CHFCF_3)
89) HFC-236cb ($CH_2FCF_2CF_3$)
90) HFC-236ea (CHF_2CHFCF_3)
91) HFC-236fa ($CF_3CH_2CF_3$)
92) HFC-245ca ($CH_2FCF_2CHF_2$)
93) HFC-245fa ($CHF_2CH_2CF_3$)
94) HFC-365mfc ($CH_3CF_2CH_2CF_3$)
95) HFC-43-10mee ($CF_3CHFCHFCF_2CF_3$)
96) HFC-43-10mee ($CF_3CHFCHFCF_2CF_3$)
97) HFC-227ca ($CF_3CF_2CHF_2$)
98) HFC-245cb ($CF_3CF_2CH_3$)
99) HFC-245ea ($CHF_2CHFCHF_2$)
100) HFC-245eb ($CH_2FCHFCF_3$)
101) HFC-263fb ($CH_3CH_2CF_3$)
102) HFC-272ca ($CH_3CF_2CH_3$)
103) HFC-329p ($CHF_2CF_2CF_2CF_3$)
104) HFC-1132a ($CH_2=CF_2$)
105) HFC-1141 ($CH_2=CHF$)
106) (Z)-HFC-1225ye ($CF_3CF=CHF(Z)$)

33) R-422B (55% HFC-125; 42% HFC-134a)
34) R-422C (82% HFC-125; 15% HFC-134a)
35) R-500 (26.2% HFC-152a)
36) R-503 (40.1% HFC-23)
37) R-504 (48.2% HFC-32)
38) R-507A (50% HFC-125; 50% HFC-143a)
39) R-508A (39% HFC-23; 61% PFC-116)
40) R-508B (46% HFC-23; 54% PFC-116)
41) R-509A (56% PFC-218)
42) R-407F (30% HFC-32/30% HFC-125/40% HFC-134a)
43) R-422D (65.1% HFC-125/31.5% HFC-134a/3.4% HC-600a)
44) R-427A (15% HFC-32/25% HFC-125/10% HFC-143a/50% HFC-134a)
45) R-438A (8.5% HFC-32/45% HFC-125/44.2% HFC-134a/1.7% HC-600/0.6% HC-601a)
46) R-448A (26% HFC-32/26% HFC-125/20% HFC-1234yf /21% HFC-134a/7% (E)-HFC-1234ze)
47) R-449A (24.3% HFC-32/24.7% HFC-125/25.7% HFC-134a/25.3% HFC-1234yf)
48) R-452A (11% HFC-32/59% HFC-125/30% HFC-1234yf)
49) R-442A (31% HFC-32/31% HFC-125/30% HFC-134a/3% HFC-152a/5% HFC-227ea)
50) PFC-14 (CF_4)
51) PFC-116 (C_2F_6)
52) PFC-218 (C_3F_8)
53) PFC-318 (c-C_4F_8)
54) PFC-3-1-10 (C_4F_{10})
55) PFC-4-1-12 (C_5F_{12})
56) PFC-5-1-14 (C_6F_{14})
57) PFC-c216 (c-C_3F_6)
58) Perfluorocyclopentene (c-C_5F_8)
59) PFC-61-16 (n-C_7F_{16})
60) PFC-71-18 (C_8F_{18})
61) PFC-91-18 ($C_{10}F_{18}$)
62) Perfluorodecalin (cis) (Z-$C_{10}F_{18}$)
63) Perfluorodecalin (trans) (E-$C_{10}F_{18}$)
64) PFC-1114 (CF_2=CF_2)
65) PFC-1216 (CF_3CF=CF_2)
66) Perfluorobuta-1,3-diene (CF_2=CFCF=CF_2)
67) Perfluorobut-1-ene (CF_3CF_2CF=CF_2)
68) Perfluorobut-2-ene (CF_3CF=$CFCF_3$)
107) (E)-HFC-1225ye (CF_3CF=CHF(E))
108) (Z)-HFC-1234ze (CF_3CH=CHF(Z))
109) HFC-1234yf (CF_3CF=CH_2)
110) (E)-HFC-1234ze (trans-CF_3CH=CHF)
111) (Z)-HFC-1336 (CF_3CH=$CHCF_3$(Z))
112) HFC-1243zf (CF_3CH=CH_2)
113) HFC-1345zfc (C_2F_5CH=CH_2)
114) 3,3,4,4,5,5,6,6,6-Nonafluorohex-1-ene (C_4F_9CH=CH_2)
115) 3,3,4,4,5,5,6,6,7,7,8,8,8 Tridecafluorooct-1-ene ($C_6F_{13}CH$=CH_2)
116) 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-Heptadecafluorodec-1-ene ($C_8F_{17}CH$=CH_2)

Method 1: Calculation Approach

Based on the 2006 IPCC Guidelines[59], Method 1: Calculation Approach uses the following formula:

$$E_g = \left(QU_g + QD_g\right) \times GWP_g$$

[59] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 7, pages 7.43 to 7.60 for more details.

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions of GHG (g) i.e. HFCs or PFCs	tonne CO_2e	Calculated
QU_g	Amount of GHG (g) topped up in the equipment	tonne	Reported (in kg)
QD_g	Amount of GHG (g) in the equipment disposed onsite[60]	tonne	Reported (in kg)
g	Type of GHG	Nil	Reported
GWP_g	Global warming potential for GHG (g)	Nil	Constant

The facility is required to report the amount of HFCs or PFCs used to top up the equipment, and the amount of HFCs or PFCs in the equipment disposed of. If no servicing is conducted to top up HFCs or PFCs, the amount of HFCs or PFCs "topped up" should be equal to the initial charge during manufacturing minus the amount of HFCs or PFCs in equipment disposed of during the reporting period.

Figure 30 shows a typical configuration for the use of HFCs in refrigeration and air-conditioning equipment in the MP Template. In the example, the amount of HFCs used to top up the equipment is derived from the amount topped up as recorded in the invoice billed by air-conditioning contractors. An additional activity data entry has been specified for the amount of HFCs contained in equipment disposed of. Refer to section 5.6.2 of the GHG M&R Guidelines Part II for more details on managing multiple activity data entries. The amount of HFCs contained in equipment disposed of is derived from measuring the weight of the HFC gas cylinders disposed of. The proportion of the activity data for top up and disposal is 50:50.

Figure 30 – Use of HFCs or PFCs in refrigeration and air-conditioning equipment using Method 1: Calculation Approach in the MP Template

CA_P1 — Emission source: **Use of HFCs or PFCs in refrigeration and air-conditioning equipment**

Emission stream type: **R-407C (23% HFC-32; 25% HFC-125; 52% HFC-134a)**

(a) GHG quantification approach description:

The facility maintains a series of air-conditioning units for plant area environmental conditioning. All units are inspected on an annual basis to check for leaks. Units found to be low are assessed and either replaced or topped up. Refrigerant R-407C (a blend of HFC-32/HFC-125/HFC-134a) is used. The quantity of R-407C used is measured by our contractors based on the change in cylinder weight. The proportion of each gas has been provided by the contractor. The capacity of units disposed of is recorded and aggregated for annual reporting.

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

Document reference/name: GHG Reporting - Basis of Preparation

Activity data

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:	Active from	Active to	Proportion
Refigerant use for top-up	4 - Accurate Measurement	0.5%	01-Jan-19		50.00
Weigh scales					

Activity data measurement:	Tier:	Uncertainty:	Active from	Active to	Proportion
HFC Capacity	4 - Accurate Measurement	1.0%	01-Jan-19		50.00
Equipment capacity					

Uncertainty Assessment

Emission stream uncertainty: 0.56%

[60] Refrigerants that are not disposed onsite will not need to be reported.

Default conversion factors and uncertainty

No conversion factor is required for this emission source type. The default uncertainty values would depend on the activity data tier selected and the measurement instrument involved.

2.13 Use of HFCs and PFCs in solvents

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☐ Method 3: Direct Measurement

According to the 2006 IPCC Guidelines, HFC or PFC solvent applications occur in four main areas i.e. precision cleaning, electronics cleaning, metal cleaning and deposition applications, and 100% of the chemical is typically emitted (i.e. released into the atmosphere) within two years of initial use. [61] The HFC/PFC used in the solvent is specified as the emission stream type in the MP Template.

1) HFC-23 (CHF_3)
2) HFC-32 (CH_2F_2)
3) HFC-41 (CH_3F)
4) HFC-125 (CHF_2CF_3)
5) HFC-134 (CHF_2CHF_2)
6) HFC-134a (CH_2FCF_3)
7) HFC-143 (CH_2FCHF_2)
8) HFC-143a (CH_3CF_3)
9) HFC-152 (CH_2FCH_2F)
10) HFC-152a (CH_3CHF_2)
11) HFC-161 (CH_3CH_2F)
12) HFC-227ea (CF_3CHFCF_3)
13) HFC-236cb ($CH_2FCF_2CF_3$)
14) HFC-236ea (CHF_2CHFCF_3)
15) HFC-236fa ($CF_3CH_2CF_3$)
16) HFC-245ca ($CH_2FCF_2CHF_2$)
17) HFC-245fa ($CHF_2CH_2CF_3$)
18) HFC-365mfc ($CH_3CF_2CH_2CF_3$)
19) HFC-43-10mee ($CF_3CHFCHFCF_2CF_3$)
20) HFC-227ca ($CF_3CF_2CHF_2$)
21) HFC-245cb ($CF_3CF_2CH_3$)
22) HFC-245ea ($CHF_2CHFCHF_2$)
23) HFC-245eb ($CH_2FCHFCF_3$)
24) HFC-263fb ($CH_3CH_2CF_3$)
25) HFC-272ca ($CH_3CF_2CH_3$)
26) HFC-329p ($CHF_2CF_2CF_2CF_3$
27) HFC-1132a ($CH_2{=}CF_2$)
28) HFC-1141 ($CH_2{=}CHF$)
29) (Z)-HFC-1225ye ($CF_3CF{=}CHF$(Z))
30) (E)-HFC-1225ye ($CF_3CF{=}CHF$(E))
31) (Z)-HFC-1234ze ($CF_3CH{=}CHF$(Z))
32) HFC-1234yf ($CF_3CF{=}CH_2$)
33) (E)-HFC-1234ze (trans-$CF_3CH{=}CHF$)
34) (Z)-HFC-1336 ($CF_3CH{=}CHCF_3$(Z)
35) HFC-1243zf ($CF_3CH{=}CH_2$)
36) HFC-1345zfc ($C_2F_5CH{=}CH_2$)
37) 3,3,4,4,5,5,6,6,6-Nonafluorohex-1-ene ($C_4F_9CH{=}CH_2$)
38) 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooct-1-ene ($C_6F_{13}CH{=}CH_2$)
39) 3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-Heptadecafluorodec-1-ene ($C_8F_{17}CH{=}CH_2$)
40) PFC-14 (CF_4)
41) PFC-116 (C_2F_6)
42) PFC-218 (C_3F_8)
43) PFC-318 (c-C_4F_8)
44) PFC-3-1-10 (C_4F_{10})
45) PFC-4-1-12 (C_5F_{12})
46) PFC-5-1-14 (C_6F_{14})
47) PFC-c216 (c-C_3F_6)
48) Perfluorocyclopentene (c-C_5F_8)
49) PFC-61-16 (n-C_7F_{16})
50) PFC-71-18 (C_8F_{18})
51) PFC-91-18 ($C_{10}F_{18}$)
52) Perfluorodecalin (cis) (Z-$C_{10}F_{18}$)
53) Perfluorodecalin (trans) (E-$C_{10}F_{18}$)
54) PFC-1114 ($CF_2{=}CF_2$)
55) PFC-1216 ($CF_3CF{=}CF_2$)
56) Perfluorobuta-1,3-diene ($CF_2{=}CFCF{=}CF_2$)
57) Perfluorobut-1-ene ($CF_3CF_2CF{=}CF_2$)
58) Perfluorobut-2-ene ($CF_3CF{=}CFCF_3$)

[61] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 7, pages 7.23 to 7.27 for more details.

Method 1: Calculation Approach

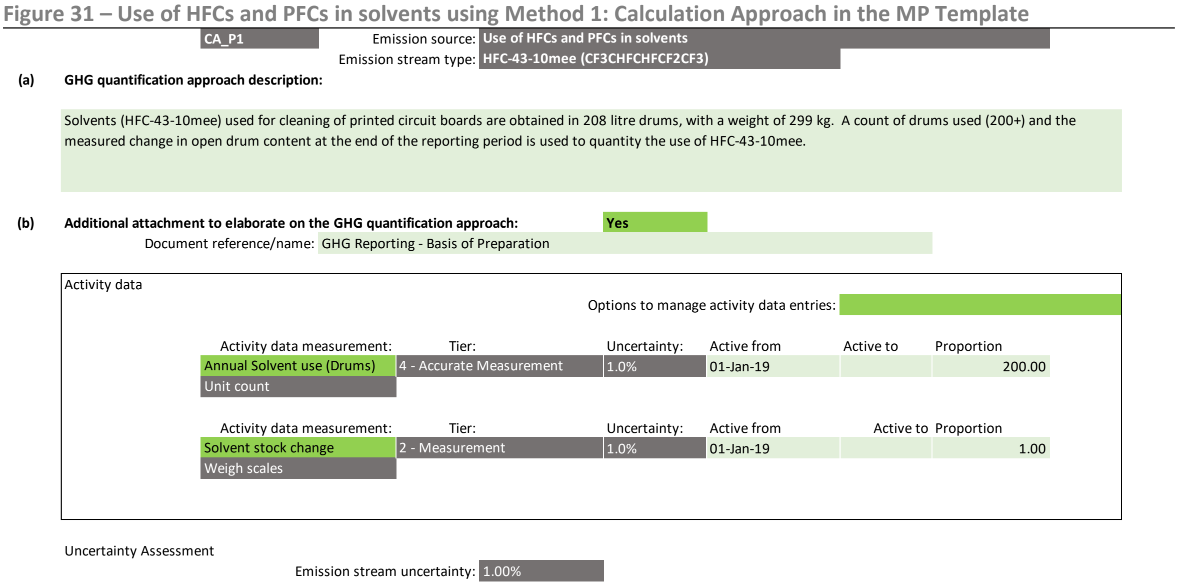
As mentioned, the 2006 IPCC Guidelines assumes all HFCs and PFCs from solvent applications are typically emitted over a two-year period from initial use. However, for ease of reporting, all HFCs and PFCs from solvent applications are assumed to be emitted in the form of a net usage during the reporting period (i.e. within the year of use). This net usage amount would have to be determined by the facility e.g. the total amount that is used in the application less any amount disposed of via a third-party vendor and/or any amount destroyed or recovered during the reporting period. Thereafter, the quantity of HFCs and PFCs emitted is derived based on the stated mass content of the applicable solvent used during the reporting period.

$$E_g = Q_g \times GWP_g$$

Parameter ID	Parameter description	Units	Reporting status
E_g	Emissions of GHG (g) i.e. HFC or PFC	tonne CO_2e	Calculated
Q_g	Quantity of HFC or PFC solvent (g) emitted	tonne	Reported
g	Type of GHG (g) i.e. HFC or PFC	Nil	Reported
GWP_g	Global warming potential for GHG (g)	Nil	Constant

Figure 31 shows a typical configuration for the use of HFCs/PFCs in solvents in the MP Template. In the example, the quantity of solvent used has been estimated based on a count of drums used during the reporting period, with the measurement of the quantity remaining in each open drum at the start and end of the period.

Figure 31 – Use of HFCs and PFCs in solvents using Method 1: Calculation Approach in the MP Template



The unit count and change in stock holding must first be specified on Tab **D. Calc Apch – Metering & Analysis,** as shown in Figure 32, before it could be selected from the activity data measurement dropdown selection in Tab **E. Calc Apch – Emission Streams**.

The uncertainty assessment in the MP Template is focused on statistical uncertainty which is associated with the natural variability of materials/rates of flow and measurement repeatability i.e. how accurate is the instrument and how constant are the measurements (refer to Section 3.3.1 of the

GHG M&R Guidelines Part II). A unit count is an absolute count of items which would nominally have no statistical uncertainty (i.e. default uncertainty is 0%).

In the example, however, statistical uncertainty exists in the estimate of the quantity of solvents actually contained in each drum due to the variability of the manufacturer's filling process. This has not been factored in the default uncertainty of a unit count measurement instrument. As such, the facility has specified a low site-specific uncertainty of 1.0% due to the high value product. Supporting information on how the site-specific uncertainty value was derived will need to be provided.

Figure 32 – Specifying an item count in the MP Template

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument or technique	Tier	Default uncertainty (+/-%)	Site-specific uncertainty (+/-%)	Management procedure name
P1	Annual Solvent use (Drums)	Unit count	4 - Accurate Measurement	0.0%	1.0%	SoP Stores procedures
P1	Solvent stock change	Weigh scales	2 - Measurement	1.0%		SoP Stores procedures

Default conversion factors and uncertainty

No conversion factor is required for this emission source type. The default uncertainty values would depend on the activity data tier selected and the measurement instrument involved.

2.14 Use of lubricants or paraffin waxes

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☐ Method 3: Direct Measurement

There are five emission stream types for the use of lubricants or paraffin waxes based on the 2006 IPCC Guidelines. This is based on the type of lubricants or paraffin waxes used. Lubricants that were topped up due to losses need to be reported.

The use of lubricants in engines is primarily for their lubricating properties and associated emissions are considered as non-combustion emissions to be reported in the IPPU Sector. However, in the case of 2-stroke engines, where the lubricant is mixed with another fuel and thus co-combusted in the engine for providing energy purpose, the emissions should be estimated and reported as part of the combustion emissions (see Section 2.1 Fuel Combustion).

It is difficult to determine which fraction of the lubricant consumed in machinery and in vehicles is actually combusted and thus directly results in CO2 emissions, and the fraction not fully oxidised that results firstly in NMVOC and CO emissions (except for the use in 2-stroke engines, which is excluded here). For this reason, these NMVOC and CO emissions are very seldom reported by countries in the emission inventories. Therefore, for calculating CO2 emissions, the total amount of lubricants lost during their use is assumed to be fully combusted and these emissions are directly reported as CO2 emissions.

i) Lubricating oil (motor oil / industrial oil)

ii) Grease

iii) Average lubricants (default)

iv) Other lubricants

v) Paraffin Wax

For use of lubricants, the facility should select Lubricating oil (motor oil / industrial oil) or Grease (or specify its own type of lubricant) when the different types of lubricants can be quantified independently. Otherwise, the Average lubricants (default) option should be selected and a default weighted average Oxidised During Use (ODU) or oxidation fraction should be applied to the total lubricants quantity.

Method 1: Calculation Approach

Based on the 2006 IPCC Guidelines[62], Method 1: Calculation Approach uses the following formula:

$$E_{CO2} = Q_f \times NCV_f \times C_f \times O_f \times \frac{44}{12}$$

Parameter ID	Parameter description	Units	Reporting status

[62] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 5, pages 5.6 to 5.13 for more details.

E_{CO2}	Emissions of CO_2	tonne CO_2e	Calculated
Q_f	Quantity of lubricant or paraffin wax (f) used	tonne or litre	Reported
NCV_f	Net calorific value of lubricant or paraffin wax (f) used	TJ/tonne or TJ/litre	Constant
C_f	Carbon content of lubricant or paraffin wax (f)	tonne of Carbon/TJ	Reported
O_f	Fraction of the lubricant or paraffin wax (f) oxidised during use	Nil	Reported
f	Lubricant or paraffin wax type (f)	Nil	Reported

The emissions quantification method for the use of lubricants or paraffin waxes is similar to that for fuel combustion, except that the emission factors used incorporate a low oxidation rate that represents the small proportion of lubricants or paraffin waxes that are used in a manner leading to GHG emissions. Only CO_2 emissions are quantified as CH_4 and N_2O emissions are assumed to be negligible.

Figure 33 shows a typical configuration for the use of lubricants in the MP Template. In the example, an engineering estimate has been used to estimate the annual usage of lubricating oils that were subject to high enough temperatures for oxidation to occur. The estimate is derived from the amount of lubricants dispatched from the store which is recorded during a three-month period. The IPCC default oxidation fraction of 20% for lubricating oils is used.

The engineering estimate must first be specified on Tab **D. Calc Apch – Metering & Analysis,** as shown in Figure 34, before it could be selected from the activity data measurement dropdown selection in Tab **E. Calc Apch – Emission Streams**. For engineering estimates, the facility is required to provide a description of the engineering estimate (i.e. the methodology and assumption used) in the Monitoring Plan submission, as well as a justification that the engineering estimate (i) is appropriate, (ii) enables the GHG emissions to be accurately computed, and (iii) is based on technical or scientific considerations.

The default uncertainty of 10% for engineering estimate is used. The overall uncertainty, as shown in Figure 33, is mainly influenced by the high uncertainty of the oxidation fractions as they are based on limited knowledge of typical lubricant oxidation rates.

Figure 33 – Use of lubricants using Method 1: Calculation Approach in the MP Template

CA_P1 Emission source: Use of lubricants or paraffin waxes

Emission stream type: Lubricating oil (motor oil / industrial oil)

(a) GHG quantification approach description:

Lubricants are used on-site in a number of plant equipment. The quantity of lubricants consumed is derived as an engineering estimate based on an analysis of store records for a three month period. One month included a plant major maintenance shutdown, when the use of lubricants increased by a factor of four. An estimate has been determined of the estimated annual usage. The analysis indicated that only lubricant oils are subject to applications with sufficient heating for combustion to occur. No grease is included. The default carbon and oxidation factors are used.

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

Document reference/name: GHG Reporting - Basis of Preparation

Activity data

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Annual lubricant oil use	1 - Engineering estimate	10.0%
Engineering estimate		

Overall Activity data uncertainty: 10.00%

Conversion factor: Carbon content Emission factor

Data source: Default

Uncertainty: 3.0%

Conversion factor: Oxidation fraction

Data source: Default

Uncertainty: 50.0%

Uncertainty Assessment

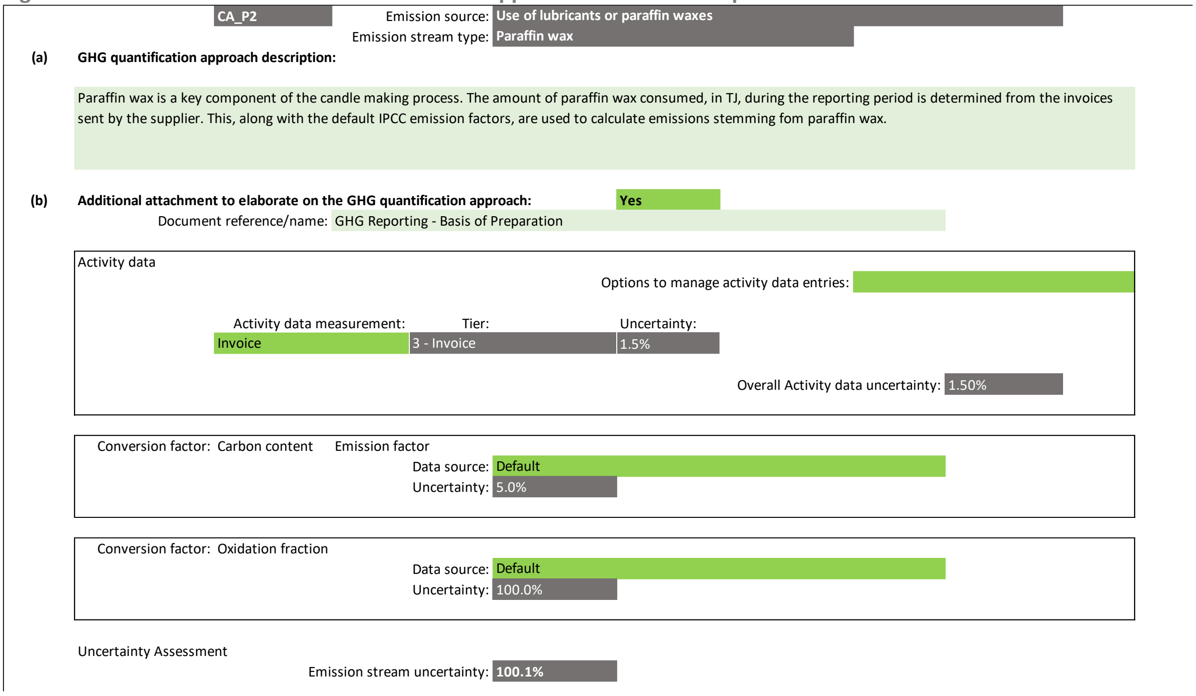
Emission stream uncertainty: 51.1%

Figure 34 – Specifying an engineering estimate in the MP Template

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument or technique	Tier	Default uncertainty (+/-%)	Specified uncertainty (+/-%)	Measurement procedure reference/name
P1	Annual lubricant oil use	Engineering estimate	1 - Engineering estimate	10.0%		SoP Stores procedures

Figure 35 shows a typical configuration for the use of paraffin wax in the MP Template. In the example, the IPCC default for the carbon content of the paraffin wax and the oxidation fraction are used. The amount of paraffin wax consumed will be derived from the invoice data received from suppliers to calculate the emissions.

Figure 35 – Use of Paraffin Wax with Calculation approach in the MP Template


CA_P2 Emission source: Use of lubricants or paraffin waxes
Emission stream type: Paraffin wax

(a) GHG quantification approach description:

Paraffin wax is a key component of the candle making process. The amount of paraffin wax consumed, in TJ, during the reporting period is determined from the invoices sent by the supplier. This, along with the default IPCC emission factors, are used to calculate emissions stemming fom paraffin wax.

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

Activity data
Options to manage activity data entries:
Activity data measurement: Invoice
Tier: 3 - Invoice
Uncertainty: 1.5%
Overall Activity data uncertainty: 1.50%

Conversion factor: Carbon content Emission factor
Data source: Default
Uncertainty: 5.0%

Conversion factor: Oxidation fraction
Data source: Default
Uncertainty: 100.0%

Uncertainty Assessment
Emission stream uncertainty: 100.1%

Default conversion factors and uncertainty

The quantity of lubricant or paraffin wax used is usually reported in terms of tonne or litres. The default net calorific values (NCV) to convert the quantity of lubricants and paraffin waxes from tonne or litres to TJ are the same as those used for reporting in the ECA EUR (GHG from non-fuel combustion processes or activities) i.e. IPPU Emission Spreadsheet (refer to

Table 17).

Table 17 – Net calorific values for lubricants and paraffin waxes

Emission stream type	Net calorific value, NCV_f	
	TJ/litre (l)	TJ/tonne
Lubricating oil (motor oil / industrial oil)	0.00003708961845608 (or 3.70896E-05)	0.0418
Grease		
Average lubricants (default)		
Other lubricants		
Paraffin wax	0.00003197115384615 (or 3.19712E-05)	0.0399

The default carbon content[63] (based on lower heating value), oxidation fraction[64] and uncertainty values[65] for use of lubricant and paraffin wax are shown in Table 18. These conversion factors and uncertainty values are based on the 2006 IPCC Guidelines.

[63] Refer to the 2006 IPCC Guidelines, Volume 2, Chapter 1, Table 1.3 (lubricant) for more details.
[64] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 5, Table 5.2 (Oxidation During Use (ODU)) for more details.
[65] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 5, section 5.2.3.1 and section 5.3.3.1 for more details.

The default oxidation fractions developed by IPCC are very broad estimates, as they are based on limited knowledge of the typical lubricant oxidation rates and the limited knowledge of the circumstances of paraffin waxes used. The default oxidation fraction is four times smaller for greases than for lubricating oils or paraffin waxes. For Average (default) lubricant type, the default oxidation fraction is the weighted average oxidation fraction for lubricants as a whole. This assumes 90% of the mass of lubricants is lubricating oil and 10% is grease, and these weights are applied to the oxidation fractions for oils and greases.

Based on the assumption that site-specific carbon content and oxidation fraction are more accurate, the default uncertainty values for Tier 1 site-specific conversion factors assume a higher accuracy reflecting GHG specific and equipment specific data. The default uncertainty is assumed to be 2% for Tier 1 site-specific carbon content factor for lubricants, and 3% for paraffin waxes. These uncertainty values reflect facilities knowing the specific type of oil being used compared to the variability represented by the IPCC default uncertainty values, without actual ongoing analysis by the facility. Where a facility provides a Tier 1 site-specific oxidation fraction, the uncertainty is assumed to be 10%, significantly lower than the uncertainty for the IPCC default oxidation fraction which covers a wide variety of applications/circumstances. The 10% uncertainty has been used to represent the difficulty in measuring the actual combustion rates.

Table 18 – Tier 1 default conversion factors and uncertainty values for the use of lubricants or paraffin waxes

Emission stream type	Carbon content factor, C_f			Oxidation fraction, O_f		
	tonne C/TJ	Tier 1 default uncertainty	Tier 1 site-specific uncertainty	Fraction	Tier 1 default uncertainty	Tier 1 site-specific uncertainty
Lubricating oil (motor oil / industrial oil)	20	3%	2%	0.2	50%	10%
Grease	20	3%	2%	0.05	50%	10%
Average lubricants (default)	20	3%	2%	0.2	50%	10%
Other lubricants	N/A	N/A	2%	N/A	N/A	10%
Paraffin wax	20	5%	3%	0.2	100%	10%

2.15 Use of SF_6 in electrical equipment

☒ Method 1: Calculation Approach

☐ Method 2: Material Balance

☐ Method 3: Direct Measurement

SF6 is used in electrical equipment such as insulated switchgear and substations (GIS), gas circuit breakers (GCB), high voltage gas insulated lines (GIL), outdoor gas-insulated instrument transformer and other equipment.

There are 12 emission stream types for the use of SF_6 in electrical equipment. The emission stream types are grouped into manufacture, use/installation[66] and disposal, and further divided by the type of electrical equipment as listed in the IPPU emission spreadsheet.

i) Use - Sealed Pressure[67] (MV Switchgear)

ii) Use - Closed Pressure[68] (HV Switchgear)

iii) Use - Gas Insulated Transformers

iv) Use - Others

v) Manufacture - Sealed Pressure (MV Switchgear)

vi) Manufacture - Closed Pressure (HV Switchgear)

vii) Manufacture - Gas Insulated Transformers

viii) Manufacture - Others

ix) Disposal - Sealed Pressure (MV Switchgear)

x) Disposal - Closed Pressure (HV Switchgear)

xi) Disposal - Gas Insulated Transformers

xii) Disposal - Others

[66] The usage and installation of SF_6 equipment share the same emission stream form. For emissions arising from installation of SF_6 equipment, the facility is required to select "Use – Sealed Pressure (MV Switchgear)", "Use – Closed Pressure (HV Switchgear)", "Use – Gas Insulated Transformers" or "Use – Others" as the emission stream type.
[67] Sealed pressure systems are defined as equipment that do not require any refilling with gas during its lifetime and which generally contain less than 5kg of gas per functional unit.
[68] Closed pressure systems are defined as equipment that require refilling with gas during its lifetime and which generally contain between 5 and ~100 kg of gas per functional unit.

Method 1: Calculation Approach

The 2006 IPCC Guidelines[69] use the following formula:

Total Emissions = Manufacturing Emissions + Equipment Installation Emissions + Equipment Use Emissions + Equipment Disposal Emissions

Equipment use and installation emissions

The facility using electrical equipment containing SF_6 is required to report emissions due to:

- Losses during filling of new equipment (installation); and
- Leakage from installed equipment.

Method 1: Calculation Approach uses the following formula:

$$E_{SF6} = E_{SF6,install} + E_{SF6,usage}$$

The emissions from filling of new equipment can be derived from difference between the quantity of SF_6 used to fill the new equipment and the capacity of the new equipment:

$$E_{SF6,install} = (Q_{t,SF6} - Cap_{t,New}) \times GWP_{SF6}$$

The emissions from use of installed equipment is determined based on the following formula:

$$E_{SF6,Use} = (Cap_{t,Stock} \times EF_{t,Stock}) \times GWP_{SF6}$$

The usage leakage rate for equipment use includes emissions due to leakage, servicing, and maintenance as well as failures. As the leakage rate for equipment use is difficult to measure, an alternative approach is to report the quantity of SF_6 used to top up the installed equipment. In this case, the leakage rate for equipment use will be 1 (i.e. quantity of SF_6 topped up equals to leakage quantity). The facility is required to specify the type of activity data to be used for equipment use emissions, either 'Equipment Capacity' or 'Quantity used' (refer to Figure 36).

Parameter ID	Parameter description	Units	Reporting status
E_{SF6}	Emissions of SF_6	tonne CO_2e	Calculated
$E_{SF6, Install}$	Emissions of SF_6 from filling of new equipment	tonne CO_2e	Calculated
$E_{SF6, Use}$	Emissions of SF_6 from use of installed equipment	tonne CO_2e	Calculated
$Cap_{t,New}$	Capacity of new equipment (t)	tonne SF_6	Reported
$Q_{t,SF6}$	Quantity of SF_6 used to fill new equipment (t)	tonne SF_6	Reported
$Cap_{t,Stock}$	Capacity of installed equipment (t)	tonne SF_6	Reported
$EF_{t, Stock}$	Usage leakage rate for equipment (t) during use	Factor	Reported

[69] Refer to 2006 IPCC Guidelines, Volume 3, Chapter 8, pages 8.6 to- 8.22 for more details.

Parameter ID	Parameter description	Units	Reporting status
t	Type of equipment (i.e.: sealed-pressure, closed-pressure, gas-insulated transformers, other)	Nil	Reported
GWP_{SF6}	Global warming potential for SF_6	Nil	Constant

The facility may wish to consider the application of industry protocols for the management and reporting of SF_6. Examples of these inventory reporting protocols are detailed in the following documents:

i) *ENA Industry Guideline for SF_6 Management*, Energy Networks Association, 2008[70]. Appendix A

ii) *ENA Industry Guideline for SF_6 Management*, Energy Networks Association, 2008. Section 6.3 (Potentially tier 3)

Depending on the approach for quantifying the activity data, the facility is required to specify either or both of the following:

i) SF_6 capacity of electrical equipment (new and/or installed)

ii) Quantity of SF_6 used to top up installed equipment and/or fill new equipment.

Figure 36 shows an example where a facility uses the SF_6 capacity of installed equipment and the default leakage rate to quantify emissions from use of installed equipment. For the 'Activity data to be used', the facility selects 'Equipment Capacity'. The SF_6 capacity of each installed equipment is determined based on the nameplate/design capacity and an inventory is maintained on the number of each equipment type.

In the example, the emissions from filling of new equipment is determined based on the difference between the quantity of SF_6 used to fill any new equipment that may be installed and the SF_6 capacity of the new equipment that may be installed. The new equipment is filled using bottles and the bottles are weighed before and after use to quantify the amount used. If there is no new equipment installed, the 'Quantity of SF_6 used to fill new equipment and/or top up equipment' section can be left blank.

[70] Refer to http://infostore.saiglobal.com/store/Details.aspx?ProductID=1506769 for more details.

Figure 36 – Use of SF_6 in electrical equipment using equipment capacity for quantifying equipment use emissions

CA_P1	Emissions source:	SF6 in electrical equipment
	Emissions stream type:	Use - Closed Pressure (HV Switchgear)
	Activity data to be used:	Equipment Capacity

(a) GHG quantification approach description:

SF6 is used in a number of electrical switchgear items. The capacity of SF6 for each equipment type has been determined and an inventory maintained of the number of items of each type. The default leakage rate will be used to estimate emissions.
Any new equipment received is filled from bottles. The bottles used to fill new equipment are weighed before and after use. The unaccounted SF6 (used – capacity) will be used to derive the loss rate for new equipment.

(b) Additional attachment? Yes

Benchmark/justification document reference/name: GHG Reporting - Basis of Preparation

SF_6 capacity of equipment

Activity data measurement:	Tier:	Uncertainty:
SF6 in electrical equipment	4 - Accurate Measurement	1.0%
Equipment capacity		

Overall Activity data uncertainty: 1.00%

Conversion factor: Annual leakage rate

Data source: Default
Uncertainty: 30.0%

Quantity of SF_6 used to fill new equipment and/or top up equipment

Activity data measurement:	Tier:	Uncertainty:
Quantity of SF6 used	2 - Measurement	1.0%
Weigh scales		

Overall Activity data uncertainty: 1.00%

Uncertainty Assessment

Emissions stream uncertainty: **30.0%**

Figure 37 shows an example where a facility uses the quantity of SF_6 used to top up the installed equipment to quantify the emissions from use of installed equipment. The facility selects ‘Quantity used’ for the ‘Activity data to be used’. The quantity used to top up is determined by weighing the bottles used before and after use. The section for ‘Conversion factor: Annual leakage rate’ should be left blank as the quantity of SF_6 topped up is measured.

In this example, the emissions from filling of new equipment is determined based on the difference between the quantity of SF_6 used to fill any new equipment that may be installed and the SF_6 capacity of the new equipment that may be installed. The new equipment is filled using bottles and the bottles are weighed before and after use to quantify the amount used. As the activity data measurement for the quantity topped-up for installed equipment and the quantity used to fill new equipment are the same (i.e. using weighing scale to measure weight before and after use), only one activity data measurement entry is required. Otherwise, an additional activity data measurement entry should be added.

Figure 37 – Use of SF_6 in electrical equipment using the quantity of SF_6 used to top up for quantifying equipment use emissions

CA_P2 Emissions source: SF6 in electrical equipment

Emissions stream type: Use - Sealed Pressure (MV Switchgear)

Activity data to be used: Quantity used

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

SF6 is used in a number of electrical switchgear items. The equipment type used allows top ups, which are undertaken as required on an annual review. The bottles used to fill equipment are weighed before and after use.

(b) **Additional attachment?** **Yes**

Benchmark/justification document reference/name: GHG Reporting - Basis of Preparation

SF_6 capacity of equipment

Activity data measurement:	Tier:	Uncertainty:
SF6 Capacity of equipment	4 - Accurate Measurement	1.0%
Equipment capacity		

Overall Activity data uncertainty: 1.00%

Conversion factor: Annual leakage rate

Data source:

Uncertainty: -

Quantity of SF_6 used to fill new equipment and/or top up equipment

Activity data measurement:	Tier:	Uncertainty:
Quantity of SF6 used	2 - Measurement	1.0%
Weigh scales		

Overall Activity data uncertainty: 1.00%

Uncertainty Assessment

Emissions stream uncertainty: **1.0%**

For both examples above, the measurement instrument for activity data must first be specified on Tab **D. Calc Apch – Metering & Analysis,** as shown in Figure 38, before it could be selected from the activity data measurement dropdown selection in Tab **E. Calc Apch – Emission Streams**.

In Figure 38, the facility specified the 'Equipment capacity' and 'Weigh scales' used for the SF_6 capacity of the installed and/or new equipment, and the quantity of SF_6 used for top up and/or for the filling of new equipment. The default uncertainty[71] for the measurement instruments are used.

If the facility is unable to develop a complete inventory of the installed equipment and the SF_6 capacity, or accurately measure the quantity of SF_6 used, an engineering estimate could be used. The engineering estimate should also be specified on Tab **D. Calc Apch – Metering & Analysis**.

Figure 38 – Specifying the activity data measurement instrument or technique in the MP Template for use of SF_6 in electrical equipment

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument or technique	Tier	Default uncertainty (+/-%)	Specified uncertainty (+/-%)	Measurement procedure reference/name	Remove row Options
CA_P1	SF6 in electrical equipment	Equipment capacity	4 - Accurate Measurement	1.0%		SOP - SF6 management	
CA_P1	Quantity of SF6 used	Weigh scales	2 - Measurement	1.0%		SOP - SF6 management	

Manufacturing emissions

The facility which manufacture electrical equipment containing SF_6 is required to report the emissions due to losses during filling of the equipment.

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

71 For equipment capacity, the uncertainty is associated with the accuracy of the stated nameplate capacity of the equipment.

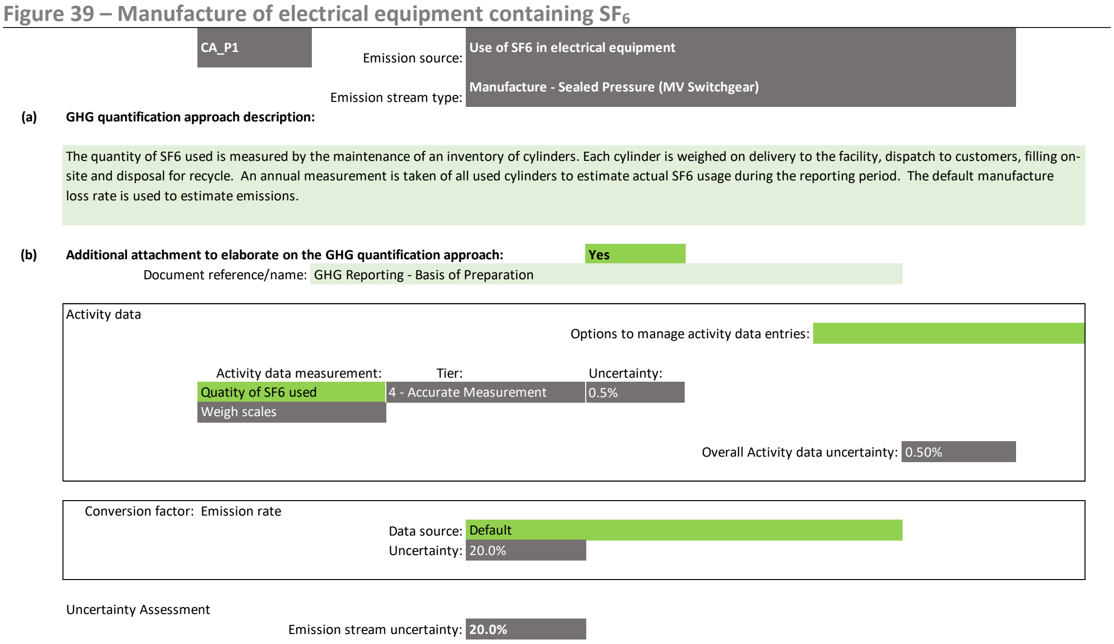
$$E_{SF6} = Q_t \times EF_t \times GWP_{SF6}$$

Parameter ID	Parameter description	Units	Reporting status
E_{SF6}	Emissions of SF_6	tonne CO_2e	Calculated
Q_t	Quantity of SF_6 used to fill equipment by (t)	tonne SF_6	Reported
EF_t	Manufacture emission rate for equipment (t) during filling	Factor	Reported
t	Type of equipment (i.e. sealed-pressure, closed-pressure, gas-insulated transformers, other)	Nil	Reported
GWP_{SF6}	Global warming potential for SF_6	Nil	Constant

Figure 39 shows an example where a facility measures the quantity of SF_6 used to fill equipment and the default manufacture emission rate. The quantity of SF_6 used can be measured using weighing scales or based on the invoiced quantity of SF_6 received during the reporting period. The quantity shall also include the quantity of SF_6 leaked during maintenance and servicing.

For this example, the measurement instrument for measuring the quantity of SF_6 used must first be specified on Tab **D. Calc Apch – Metering & Analysis,** as shown in Figure 38, before it could be selected from the activity data measurement dropdown selection in Tab **E. Calc Apch – Emission Streams**.

Figure 39 – Manufacture of electrical equipment containing SF_6


CA_P1

Emission source: Use of SF6 in electrical equipment

Emission stream type: Manufacture - Sealed Pressure (MV Switchgear)

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

The quantity of SF6 used is measured by the maintenance of an inventory of cylinders. Each cylinder is weighed on delivery to the facility, dispatch to customers, filling on-site and disposal for recycle. An annual measurement is taken of all used cylinders to estimate actual SF6 usage during the reporting period. The default manufacture loss rate is used to estimate emissions.

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

Document reference/name: GHG Reporting - Basis of Preparation

Activity data

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
Quatity of SF6 used	4 - Accurate Measurement	0.5%
Weigh scales		

Overall Activity data uncertainty: 0.50%

Conversion factor: Emission rate

Data source: Default

Uncertainty: 20.0%

Uncertainty Assessment

Emission stream uncertainty: 20.0%

The facility using a site-specific manufacture emission rate can derive it from the quantity of SF_6 used to fill the equipment compared to the capacity of the equipment:

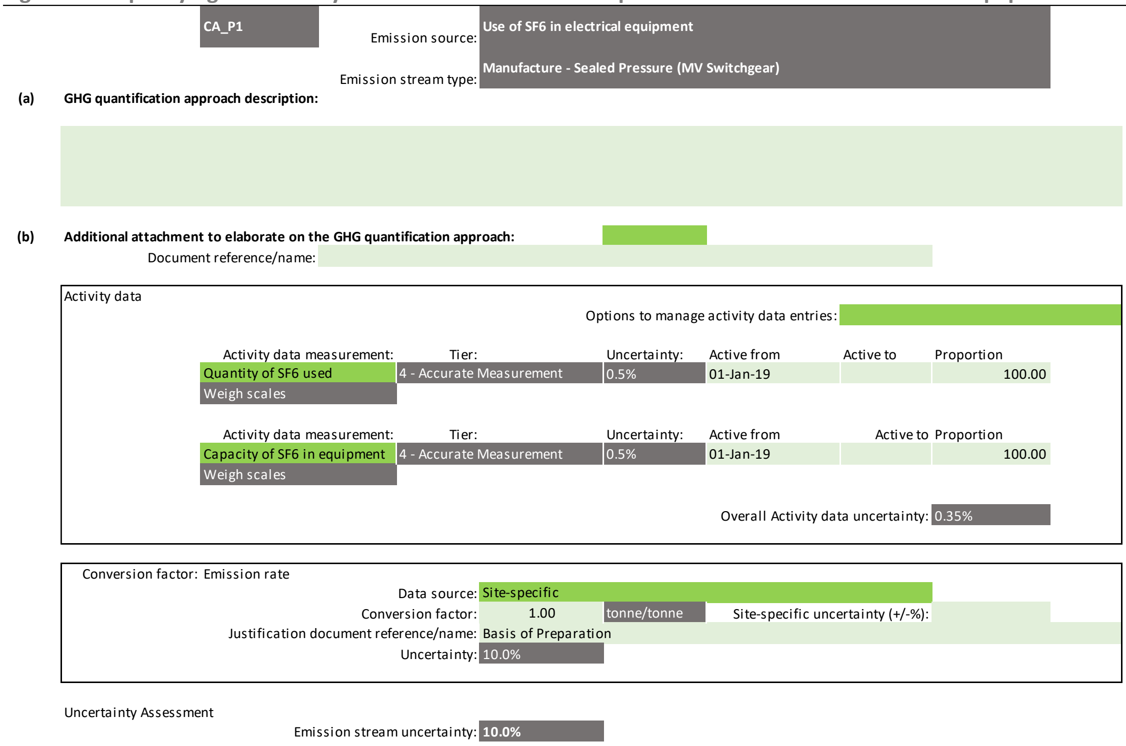
$$EF_t = \frac{Q_t - Cap_t}{Q_t}$$

Where Cap_t is the capacity of the equipment of type (t).

In the example in Figure 40, two activity data values are recorded in Tab **E. Calc Apch – Emission Streams**, one is for the quantity of gas used (Q_t) and another for the capacity of equipment manufactured (Cap_t). The difference is essentially the manufacture emissions.

$$E_{SF6} = Q_t \times \frac{Q_t - Cap_t}{Q_t} \times GWP_{SF6} = (Q_t - Cap_t) \times GWP_{SF6}$$

Figure 40 – Specifying two activity data entries in the MP Template for manufacture of electrical equipment with SF_6



Equipment disposal emissions

The facility which dispose of electrical equipment that contain SF_6 must either:

i) provide evidence to the NEA that the recycling company engaged to dispose of equipment will manage the SF_6 gas contained in the equipment in an approved manner; or

ii) report emissions due to SF_6 remaining in the disposed equipment and not captured for recycling or destruction.

The IPCC method uses the following formulae:

$$E_{SF6} = Cap_t \times EF_t \times GWP_{SF6}$$

Parameter ID	Parameter description	Units	Reporting status
E_{SF6}	Emissions of SF_6	tonne CO_2e	Calculated
Cap_t	SF_6 capacity of equipment (t)	tonne SF_6	Reported
EF_t	Fraction of SF_6 remaining (not captured for recycling or destruction) at disposal for equipment (t)	Factor	Reported
t	Type of equipment (i.e. sealed-pressure, closed-pressure, gas-insulated transformers, other)	Nil	Reported

Parameter ID	Parameter description	Units	Reporting status
GWP_{SF6}	Global warming potential for SF_6	Nil	Constant

The facility using a site-specific fraction of SF_6 remaining in the disposed equipment can derive it from the quantity of SF_6 released from the equipment and the capacity of the equipment:

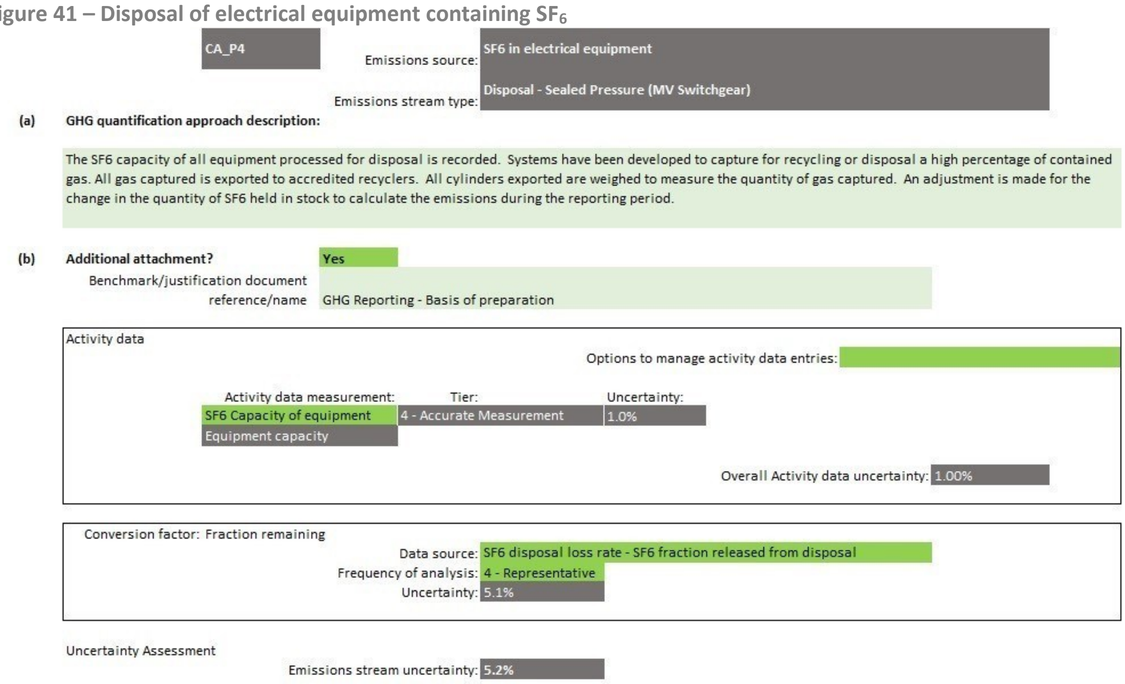
$$EF_t = \frac{Cap_t - Q_t}{Cap_t}$$

Where Q_t is the quantity of SF_6 not captured for recycling from equipment of type (t) as measured by the change in weight of the equipment after removal of the gas.

Figure 41 shows an example where a facility measures the SF_6 capacity of all equipment disposed and the site-specific fraction of SF_6 remaining in the disposed equipment. The facility captures the majority of the gas received in the equipment and exports to accredited recyclers. All cylinders exported are weighed to measure the quantity of gas captured and exported. The facility calculates the site-specific fraction remaining (EF_t) based on the rated capacity of the equipment and the quantity of gas exported, including an allowance for the quantity of gas held in stock. This adjustment ensures the emissions calculated are aligned to the reporting period.

For the example below, the approach for measuring the SF_6 capacity of equipment must first be specified on Tab **D. Calc Apch – Metering & Analysis,** as shown in Figure 38, before it could be selected from the activity data measurement dropdown selection in Tab **E. Calc Apch – Emission Streams**.

Figure 41 – Disposal of electrical equipment containing SF_6


CA_P4

Emissions source: SF6 in electrical equipment

Emissions stream type: Disposal - Sealed Pressure (MV Switchgear)

(a) GHG quantification approach description:

The SF6 capacity of all equipment processed for disposal is recorded. Systems have been developed to capture for recycling or disposal a high percentage of contained gas. All gas captured is exported to accredited recyclers. All cylinders exported are weighed to measure the quantity of gas captured. An adjustment is made for the change in the quantity of SF6 held in stock to calculate the emissions during the reporting period.

(b) Additional attachment? Yes

Benchmark/justification document reference/name: GHG Reporting - Basis of preparation

Activity data

Options to manage activity data entries:

Activity data measurement:	Tier:	Uncertainty:
SF6 Capacity of equipment	4 - Accurate Measurement	1.0%
Equipment capacity		

Overall Activity data uncertainty: 1.00%

Conversion factor: Fraction remaining

Data source: SF6 disposal loss rate - SF6 fraction released from disposal

Frequency of analysis: 4 - Representative

Uncertainty: 5.1%

Uncertainty Assessment

Emissions stream uncertainty: 5.2%

Figure 42 shows how the analysis of the fraction remaining could be detailed on Tab **D. Calc Apch – Metering & Analysis**. The fraction remaining is calculated from the measured quantity of SF_6 captured and the rated SF_6 capacity of the equipment processed. This is an analysis technique rather than an instrument type. The facility entered a description of the technique and conversion factor parameter. As an instrument type was not selected from the available dropdown, a site-specific uncertainty must be specified. In the example, an uncertainty of 5.1%[72] was specified based on the combined uncertainty of the measurement of SF_6 capture and accuracy of gas contained in the equipment as received against the rated capacity.

Figure 42 – Specifying site-specific fraction remaining in the MP Template for disposal of electrical equipment with SF_6

Relevant emission stream(s)	Internal identifier/name	Type of measurement instrument	Conversion factor	Default uncertainty (+/-%)	Specified uncertainty (+/-%)	Analysis procedure reference/name	Remove row Options
CA_P2	SF6 loss rate	Calculation from usage and capacity	SF6 fraction released from disposal		4.0%	SOP - SF6 management	

Default conversion factors and uncertainty

The default IPCC conversion factors[73] and uncertainty[74] for SF_6 in electrical equipment are shown in Table 19. The conversion factors were obtained based on the regional values for Japan[75]. The default uncertainty values for the fraction remaining were not provided by IPCC. An uncertainty of 5% has been assumed based on the default factor of 95%.

The default uncertainty for Tier 1 site-specific conversion factors is half or one-third of the default for the manufacturing emission rates due to the ability of the facility to measure actual loss for the facility. The uncertainty will still remain relatively high as it is based on the comparison between losses and gas used. It may be lower than 10%, however facilities would need to justify a lower value. The site-specific uncertainty for fraction remaining at disposal is equal to the default (5%) as facilities may not have any control over the life span of equipment and leakage over the period.

Table 19 – Tier 1 default conversion factors and uncertainty values for use of SF_6 in electrical equipment

Equipment type	Manufacture emission rate			Usage leakage rate			Fraction remaining at disposal		
Equipment type	Factor	Tier 1 default uncertainty	Tier 1 site-specific uncertainty	Factor	Tier 1 default uncertainty	Tier 1 site-specific uncertainty	Factor	Tier 1 default uncertainty	Tier 1 site-specific uncertainty
Sealed Pressure (MV Switchgear)	0.29	20%	10%	0.007	20%	10%	0.95	5%	5%
Closed Pressure (HV Switchgear)	0.29	30%	10%	0.007	30%	10%	0.95	5%	5%
Gas Insulated Transformers	0.29	30%	10%	0.007	30%	10%	0.95	5%	5%
Others	Not available		10%	Not available		10%	Not available		5%

[72] Assumptions: Uncertainty for measurement of SF_6 captured is 1% and uncertainty for gas in equipment compared to rated capacity is 5%. Combined uncertainty is Ö(1%^{2} + 5%^{2}) = 5.1%. The 5% uncertainty for capacity represents the potential loss of gas over the life of the equipment from leakage (refer Table 19, Faction remaining at disposal).

[73] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 8, Tables 8.2 to 8.4.

[74] Refer to the 2006 IPCC Guidelines, Volume 3, Chapter 8, Table 8.5.

[75] Based on data reported by the Federation of Electric Power Companies (FEPC) and the Japan Electrical Manufacturers' Association (JEMA) (FEPC and JEMA, 2004). These organisations did not distinguish among equipment types in reporting average emission factors. The factors are therefore intended to be applied to all equipment types, including sealed pressure systems, closed pressure systems, and gas-insulated transformers.

2.16 Any other process or activity resulting in greenhouse gas emissions

☒ Method 1: Calculation Approach

☒ Method 2: Material Balance

☒ Method 3: Direct Measurement

The facility should use the appropriate and specific IPPU emission source as defined in the MP Template when available. The MP Template allows a facility to report any emission source that is not covered. The facility would have to select "Any other process or activity resulting in greenhouse gas emissions" as the emission source and enter a relevant description for the emission stream type. Any of the three emissions quantification methods can be selected.

Method 1: Calculation Approach

The facility may identify a calculation formula that can be used to estimate emissions. The formula will include activity data and conversion factors. The source of the activity data and conversion factors should be recorded in the MP Template.

The emission stream form is a generic form for calculation method which allows the entry of up to eight activity data measurements and four conversion factors. If more activity data measurements or conversion factors are required, the facility can add a second emission stream.

The emission stream form used for this emission source is also used for most sub-processes under 'Vents'. Figure 11 shows an example of the form where the facility can specify its own conversion factors.

The facility is required to calculate the uncertainty of the conversion factor specified. Generally, Equation A in Section 3.3.4 of the M&R Guidelines Part II is used to calculate the uncertainty of each GHG, and Equation B is used to aggregate the uncertainty of each GHG to calculate the overall uncertainty for the emission stream. However, if the formula for an individual gas includes the aggregation of multiple activity data values, Equation B may also be required.

Method 2: Material Balance

Method 2: Material Balance can be used if CO_2 emissions are released and carbon is contained in a process feedstock as well as in a product or waste stream.

The emission stream form is a generic form for material balance which allows the entry of up to eight material streams (feedstock, product or waste streams). If more material streams are required, the facility can add a second emission stream.

If the emission source also includes GHG emissions other than CO_2, a separate emission stream would be required to record the monitoring and reporting approach for the other GHGs. Method 1: Calculation Approach or Method 3: Direct Measurement could be used for the non-CO_2 emissions.

The emission stream form for this emission source is also used for:

i) The steam methane reforming (hydrogen plants) sub-process under the vents emission source. Figure 16 shows an example of how the form is used.

ii) The coal gasification emission source. Figure 20 shows an example of how the form is used.

The form will automatically calculate the overall uncertainty of the emission stream.

Method 3: Direct Measurement

Method 3: Direct Measurement can be used if the GHG emissions are measured directly within a constrained exhaust system.

The emission stream form is a generic form for direct measurement which allows the entry of up to four direct monitoring points (each monitoring point measures a flow rate and GHG concentration. If more monitoring points are required, the facility can add a second emission stream form.

If the emission source also includes GHG emissions which are not being measured directly, a second emission stream would be required to record the monitoring and reporting approach for the other GHGs. Method 1: Calculation Approach or Method 3: Direct Measurement could be used.

The emission stream form for this emission source is also used for:

i) The steam methane reforming (hydrogen plants) sub-process for the vents emission source. Figure 17 shows an example of how the form is used.

ii) Fuel combustion emission source. Figure 2 shows an example of how a similar form is used.

iii) Ethylene production emission source. Figure 9 shows an example of how a similar form is used.

The form will automatically calculate the overall uncertainty of the emission stream.

3. Default uncertainty values for measurement instruments

Default uncertainty values for the following list of measurement instruments used to derive (i) Tier 2 or 4 activity data and (ii) Tier 2, 3 or 4 conversion factors have been sourced from international, industry or third-party sources.

If any of the default uncertainty value is deemed to be not representative of the facility's measurement instrument and/or analysis, the facility can overwrite the default uncertainty value and provide the site-specific uncertainty in the Metering & Analysis tabs of the MP Template. Supporting documents will need to be provided to justify any site-specific uncertainty value.

Table 20 - Default uncertainty values for measurement instruments used to derive activity data and conversion factors

Activity data – Measurement instrument type	Activity data Tier 4 Uncertainty	Activity data Tier 2 Uncertainty
Availability or Operating hours	1.0%	2.0%
Bellows Meter	6.0%	12.0%
Calorimetric Flowmeter	4.0%	8.0%
Coriolis Flowmeter	1.0%	2.0%
Electromagnetic Flowmeter	0.5%	1.0%
Electronic Volume Conversion Instrument (EVCI)	0.5%	1.0%
Equipment capacity	1.0%	2.0%
Flow Nozzles	2.0%	4.0%
Orifice Plate	1.5%	3.0%
Other flowmeter type	5.0%	10.0%
Other mechanical flow meter	3.0%	6.0%
Other tank level type	2.0%	4.0%
Pitot Tubes	4.0%	8.0%
Positive Displacement Flowmeter	1.0%	2.0%
Rotary Meter	3.0%	6.0%
Segmental wedge	2.0%	4.0%
Tank level dips	1.0%	2.0%
Tank level float	1.0%	2.0%
Tank level hydrostatic gauge	1.0%	2.0%
Tank level laser level	1.0%	2.0%
Tank level radar gauge	0.5%	1.0%
Tank level ultrasonic	1.0%	2.0%
Thermal Flowmeter	3.0%	6.0%
Turbine flow meter	3.0%	6.0%
Ultrasonic Doppler Flowmeter	0.5%	1.0%

Activity data – Measurement instrument type	Activity data Tier 4 Uncertainty	Activity data Tier 2 Uncertainty
Variable Area Flowmeter or Rotameter	2.0%	4.0%
Venturi Tube	1.5%	3.0%
Vortex Flow Meter	2.0%	4.0%
Weigh scales	0.5%	1.0%
Weighbridge	1.0%	2.0%
Weighing Conveyor Belt	0.5%	1.0%
Conversion factors – Measurement instrument type	**Tier 4 Uncertainty**	
Abatement control system timer	1%	
Density (gas)	0.5%	
Density (liquid)	0.5%	
Flue Gas Analyser	3%	
Gas chromatograph	1%	
Molecular weight	1%	
Pressure	0.1%	
Specific gravity	0.5%	
Temperature	0.1%	
Wobbe index	1.1%	
Conversion factors – Laboratory analysis	**Tier 4 Uncertainty**	
Abatement system operating hours	1%	
Energy content	1%	
Composition – carbon content	1%	
GHG concentration in a gas sample	1%	

4. Other IPPU emission sources

Other than the IPPU emission sources described in Chapter 2, the remaining IPPU emission sources and their emission stream types that are provided in the MP Template are tabulated as follow. Similar to the IPPU Emission Spreadsheet (EUR under ECA), these IPPU emission sources and emission stream types are referenced from the 2006 IPCC Guidelines.

Emission source	Emission stream type	2006 IPCC Guidelines section reference
Acrylonitrile production	• SOHIO Process/ Ammoxidation of Propylene - Secondary Products Burned for Energy Recovery / Flared • SOHIO Process/ Ammoxidation of Propylene - Acetonitrile Burned for Energy Recovery/Flared • SOHIO Process/ Ammoxidation of Propylene - Acetonitrile and Hydrogen Cyanide Recovered as Product • Ammoxidation of Propane • Reaction of Propane with Hydrogen Peroxide • Other	Volume 3, Chapter 3, page 3.79
Adiabatic uses of SF6 and PFCs	• Car Tyres • Sports Shoes • Tennis Balls • Other	Volume 3, Chapter 8, page 8.31
Adipic acid production	• Catalytic destruction • Thermal destruction • Recycle to nitric acid • Recycle to feedstock for adipic acid • No abatement technology	Volume 3, Chapter 3, pages 3.27 - 3.32
Aluminium production	• Centre Worked Prebake • Side Worked Prebake • Vertical Stud Soderberg • Horizontal Stud Soderberg • Other	Volume 3, Chapter 4, pages 4.43 - 4.58
Ammonia production	• Conventional Reforming - Natural Gas • Excess Air Reforming - Natural Gas • Autothermal Reforming - Natural Gas • Partial Oxidation - Residual Fuel Oil • Other	Volume 3, Chapter 3, pages 3.11 - 3.18
By-product emissions of greenhouse gases from production of fluorinated compounds other than HCFC-22	• Telomerization Process used in the production of fluorochemicals fluids and polymers • Photooxidation of tetrafluoroethylene to make fluorochemical fluids • Direct Fluorination, often used in SF6 production • Halogen Exchange Processes to make low boiling PFCs like C_2F_6 and CF_4, HFC-134a and HFC-245fa • NF3 manufacturing by direct fluorination	Volume 3, Chapter 3, pages 3.102 - 3.106

Emission source	Emission stream type	2006 IPCC Guidelines section reference
	• Production of uranium hexafluoride • Production of fluorinated monomers like tetrafluoroethylene and hexafluoropropylene • Production of fluorochemical agrochemicals • Production of fluorochemical anesthetics • Other	
Caprolactam, glyoxal and glyoxylic acid production	• Caprolactam Acid with abatement • Glyoxal Acid with abatement • Glyoxylic Acid with abatement • Caprolactam Acid without abatement • Glyoxal Acid without abatement • Glyoxylic Acid without abatement	Volume 3, Chapter 3, pages 3.33 - 3.39
Carbide production	• Silicon Carbide (SiC) produced • Calcium Carbide (CaC2) produced • Calcium Carbide Used in Acetylene Production • Silicon Carbide (SiC) per tonne raw material • Calcium Carbide (CaC2) per tonne raw material • Other Carbide produced • Other Carbide per tonne raw material	Volume 3, Chapter 3, pages 3.40 - 3.46
Carbon black production	• Thermal treatment of tail gas • Other abatement technology • No abatement technology	Volume 3, Chapter 3, page 3.80
Cement production (if clinker used is produced in Singapore)	• Portland (PC) • Masonry (MC) • Slag-modified portland (I(SM)) • Portland BF Slag (IS) • Portland pozzolan (IP and P) • Pozzolan-modified portland (I(PM)) • Slag cement (S) • Other	Volume 3, Chapter 2, pages 2.7 - 2.19
Disposal of SF_6 in sound-proof glazing	N.A., user-specified	Volume 3, Chapter 8, page 8.31
Ethylene dichloride (EDC)/ Vinyl chloride monomer (VCM) production	• Ethylene dichloride - Direct Chlorination • Ethylene dichloride – Oxychlorination • Ethylene dichloride - Balanced Process (default) • Ethylene dichloride – Other • Vinyl chloride monomer - Direct Chlorination • Vinyl chloride monomer – Oxychlorination • Vinyl chloride monomer - Balanced Process (default) • Vinyl chloride monomer - Other	Volume 3, Chapter 3, pages 3.76 - 3.78
Ferroalloys production	• Ferrosilicon 45% Si • Ferrosilicon 65% Si • Ferrosilicon 75% Si • Ferrosilicon 90% Si	Volume 3, Chapter 4, pages 4.32 - 4.42

Emission source	Emission stream type	2006 IPCC Guidelines section reference
	• Ferromanganeses (7% C) • Ferromanganeses (1% C) • Silicomanganese • Silicon metal • Ferrochromium (with sinter plant) • Ferrochromium (without sinter plant) • Other	
Fugitive emissions from production of fluorinated compounds other than HCFC-22	• Telomerization Process used in the production of fluorochemicals fluids and polymers • Photooxidation of tetrafluoroethylene to make fluorochemical fluids • Direct Fluorination, often used in SF6 production • Halogen Exchange Processes to make low boiling PFCs like C_2F_6 and CF_4, HFC-134a and HFC-245fa • NF3 manufacturing by direct fluorination • Production of uranium hexafluoride • Production of fluorinated monomers like tetrafluoroethylene and hexafluoropropylene • Production of fluorochemical agrochemicals • Production of fluorochemical anesthetics • Other	Volume 3, Chapter 3, pages 3.102 - 3.106
Glass production	• Float • Container (Flint) • Container (Amber/Green) • Fiberglass (E-glass) • Fiberglass (Insulation) • Specialty (TV Panel) • Specialty (TV Funnel) • Specialty (Tableware) • Specialty (Lab/Pharma) • Specialty (Lighting) • Other	Volume 3, Chapter 2, pages 2.27 - 2.32
HCFC-22 production	• With abatement • Without abatement	Volume 3, Chapter 3, pages 3.92 - 3.102
Lead production	• Imperial Smelt Furnace Production (ISF) • Direct Smelting Production (DS) • Treatment of Secondary Raw Materials • Average (default) • Other	Volume 3, Chapter 4, pages 4.71 - 4.77
Lime production	• High Calcium Lime • Dolomitic Lime • Hydraulic Lime • Other	Volume 3, Chapter 2, pages 2.19 - 2.27
Magnesium production	• Produced from Dolomite • Produced from Magnesite	Volume 3, Chapter 4, pages 4.59 - 4.70

Emission source	Emission stream type	2006 IPCC Guidelines section reference
	• Produced from Other raw materials	
Methanol production	• Natural gas - Conventional Steam Reforming without primary reformer (default) • Natural gas - Conventional steam reforming with primary reformer • Natural gas - Conventional steam reforming, Lurgi Conventional process • Natural gas - Conventional steam reforming, Lurgi Low Pressure process • Natural gas - Combined steam reforming, Lurgi Combined process • Natural gas - Conventional steam reforming, Lurgi Meta Methanol process • Natural gas - Conventional steam reforming with integrated ammonia production • Natural gas and CO2 - Conventional steam reforming, Lurgi Conventional process • Oil - Partial Oxidation process • Coal - Partial Oxidation process • Lignite - Partial Oxidation process • Other	Volume 3, Chapter 3, pages 3.73 - 3.74
N_2O emissions from medical applications and in aerosol products	• Use as a propellant in aerosol products, primarily in the food industry • Medical Applications • Other	Volume 3, Chapter 8, pages 8.35 - 8.38
Nitric acid production	• Plants with Non-Selective Catalytic Reduction (NSCR) (default) • Plants with process-integrated or tailgas N2O destruction • Atmospheric pressure plants (low pressure) • Medium pressure combustion plants • High pressure plants • Other	Volume 3, Chapter 3, pages 3.19 - 3.26
Other applications of HFCs and PFCs	N.A., user-specified	Volume 3, Chapter 7, pages 7.66 - 7.69
Other uses of carbonates in production	N.A., user-specified	Volume 3, Chapter 2, pages 2.32 - 2.40
Photovoltaic material production	• PFC-14 (CF_4) • PFC-116 (C_2F_6) • Other GHGs	Volume 3, Chapter 6, pages 6.5 - 6.16 and 6.22 - 6.23
SF_6 and PFC emissions from use of tracers or production of optical cables	• Tracers • Optical Cables	Volume 3, Chapter 8, page 8.32
Soda ash production	• Soda ash produced • Raw material used	Volume 3, Chapter 3, pages 3.52 - 3.56

Emission source	Emission stream type	2006 IPCC Guidelines section reference
Titanium dioxide production, including titanium slag, synthetic rutile and rutile titanium dioxide	• Titanium Slag • Synthetic Rutile • Rutile Titanium Dioxide (chloride route) • Others	Volume 3, Chapter 3, pages 3.47 - 3.51
Use of C_6F_{14} as heat transfer fluid	N.A., user-specified	Volume 3, Chapter 6, pages 6.5 - 6.16
Use of HFCs and PFCs in aerosols	N.A., user-specified	Volume 3, Chapter 7, pages 7.28 - 7.31
Use of HFCs or PFCs as foam blowing agents to produce closed cell foam	• PU - Integral Skin • PU - Continuous Panel • PU - Discontinuous Panel • PU - Appliance • PU - Injected • One Component Foam (OCF) • Extruded Polystyrene (XPS) • Extruded Polyethylene (PE) • PU - Continuous Block • PU - Discontinuous Block for pipe sections • PU - Discontinuous Block for panels • PU - Continuous Laminate / Boardstock • PU - Spray • PU - Pipe-in-pipe • Phenolic - Discontinuous Block • Phenolic - Discontinuous Laminate • Other	Volume 3, Chapter 7, pages 7.32 - 7.42
Use of HFCs or PFCs as foam blowing agents to produce open cell foam	N.A., user-specified	Volume 3, Chapter 7, pages 7.32 - 7.42
Use of SF_6 in airborne warning and control systems	N.A., user-specified	Volume 3, Chapter 8, page 8.23
Use of SF_6 in industrial and medical particle accelerators	• Industrial Particle Accelerators - high voltage (0.3-23 MV) • Industrial Particle Accelerators - low voltage (<0.3 MV) • Medical (Radiotherapy) • Other	Volume 3, Chapter 8, pages 8.29 - 8.30
Use of SF_6 in installed sound-proof glazing	N.A., user-specified	Volume 3, Chapter 8, page 8.31
Use of SF_6 in manufacture of sound-proof glazing	N.A., user-specified	Volume 3, Chapter 8, page 8.31
Use of SF_6 in university and research particle accelerators	• Industrial Particle Accelerators - high voltage (0.3-23 MV) • Industrial Particle Accelerators - low voltage (<0.3 MV)	Volume 3, Chapter 8, pages 8.26 - 8.28

Emission source	Emission stream type	2006 IPCC Guidelines section reference
	• Medical (Radiotherapy) • Other	
Zinc production	• Default • Waelz Kiln • Pyrometeallurgical (Imperial Smelting Furnace) • Electro-thermic • Others (please specify)	Volume 3, Chapter 4, pages 4.78 - 4.83