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CANADA'S GREENHOUSE GAS QUANTIFICATION REQUIREMENTS

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GLOSSARY

“2017 GHGRP Notice” means the *Notice with respect to reporting of greenhouse gases (GHGs) for 2017, Canada Gazette, Part I*.

“aluminium manufacturing” means primary processes that are used to manufacture aluminium from alumina, including electrolysis in prebake and Søderberg cells, anode and cathode baking for prebake cells, and green coke calcination.

“biomass” means plants or plant materials, animal waste or any product made of either of these, including wood and wood products, charcoal, and agricultural residues; biologically derived organic matter in municipal and industrial wastes, landfill gas, bio-alcohols, black liquor, sludge digestion gas and animal- or plant-derived oils.

“carbon dioxide equivalent (CO₂ eq.)” means a unit of measure for comparison between greenhouse gases that have different global warming potentials (GWPs).

“cement manufacturing” means all processes used to manufacture portland, ordinary portland, masonry, pozzolanic or other hydraulic cements.

“CEMS” means Continuous Emission Monitoring system.

“CKD” means cement kiln dust.

“CO₂ capture” means the capture of CO₂ at an integrated facility that would otherwise be released to atmosphere.

“CO₂ emissions from biomass decomposition” means releases of CO₂ resulting from aerobic decomposition of biomass and from the fermentation of biomass.

“CO₂ injection” means an activity that places captured CO₂ into, a long-term geological storage site or an enhanced fossil fuel recovery operation.

“CO₂ storage” means a long-term geological formation where CO₂ is stored.

“CO₂ transport system” means transport of captured CO₂ by any mode.

“cogeneration unit” means a fuel combustion device which simultaneously generates electricity and either heat or steam.

“Continuous Emission Monitoring system” means the complete equipment for sampling, conditioning, and analyzing emissions or process parameters and for recording data.

“CSM” means cyclohexane-soluble matter.

“electricity generating unit” means any device that combusts solid, liquid, or gaseous fuel for the purpose of producing electricity either for sale or for use on-site. This includes cogeneration unit(s), but excludes portable or emergency generators that have less than 50 kW in nameplate generating capacity or that generate less than 2 MWh during the reporting year.

“emissions” means direct releases from sources that are located at the facility.

“enhanced fossil fuel recovery operation” means enhanced oil recovery, enhanced natural gas recovery and enhanced coal bed methane recovery.

“facility” means an integrated facility, a pipeline transportation system, or an offshore installation.

“*flaring emissions*” means controlled releases of gases from industrial activities, from the combustion of a gas or liquid stream produced at the facility, the purpose of which is not to produce useful heat or work. This includes releases from: waste petroleum incineration; hazardous emission prevention systems (in pilot or active mode); well testing; natural gas gathering system; natural gas processing plant operations; crude oil production; pipeline operations; petroleum refining; chemical fertilizer production; steel production.

“*fossil fuel production and processing*” means the exploration, extraction, processing including refining and upgrading, transmission, storage and use of solid, liquid or gaseous petroleum, coal or natural gas fuels, or any other fuels derived from these sources.

“*fugitive emissions*” means releases from venting, flaring or leakage of gases from fossil fuel production and processing; iron and steel coke oven batteries; CO₂ capture, transport, injection and storage infrastructure.

“*GHGRP Technical Guide*” means the *Technical Guidance on Reporting Greenhouse Gas Emissions*, March 2018, Environment and Climate Change Canada. (Cat No.: En81-6E-PDF)

“*GHGs*” means greenhouse gases.

“*GWP*” means global warming potential.

“*HFCs*” means hydrofluorocarbons.

“*industrial process emissions*” means releases from an industrial process that involves a chemical or physical reaction other than combustion, and the purpose of which is not to produce useful heat or work. This does not include venting from hydrogen production associated with fossil fuel production and processing.

“*industrial product use emissions*” means releases from the use of a product for an industrial process that does not involve a chemical or physical reaction and does not react in the process. This includes releases from the use of SF₆, HFCs and PFCs as cover gases, and the use of HFCs and PFCs in foam blowing. This does not include releases from PFCs and HFCs in refrigeration, air conditioning, semiconductor manufacturing, fire extinguishing, solvents, aerosols and SF₆ in explosion protection, leak detection, electronic applications and fire extinguishing.

“*integrated facility*” means all buildings, equipment, structures, on-site transportation machinery, and stationary items that are located on a single site, on multiple sites or between multiple sites that are owned or operated by the same person or persons and that function as a single integrated site. “Integrated facility” excludes public roads.

“*iron and steel manufacturing*” means primary iron and steel production processes, secondary steelmaking processes, iron production processes, coke oven battery production processes, iron ore pellet firing processes, or iron and steel powder processes.

“*leakage emissions*” means accidental releases and leaks of gases from fossil fuel production and processing, transmission and distribution; iron and steel coke oven batteries; CO₂ capture, transport, injection and storage infrastructure for long-term geological storage.

“*lime manufacturing*” means all processes that are used to manufacture a lime product by calcination of limestone or other calcareous materials.

“*NAICS*” means the North American Industry Classification System.

“*non-variable fuels*” means fuels with consistent composition.

“*offshore installation*” means an offshore drilling unit, production platform or ship, or sub-sea installation that is attached or anchored to the continental shelf of Canada in connection with the exploitation of oil or natural gas.

“*on-site transportation emissions*” means releases from machinery used for the transport or movement of substances, materials, equipment or products that are used in the production process at an integrated facility. This includes releases from vehicles without public road licences.

“*PFCs*” means perfluorocarbons.

“*pipeline transportation system*” means all pipelines that are owned or operated by the same person within a province or territory that transport/distribute CO₂ or processed natural gas and their associated installations, including meter sets and storage installations but excluding straddle plants or other processing installations.

“*stationary fuel combustion emissions*” means releases from stationary fuel combustion sources, in which fuel is burned for the purpose of producing useful heat or work. This includes releases from the combustion of waste fuels to produce useful heat or work.

“*stationary fuel combustion sources*” means devices that combust solid, liquid, gaseous, or waste fuel for the purpose of producing useful heat or work. This includes boilers, electricity generating units, cogeneration units, combustion turbines, engines, incinerators, process heaters, and other stationary combustion devices, but does not include emergency flares.

“*surface leakage*” means CO₂ emitted from geological formations used for long term storage of CO₂.

“*GHGRP Technical Guide*” means the *Technical Guidance on Reporting Greenhouse Gas Emissions*, December 2016, Environment and Climate Change Canada.
(Cat No.: En81-6E-PDF)

“*variable fossil fuels*” means fuels of variable composition that require the determination of facility specific carbon content.

“*venting emissions*” means controlled releases of a process or waste gas, including releases of CO₂ associated with carbon capture, transport, injection and storage; from hydrogen production associated with fossil fuel production and processing; of casing gas; of gases associated with a liquid or a solution gas; of treater, stabilizer or dehydrator off-gas; of blanket gases; from pneumatic devices which use natural gas as a driver; from compressor start-ups, pipelines and other blowdowns; from metering and regulation station control loops.

“*waste emissions*” means releases that result from waste disposal activities at a facility including landfilling of solid waste, flaring of landfill gas, and waste incineration. This does not include releases from the combustion of waste fuels to produce useful heat or work.

“*wastewater emissions*” means releases resulting from wastewater and wastewater treatment at a facility.

CHANGES AND ERRATA

The following corrections have been made to this document:

- **2018-03-29.** In section 6.A.4 (Sinter), Equation 6-5 was corrected. Emissions from sinter feed material (FE) are now added instead of being erroneously subtracted.
- **2019-09-05.** In Table 2-9 (CH₄ and N₂O Emission factors for Still Gas), the N₂O emission factor in units of g/GJ was corrected to match the units provided.

Introduction

This document describes the quantification requirements for persons that are required to report information to Environment and Climate Change Canada under Schedules 6 through 11 of the 2017 GHGRP Notice. The 2017 GHGRP Notice shall prevail over this document, should any inconsistencies be found between them.

It is organized as follows:

- Section 1 deals with carbon capture, transport and storage facilities.
- Section 2 deals with fuel combustion that occurs in facilities.
- Section 3 deals with calcination processes in lime manufacturing kilns.
- Section 4 deals with clinker production in cement manufacturing kilns.
- Section 5 deals with industrial processes in aluminium manufacturing.
- Section 6 deals with industrial processes in iron and steel manufacturing.

Separate guidance is available in the GHGRP Technical Guide for those persons to whom Schedules 6 through 11 of the 2017 Gazette Notice do not apply.

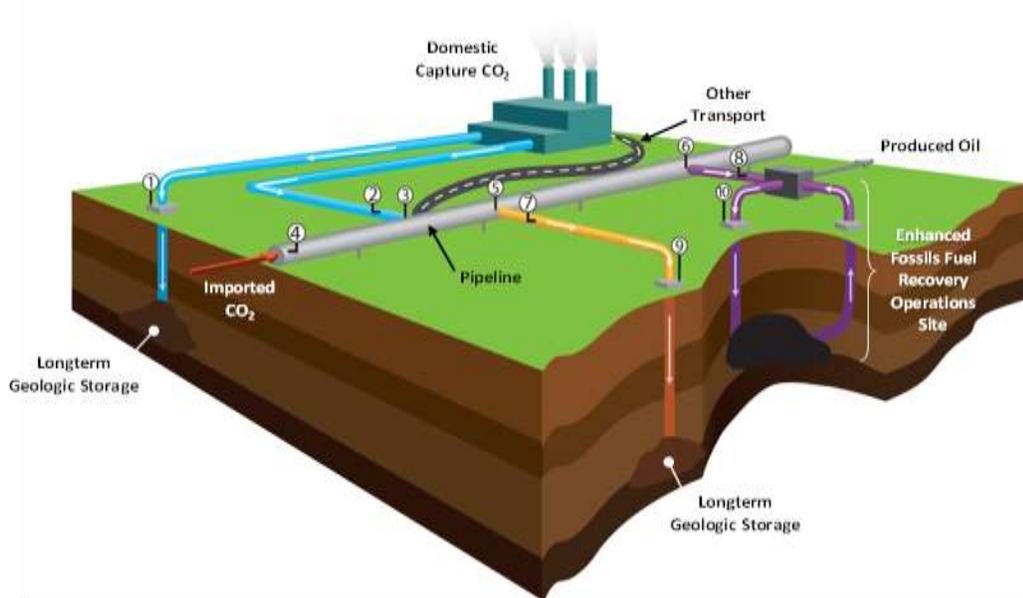
1 Quantification Methods for Carbon Capture, Transport and Storage

A CO₂ carbon capture, transport and storage facility (CCTS system) consists of some, or all, of the following components:

- A CO₂ capture facility including all infrastructures, equipment and process modifications designed to capture otherwise vented CO₂ emissions. Calculate the total annual quantity of captured CO₂ using Equation 1-1 or Equation 1-2.
- A CO₂ pipeline, or other system, used to transport CO₂, within Canada, from the capture facility to the injection facility. Calculate the total annual quantity of CO₂ transported using Equation 1-3 or Equation 1-4.
- A long-term geological storage facility, including sites injecting CO₂ both directly into deep saline aquifers and into enhanced fossil fuel recovery operations, with the final goal of long-term storage. Calculate the total annual quantity of CO₂ received for injection and injected using Equation 1-5 or Equation 1-6.

Figure 1-1 presents an illustration of a CCTS system, with required metered reporting locations.

Figure 1-1: Illustration of CCTS Sites and Metering Points



Meters 1, 9, 10—Injection point meters
Meters 2, 5, 6—Outgoing custody transfer meter
Meters 3, 4, 7, 8—Incoming custody transfer meter

1.A Calculation of Annual CO₂ Quantities

To measure annual concentrations, densities, masses and volumes of any CO₂ quantity, facility operators shall employ measuring and estimating methods published in *Alberta Directive 017 – Measurement Requirements for Oil and Gas Operations*, AER, 2016 or *Saskatchewan Directive PNG017 – Measurement Requirements for Oil and Gas Operations*, Sections 1 and 14. The weighted average parameters used to calculate annual mass of CO₂ shall be based on all available measurements for the calendar year.

Facility operators shall estimate fugitive emissions associated with CCTS using standards published in *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry*, American Petroleum Institute, 2009, Section 2.2.5 and Appendix C3.8.

1.A.1 CO₂ Capture Facility

Calculate the annual mass of CO₂ associated with the capture facility, as measured by the outgoing custody transfer flow meter (Figure 1-1, Meter 2), using the equations specified in this section.

1.A.1.a Mass Flow Approach

Calculate the annual mass of CO₂ flowing through the outgoing custody transfer point flow meter using Equation 1-1.

Equation 1-1

$$CO_2 = \sum_{p=1}^n M_p \times C_{CO_2 p}$$

Where:

CO₂ = Annual mass of CO₂ measured by the outgoing custody transfer point flow meter (tonnes).

M_p = Total mass flow, measured by the outgoing custody transfer point flow meter, for specified measurement period “p” (tonnes).

C_{CO₂ p} = Weighted average CO₂ concentration at the outgoing custody transfer point flow meter, for specified measurement period “p”, expressed as a decimal fraction.

n = Number of measurement periods in calendar year.

1.A.1.b Volumetric Flow Approach

Calculate the annual mass of CO₂ flowing through the outgoing custody transfer flow meter using Equation 1-2.

Equation 1-2

$$CO_2 = \sum_{p=1}^n Q_p \times D_p \times C_{CO_2 p}$$

Where:

CO₂ = Annual mass of CO₂ measured by the outgoing custody transfer point production flow meter (tonnes).

Q_p = Total volumetric flow measured by the outgoing custody transfer flow meter, for specified measurement period “p”, at stated temperature and pressure (m³).

D_p = Weighted average density of volumetric flow, for specified measurement period “p”, at stated temperature and pressure (tonnes per m³).

C_{CO₂ p} = Weighted average CO₂ concentration at the outgoing custody transfer flow meter, for specified measurement period “p” (percent volume CO₂, expressed as a decimal fraction).

n = Number of measurement periods in calendar year.

If CO₂ is delivered through more than one flow meter, calculate the sum of the annual mass delivered through all meters.

1.A.2 CO₂ Transport System

Calculate the annual mass of CO₂ associated with the transport system, measured by the incoming custody transfer flow meters (Figure 1-1, Meters 3 and 4) and the outgoing custody transfer flow meters (Figure 1-1, Meters 5 and 6) attached to the CO₂ pipeline or other transport system, using the equations specified in this section.

1.A.2.a Mass Flow Approach

Calculate the annual mass of CO₂ measured by the incoming custody transfer flow meter or the outgoing custody transfer flow meter, using Equation 1-3.

Equation 1-3

$$CO_2 = \sum_{p=1}^n M_p \times C_{CO_2 p}$$

Where:

CO₂ = Annual mass of CO₂ measured by the incoming custody transfer flow meter or the outgoing custody transfer flow meter attached to the CO₂ pipeline or other transport mode (tonnes).

M_p = Total flow mass measured by the incoming custody transfer flow meter, or the outgoing custody transfer flow meter, for specified measurement period “p” (tonnes).

C_{CO₂ p} = Weighted average CO₂ concentration at the incoming custody transfer flow meter or the outgoing custody transfer flow meter, for specified measurement period “p”, expressed as a decimal fraction.

n = Number of measurement periods in calendar year.

1.A.2.b Volumetric Flow Approach

Calculate the annual mass of CO₂, measured by the incoming custody transfer flow meter or the outgoing custody transfer flow meter, using Equation 1-4.

Equation 1-4

$$CO_2 = \sum_{p=1}^n Q_p \times D_p \times C_{CO_2 p}$$

Where:

CO₂ = Annual mass of CO₂ measured by the incoming custody transfer flow meter or the outgoing custody transfer flow meter attached to the CO₂ pipeline or other transport mode (tonnes).

Q_p = Total volumetric flow measured by the incoming custody transfer flow meter, or the outgoing custody transfer flow meter, for specified measurement period “p”, at stated temperature and pressure (m³).

D_p = Weighted average density of flow at stated temperature and pressure, for specified measurement period “p” (tonnes per m³).

C_{CO₂ p} = Weighted average CO₂ concentration at the incoming custody transfer flow meter, or the outgoing custody transfer flow meter, for specified measurement period “p” (percent volume CO₂, expressed as a decimal fraction).

n = Number of reporting periods in calendar year.

If CO₂ is received through more than one incoming custody transfer flow meter, or delivered through more than one outgoing custody transfer flow meter, sum the annual mass of all CO₂ received or delivered.

1.A.3 CO₂ Injection Site

For all sites, calculate the annual mass of CO₂ entering the injection site, measured by the incoming custody transfer flow meter (Figure 1-1, Meters 7 and 8), using Equation 1-5 or Equation 1-6.

For sites directly injecting CO₂ into long-term geologic storage, calculate the annual mass of CO₂ measured by the injection point flow meter (Figure 1-1, Meters 1 and 9), using Equation 1-5.

For sites injecting CO₂ at enhanced fossil fuel recovery operations, with the final goal of long-term storage, calculate the annual mass of CO₂ measured by the injection point flow meter (Figure 1-1, Meter 10), including all recycled CO₂ volumes or masses, using Equation 1-5.

1.A.3.a Mass Flow Approach

Calculate the annual mass of CO₂ measured by the incoming custody transfer or injection flow meter, using Equation 1-5.

Equation 1-5

$$CO_2 = \sum_{p=1}^n M_p \times C_{CO_2 p}$$

Where:

CO₂ = Annual mass of CO₂ measured by the incoming custody transfer or injection flow meter (tonnes).

M_p = Total mass flow measured by the incoming custody transfer or injection flow meter, for specified measurement period "p" (tonnes).

C_{CO₂ p} = Weighted average CO₂ concentration at the incoming custody transfer or injection flow meter, for specified measurement period "p", expressed as a decimal fraction.

n = Number of measurement periods in calendar year.

1.A.3.b Volumetric Flow Approach

Calculate the annual mass of CO₂ measured by incoming custody transfer or injection flow meter, using Equation 1-6.

Equation 1-6

$$CO_2 = \sum_{p=1}^n Q_p \times D_p \times C_{CO_2 p}$$

Where:

CO₂ = Annual mass of CO₂ measured by the incoming custody transfer or injection flow meter associated with CO₂ injection (tonnes).

Q_p = Total volumetric flow, measured by the incoming custody transfer or injection flow meter, for specified measurement period "p", at stated temperature and pressure (m³).

D_p = Weighted average density of flow at stated temperature and pressure, for specified measurement period "p" (tonnes per m³).

C_{CO₂ p} = Weighted average CO₂ concentration at the incoming custody transfer or injection flow meter, for specified measurement period "p" (percent volume CO₂, expressed as a decimal fraction).

n = Number of measurement periods in calendar year.

If CO₂ is received or injected by more than one incoming custody transfer or injection flow meter, sum the annual mass of all CO₂ received or injected.

1.A.4 CCTS Fugitive Emissions

1.A.4.a CO₂ Capture

Calculate the annual mass of CO₂ fugitive emissions from equipment leaks, and venting from equipment located between the capture infrastructure (Figure 1-1, labelled Domestic Capture CO₂) and the outgoing custody transfer flow meters or on-site injection wellhead (Figure 1-1, Meters 1 and 2), in tonnes. Facility operators shall calculate the mass as specified in Section 2.2.5 of the *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry*, American Petroleum Institute, 2009.

1.A.4.b CO₂ Transport System

Calculate the annual mass of CO₂ from equipment leaks and venting from pipelines, or other methods used to transport the liquefied CO₂ between the receipt transfer point flow meters (Figure 1-1, Meters 3 and 4) and the delivery transfer point meters at the long-term storage site (Figure 1-1, Meters 5 and 6), in tonnes. Where a pipeline, or other transport system, crosses an international border, only calculate and report fugitive emissions for the portion within Canada. Calculate the mass using methods specified in Section 2.2.5 of the *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry*, A.P.I., 2009.

1.A.4.c CO₂ Injection

Calculate the annual mass of CO₂ from equipment leaks and venting from surface equipment located between the incoming custody transfer point flow meters (Figure 1-1, Meters 7 and 8) and the injection wellhead meters (Figure 1-1, Meters 9 and 10), in tonnes. Calculate the mass using methods specified in the *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry*, A.P.I., 2009, Section 2.2.5.

1.A.4.d Surface Leakage from Stored CO₂

Calculate the annual mass of CO₂ from surface leakage associated with long-term geological storage sites, in tonnes. Calculate the mass as specified in the IPCC 2006 Guidelines, Section 5.7.1 and Appendix Tables A 5.4 and A 5.5.

2 Quantification Methods for Fuel Combustion

GHG emissions are released when solid, liquid, or gaseous fuels are combusted for the purpose of providing useful heat and work from boilers, simple and combined cycle combustion turbines, engines, incinerators (including units that combust hazardous waste), process heaters, on-site transportation equipment and any other combustion devices. CO₂ estimation methods are presented in Section 2.A and methods to estimate CH₄ and N₂O are presented in Section 2.B for fuel combustion sources.

2.A CO₂ Emissions from Fuel Combustion

To calculate the annual mass of CO₂ emissions from fuel combustion sources, facility operators can use one or a combination of the three quantification methodologies specified in Sections 2.A.1 to 2.A.3 for each fuel type. Facilities with Continuous Emission Monitoring (CEM) systems installed are not required to use the CEM system method (Methodology 3) and instead can apply the Non-Variable (Methodology 1) and/or the Variable Fossil (Methodology 2) fuels methods. Methodology 3 is an optional approach to determining CO₂ emissions. Specification on fuel sampling, analysis and measurement requirements are in Section 2.C and guidance for the handling of biomass fuels is in Section 2.A.4.

If the sum of CO₂ emissions from one or more fuels does not exceed 0.5% of the total facility CO₂ emissions from all fuels combusted, these fuels and their emissions are not required to be reported.

Methodology 1: Non-Variable and Biomass Fuels Method

The method in Section 2.A.1 applies to non-variable and biomass fuels that have consistent composition, and CO₂ emission factors.

- (a) Use Equation 2-1 and Equation 2-2 for non-variable fuels with CO₂ emission factors listed in Table 2-1 to Table 2-3.
- (b) Use Equation 2-3 for solid biomass combusted to produce steam.
- (c) Use Equation 2-4, Equation 2-5, and Equation 2-6 for on-site transportation only when information required to use Equation 2-1 is unavailable.

Methodology 2: Variable Fossil Fuels Method

The variable fossil fuels method in Section 2.A.2 applies to fuels whose variable properties and composition require the determination of facility specific carbon content.

- (a) Use Equation 2-7, Equation 2-9, Equation 2-10 and Equation 2-11 for all other fuels not listed in Table 2-1 to Table 2-3.
- (b) Use Equation 2-8 for solid biomass fuel used to produce steam, when information is not available to apply Equation 2-7.

Methodology 3: Continuous Emission Monitoring (CEM) System

This method applies to combustion units with one or more installed CEM system(s) that include(s) both a flow monitor subsystem and a CO₂ concentration monitor. Determine CO₂ emissions data from CEM system using the prescribed method in Section 2.A.3.

Allocate CO₂ emissions by type and quantity of fuel and by the following fuel combustion sources; electricity generation, steam generation, on-site transportation, flaring, and all other stationary combustion.

For mixtures of different fuels, determine the portion of each type of fuel used by broad fuel category (i.e. natural gas, diesel, refinery fuel, biodiesel) and use the appropriate method for each fuel combusted.

Any person raising steam to generate electricity and heat and is unable to determine the actual quantity of fuel used for each purpose may use the annual quantity of each fuel combusted in the boiler, multiplied by the ratio of steam to produce electricity or heat, to calculate emissions from each.

Use any applicable higher calculation methodology for one or more of the fuels combusted. For example, if a unit combusts propane and diesel oil, a facility operator may elect to use the Non-Variable Fuels Method for propane and the Variable Fossil Fuels Method for the diesel oil, even though the Non-Variable Fuels Method could have been used for both fuels.

2.A.1 Methodology 1: Non-variable and Biomass Fuels Method

This method uses high heat values provided by the supplier or measured at the facility. Calculate the annual mass of CO₂ emissions using Equation 2-1 to Equation 2-6. If parameters required for Equation 2-1, Equation 2-2, Equation 2-4, Equation 2-5 and Equation 2-6 are not available for on-site transportation sources, calculate mass CO₂ emissions using the site specific method in Section 2.A.1.d.

2.A.1.a Non Variable Fuels

Use Equation 2-1 and Equation 2-2 to calculate the annual mass of CO₂ emissions from non-variable and biomass fuels, using CO₂ emission factors presented in Table 2-1 to Table 2-3. Non-variable fuels consist of propane, ethane, butane, gasoline, and diesel. Biomass fuels consist of ethanol, biodiesel, wood/wood waste and spent pulping liquor.

Equation 2-1: Energy Based Non-Variable Fuels Equation

$$CO_{2\ i s} = \sum_{p=1}^n Fuel_{ip} \times HHV_{ip} \times EF_{1i} \times 10^{-6}$$

or

Equation 2-2: Carbon Dioxide based Non-Variable Fuels Equation

$$CO_{2is} = \sum_{p=1}^n Fuel_{ip} \times EF_{2i} \times 10^{-3}$$

Where:

CO_{2is} = Annual mass of CO₂ emissions for a specific fuel type “i” (tonnes).

n = Number of fuel heat content measurements for the calendar year, as specified in Section 2.C.

Fuel_{ip} = Mass or volume of fuel type “i” combusted during measurement period “p” (mass in tonnes for solid fuel, volume in kilolitres for liquid fuel or volume in cubic meters, at 15°C and 101.325 kPa, for gaseous fuel), as specified in Sections 2.C.1 and 2.C.2.

HHV_{ip} = High heat value of fuel type “i” for the measurement period “p” (MJ/ tonne for solid fuel, MJ/kilolitre for liquid fuel, or MJ/cubic meter, at 15°C and 101.325 kPa, for gaseous fuel), as specified in Section 2.C.1 and 2.C.3.

EF_{1i} = Fuel type “i” specific CO₂ emission factor listed in Table 2-1 to Table 2-3, energy units.

EF_{2i} = Fuel type “i” specific CO₂ emission factors listed in Table 2-1 to Table 2-3, physical units.

10⁻³ = Conversion factor from kilograms to tonnes.

10⁻⁶ = Conversion factor from grams to tonnes.

Table 2-1: CO₂ Emission Factors for Ethane, Propane and Butane

Fuel	CO ₂ Emission Factor ¹	
	kg/kl	g/MJ
Ethane	986	57.3
Propane	1 515	59.9
Butane	1 747	61.4
¹ McCann (2000).		

Table 2-2: CO₂ Emission Factors for Diesel, Gasoline, Ethanol and Biodiesel

Fuel	CO ₂ Emission Factor	
	kg/kl	g/MJ
Diesel ¹	2 681	69.9
Gasoline ¹	2 307	69.0
Ethanol ^{1,2}	1 508	64.4
Biodiesel ^{1,3}	2 472	70.3

¹ Environment and Climate Change Canada (2017b).
² Derived from Haynes (2016).
³ Derived from BioMer (2005).

Table 2-3: CO₂ Emission Factors for Solid Biomass

Biomass Fuel	CO ₂ Emission Factor	
	g/kg	g/MJ
Wood Fuel / Wood Waste ¹	840	46.7
Spent Pulping Liquor ²	891	63.6

¹ Adapted from U.S. EPA (2003), assuming 50% moisture content and a high heat value of 10.47 MJ/kg.
² Adapted from NCASI (2010).

2.A.1.b Biomass Fuels

Use Equation 2-3 to calculate the mass of CO₂ from the use of biomass fuel to produce steam, by applying the emission factors presented in Table 2-3.

Equation 2-3: Solid Biomass Fuels

$$CO_{2i} = \text{Steam} \times B \times EF_i \times 10^{-6}$$

Where:

CO_{2i} = Annual mass of CO₂ emissions from each type of solid biomass fuel “i” (tonnes).

Steam = Total mass of steam generated by solid biomass fuel type “i” for the reporting year (tonnes steam).

B = Ratio of the boiler's design-rated heat input capacity to its design-rated steam output capacity (MJ/tonne steam).

EF_i = emission factor for solid biomass fuel type “i”, listed in Table 2-3, as applicable (g CO₂/MJ) or site-specific emission factor determined through measurements and updated no less than every third year as provided in Section 2.C.1, paragraph (8).

10⁻⁶ = Conversion factor from grams to tonnes.

2.A.1.c On-site Transportation

Calculate the annual mass of CO₂ emissions from on-site transportation using Equation 2-4, Equation 2-5 and Equation 2-6, or the on-site transportation specific emission factor method in Section 2.A.1.d only when the fuel consumption information for Equation 2-1 is unavailable. When fuel quantities or the high heat values are not measured or provided by the fuel supplier, apply Equation 2-4, Equation 2-5 and Equation 2-6. These methods use the hours that each type of on-site transportation equipment operates to calculate total mass of CO₂.

Equation 2-4: On-Site Transportation by Type of Equipment

$$E_{CO_2 ikq} = (h_{ik} \times hp_{ik} \times LF_{ik} \times BSFC_{ik} \times 10^{-3}) \times HHV_{iq} \times EF_{1i} \times 10^{-6}$$

or

Equation 2-5: Carbon Dioxide based On-Site Transportation by Type of Equipment

$$E_{CO_2 i k q} = (h_{i k} \times hp_{i k} \times LF_{i k} \times BSFC_{i k}) \times EF_{2 i} \times 10^{-6}$$

Equation 2-6: On-site Transportation

$$E_{Total CO_2} = \sum_{q=1}^4 \left(\sum_k E_{CO_2 i k q} \right)$$

Where:

$E_{CO_2 i k q}$ = Quarterly “q” mass of CO₂ emissions from each type of on-site transportation equipment “k” and fuel “i” (tonnes).

$h_{i k}$ = Quarterly hours of operation for each type of on-site transportation equipment “k” and fuel “i” (hours).

$hp_{i k}$ = Rated equipment horsepower for each type of on-site transportation equipment “k” and fuel “i” (horsepower).

$LF_{i k}$ = Load factor for each type of on-site transportation equipment “k” and fuel “i” (dimensionless; ranges between 0 and 1).

$BSFC_{i k}$ = Brake-specific fuel consumption for each type of on-site transportation equipment “k” and fuel “i” (litres/horsepower-hour).

$HHV_{i q}$ = High heat value of fuel type “i” (MJ/kl) per quarterly period “q”, as specified in Sections 2.C.1 and 2.C.3.

$EF_{1 i}$ = emission factor by fuel type “i” (g CO₂/MJ) listed in Table 2-2, energy units.

$EF_{2 i}$ = emission factor by fuel type “i” (kg CO₂/kl) listed in Table 2-2, physical units.

$E_{Total CO_2}$ = Total annual mass of CO₂ emissions by fuel type “i”, for all on-site transportation equipment “k” (tonnes).

10^{-6} = Conversion factor from grams to tonnes.

10^{-3} = Conversion factor from litres to kilolitres.

2.A.1.d Facility Specific Method for On-site Transportation

On-site transportation facility -specific method: If the variables required for Equation 2-4, Equation 2-5 and Equation 2-6 are not available for on-site transportation sources, calculate mass of CO₂ emissions using the following facility- specific method. Conduct analysis of hourly fuel use from on-site transportation sources at the facility during a range of typical operations:

- (a) Document and analyze a range of typical operating conditions for the on-site transportation sources at the facility for each type of on-site transportation equipment in operation for the calendar year.
- (b) Calculate the average hourly fuel use rate for each range of typical operations.
- (c) Determine the number of hours of each type of operation at the facility in the calendar year.
- (d) Calculate the total annual mass of mobile emissions by multiplying the hours of operation with the average fuel use rate and the fuel-specific emission factor for each of the typical operations.

Document the methodology used.

2.A.2 Methodology 2: Variable Fossil Fuels Method

Calculate the annual mass of CO₂ emissions for each type of variable fuel, using measurements of fuel carbon content or molar fraction (for gaseous fuels only), conducted on site or provided by the fuel supplier, and the quantity of fuel combusted.

2.A.2.a Solid Fuels

Use Equation 2-7 to calculate annual mass of CO₂ emissions from each type of solid fuel combusted.

Equation 2-7: Solid Fuels

$$CO_{2\ i} = \sum_{p=1}^n 3.664 \times Fuel_{i\ p} \times CC_{i\ p}$$

Where:

CO_{2 i} = Annual mass of CO₂ emissions from the combustion of solid fuel type "i", expressed in tonnes.

n = Number of carbon content determinations for the calendar year, as specified in Section 2.C for solid fuel type "i".

Fuel_{i p} = Total quantity of solid fuel type "i" combusted in measurement period "p" (tonnes), as specified in Sections 2.C.1 and 2.C.2.

CC_{i p} = Carbon content of solid fuel type "i", from the fuel analysis results for measurement period "p" expressed as decimal mass fraction, as specified in Section 2.C.4.

3.664 = Ratio of molecular weights, CO₂ to carbon.

2.A.2.b Solid Biomass Fuels

Use Equation 2-8 to calculate the annual mass of CO₂ emissions from the combustion of each type of solid biomass fuel in steam producing units or Equation 2-7 (carbon content basis).

Equation 2-8: Solid Biomass Fuels

$$CO_{2i} = \text{Steam} \times EF_i \times 10^{-3}$$

Where:

CO_{2i} = Annual mass of CO₂ emissions from the combustion of solid biomass fuel type “i” (tonnes).

Steam = Total mass of steam generated by solid biomass fuel type “i” during the reporting year (tonnes steam).

EF_i = Measured emission factor for solid biomass fuel type “i”, as applicable (kg CO₂/tonne steam), adjusted no less than every third year.

10⁻³ = Conversion factor from kilograms to tonnes.

2.A.2.c Liquid Fuels

Use Equation 2-9 to calculate annual mass of CO₂ emission from each type of liquid fuel combusted.

Equation 2-9: Liquid Fuels

$$CO_{2i} = \sum_{p=1}^n 3.664 \times \text{Fuel}_{ip} \times CC_{ip}$$

Where:

CO_{2i} = Annual mass of CO₂ emissions from the combustion of liquid fuel type “i” (tonnes).

n = Number of required carbon content determinations for the calendar year for liquid fuel type “i”, as specified in Section 2.C.

Fuel_{ip} = Volume of liquid fuel type “i” combusted in measurement period “p” (kilolitres), as specified in Sections 2.C.1 and 2.C.2.

CC_{ip} = Carbon content of liquid fuel type “i”, from the fuel analysis results for measurement period “p” (tonne C per kilolitre of fuel), as specified in Section 2.C.4.

3.664 = Ratio of molecular weights, CO₂ to carbon.

2.A.2.d Gaseous Fuels

Use Equation 2-10 to calculate the annual mass of CO₂ emissions from each type of gaseous fuel combusted. For natural gas only, Equation 2-11 may be used when carbon content for Equation 2-10 is not available. For these equations, fuel volumes must be given at standard condition (15°C and 101.325 kPa).

Where volume of the gaseous fuel is determined at non-standard conditions with temperatures between -50°C and 80°C or pressures between 10 kPa and 500 kPa, convert the volume using the ideal gas equation, Equation 2-12. For conversion from other temperatures and pressures or for converting from liquid quantities to gaseous volumes, provide a brief summary of method used.

Equation 2-10: All Gaseous Fuels

$$CO_{2i} = \sum_{p=1}^n 3.664 \times Fuel_{ip} \times CC_{ip} \times 10^{-3}$$

Where:

CO_{2i} = Annual mass of CO₂ emissions from combustion of gaseous fuel type “i”, expressed in tonnes.

n = Number of carbon content determinations for the calendar year, as specified in Section 2.C for gaseous fuel type “i”.

Fuel_{ip} = Volume of gaseous fuel type “i” combusted in period “p” (cubic meters at 15°C and 101.325 kPa), Section 2.C.1 and Section 2.C.2.

CC_{ip} = Weighted annual average carbon content of gaseous fuel type “i”, from the fuel analysis results for the period “p” (kg C per cubic meter at 15°C and 101.325 kPa), as specified in Section 2.C.4.

3.664 = Ratio of molecular weights, CO₂ to carbon.

10⁻³ = Conversion factor from kilograms to tonnes.

Equation 2-11: Natural Gas

$$CO_{2NG} = \sum_{p=1}^n Fuel_p \times (60.554 \times HHV_p - 404.15) \times 10^{-6}$$

Where:

CO_{2NG} = Annual mass of CO₂ emissions from combustion of natural gas expressed in tonnes.

n = Number of fuel heat content measurements for the calendar year, as specified in Section 2.C.

Fuel_p = Volume of natural gas fuel combusted during measurement period “p” (cubic meters at 15°C and 101.325 kPa), as specified in Sections 2.C.1 and 2.C.2.

HHV_p = High heat value of natural gas for the measurement period “p” (MJ/cubic meter, at 15°C and 101.325 kPa), as specified in Sections 2.C.1 and 2.C.3.

(60.554 × HHV_p – 404.15) = empirical equation (g of CO₂/cubic meter of natural gas) representing a very close relationship between carbon dioxide and volume of natural gas determined through high heat value with a discreet set of available data where, 60.554 is the slope and 404.15 the intercept.

10⁻⁶ = Conversion factor from grams to tonnes.

Equation 2-12: Ideal Gas Equation

$$Fuel_{STP} = \frac{P_m \times Fuel_m \times T_{STP}}{T_m \times P_{STP}}$$

Where:

Fuel_{STP} = Volume of gaseous fuel at standard temperature and pressure (volume in cubic meters, at 15°C and 101.325 kPa).

P_m = Measured pressure of gas volume, in kPa.

Fuel_m = Measured volume of gaseous fuel, at **P_m**, in cubic meters.

T_{STP} = Standard temperature, 288.15°K.

T_m = Measured temperature of gas volume **V_m**, in degrees Kelvin.

P_{STP} = Standard pressure, 101.325 kPa.

2.A.2.e On-site Transportation

Refer to Section 2.A.1.a, Equation 2-1 or Equation 2-4 and Equation 2-6 to calculate the annual mass of CO₂ emissions from on-site transportation. For non-variable fuels, determine the carbon content for each liquid fuel type “i” following the fuel analysis approach in Section 2.C.4 to apply Equation 2-9 or derive on-site transportation equipment specific emission factors to apply to Equation 2-4 or the approach in Section 2.A.1.d.

2.A.3 Methodology 3: Continuous Emission Monitoring (CEM) System

Calculate the annual mass of CO₂ emissions from all fuels combusted in a stationary combustion unit, using data from a CEM system as specified in paragraphs 2.A.3(1) through 2.A.3(7). This methodology requires a CO₂ monitor and a flow monitoring subsystem, except as otherwise provided in paragraph 2.A.3(3). CEM systems shall use methodologies provided in the *Reference Method for Source Testing: Quantification of Carbon Dioxide Releases by Continuous Emission Monitoring Systems from Thermal Power Generation* (June 2012, Cat. No.: En14-46/1-2012E-PDF).

- (1) For a facility that operates a CEM system in response to a federal, provincial, or local regulation, use CO₂ or O₂ concentrations and flue gas flow measurements to determine hourly CO₂ mass emissions using methodologies provided in the *Reference Method for Source Testing: Quantification of Carbon Dioxide Releases by Continuous Emission Monitoring Systems from Thermal Power Generation* (June 2012, Cat. No.: En14-46/1-2012E-PDF).
- (2) Calculate the annual mass CO₂ emissions for the reporting year, expressed in tonnes, based on the sum of hourly CO₂ mass emissions for the calendar year.
- (3) Facility operators may use an oxygen (O₂) concentration monitor in place of a CO₂ concentration monitor in a CEM system installed before January 1, 2012, to determine the hourly CO₂ concentrations, if the effluent gas stream monitored by the CEM system consists solely of combustion products (i.e. no process CO₂ emissions or CO₂ emissions from acid gas control are mixed with the combustion products) and only if the following fuels are combusted in the unit: coal, petroleum coke, oil and refined petroleum products, natural gas, internally produced (non-marketable) fuels, propane, butane, wood bark, or wood residue.

Additionally:

- (a) Units combusting waste-derived fuels (as defined in the General Provisions and including municipal solid waste), should not base emissions calculations on O₂ concentrations.
 - (b) Facilities combusting biomass fuels and using O₂ concentrations to calculate CO₂ concentrations, should demonstrate, using annual source testing, that calculated CO₂ concentrations compared to measured CO₂ concentrations, meet the Relative Accuracy Test Audit (RATA) requirements in the *Reference Method for Source Testing: Quantification of Carbon Dioxide Releases by Continuous Emission Monitoring Systems from Thermal Power Generation* (June 2012, Cat. No.: En14-46/1-2012E-PDF).
- (4) If both biomass and fossil fuels (including fuels that are partially biomass) are combusted during the year, determine the biogenic CO₂ mass emissions separately, as described in Section 2.A.4.
 - (5) For any units using CEM system data, industrial process and stationary combustion CO₂ emissions must be provided separately. Determine the annual quantities of each type of fossil fuel and biomass consumed, using the fuel sampling approach in Sections 2.C.1 and 2.C.2.
 - (6) If a facility subject to requirements for continuous monitoring of gaseous emissions chooses to add devices to an existing CEM system for the purpose of measuring CO₂ concentrations or flue gas flow, select and operate the added devices using appropriate requirements for the facility, as applicable in Canada.^{1,2}

¹ *Protocols and Performances Specification For Continuous Monitoring Of Gaseous Emissions From Thermal Power Generation*, Report EPS 1/PG/8, Revised December 2005

- (7) If a facility does not have a CEM system and chooses to add one in order to measure CO₂ concentrations, select and operate the CEM system using the appropriate requirements or equivalent requirements as applicable in Canada.^{1,2} CEM systems added are subject to the specifications in paragraphs 2.A.3(1) through 2.A.3(5), if applicable.

2.A.4 CO₂ Emissions from Combustion of Mixtures of Biomass and Fossil Fuels

Use the procedures in this section to estimate biogenic CO₂ emissions from units that combust a combination of biomass and fossil fuels, including combustion of waste-derived fuels (e.g. wood waste and tires, etc.) that are partially biomass.

- (1) If a CEM system is not used to measure CO₂ and the facility combusts biomass fuels that do not include waste-derived fuels, use Methodology 1 or 2, as applicable, to calculate the annual biogenic CO₂ mass emissions from the combustion of biomass fuels. Determine the mass of biomass combusted using either company records or, for premixed fuels that contain biomass and fossil fuels (e.g., mixtures containing biodiesel), the best available supplier information and document the procedure.
- (2) If a CEM system is used to measure CO₂ (or O₂ as a surrogate) and the facility combusts biomass fuels that do not include waste-derived fuels, use Methodology 1 or 2 to calculate the annual CO₂ mass emissions from the combustion of fossil fuels. Calculate biomass fuel emissions by subtracting the fossil fuel-related emissions from the total CO₂ emissions determined from the CEM system methodology.
- (3) If combusted fuels or fuel mixtures contain a biomass fraction that is unknown or cannot be documented (e.g., wood waste and tire-derived fuel, etc.), or biomass fuels with no CO₂ emission factor provided in Table 2-3, use the following to estimate biogenic CO₂ emissions:
 - (a) Methodology 2, or 3 to calculate the total annual CO₂ mass emissions, as applicable.
 - (b) Determine the biogenic portion of the CO₂ emissions using ASTM D6866-16 "*Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis*". This procedure is not required for fuels containing less than 5 percent biomass by weight or for waste-derived fuels that are less than 30 percent by weight of total fuels combusted in the year for which emissions are being reported, except, if a person wishes to report a biomass fuel fraction of CO₂ emissions.
 - (c) Conduct analysis of representative fuel or exhaust gas samples at least every three months, using ASTM D6866-16. Collect the exhaust gas samples over a minimum of 24 consecutive hours following the standard practice specified by ASTM D7459-08 (2016) "*Standard Practice for Collection of Integrated Samples for the Speciation of Biomass (Biogenic) and Fossil-Derived Carbon Dioxide Emitted from Stationary Emissions Sources*." If municipal solid waste is combusted, perform ASTM D6866-16 analysis on the exhaust gas stream.
 - (d) Divide total CO₂ emissions between biomass fuel emissions and non-biomass fuel emissions using the average proportions of the samples analyzed annually for which emissions are being reported.
 - (e) If there is a common fuel source for multiple units at the same facility, ASTM D6866-16 analysis may be done at only one unit.

² *Reference Method for Source Testing: Quantification of Carbon Dioxide Releases by Continuous Emission Monitoring Systems from Thermal Power Generation*, Cat. No.: En14-46/1-2012E-PDF, June 2012.

2.B CH₄ and N₂O Emissions from Fuel Combustion

Calculate the annual mass of CH₄ and N₂O emissions from fuel combustion sources, for each fuel type, using methods specified in this section.

- (1) Use Equation 2-13 or Equation 2-14 to calculate the annual CH₄ and N₂O emissions, where high heat values (HHVs) for each fuel are measured directly or provided by the fuel supplier, with available CH₄ and N₂O emission factors presented in Table 2-4 to Table 2-11 or facility determined fuel specific CH₄ and N₂O emission factors.

Equation 2-13: CH₄ and N₂O High Heat Value Methods, in Energy Units

$$CH_{4i} \text{ or } N_{2O_i} = \sum_{p=1}^n Fuel_{ip} \times HHV_{ip} \times 10^{-3} \times EF_{1i} \times 10^{-6}$$

or

Equation 2-14: CH₄ and N₂O High Heat Value Methods, in Physical Units

$$CH_{4i} \text{ or } N_{2O_i} = \sum_{p=1}^n Fuel_{ip} \times EF_{2i} \times k$$

Where:

CH_{4i} or N_{2O_i} = Annual mass of CH₄ or N₂O emissions for fuel type “i”, tonnes CH₄ or N₂O per year.

Fuel_{ip} = Mass or volume of fuel type “i” combusted during the measurement period “p” (mass in tonnes for solid fuel, volume in kilolitres for liquid fuel or volume in cubic meters, at 15°C and 101.325 kPa, for gaseous fuel).

HHV_{ip} = High heat value measured directly or provided by the fuel supplier for the measurement period “p” of fuel type “i” (MJ per tonne for solid fuel, MJ per kilolitre for liquid fuel, or MJ per cubic meter, at 15°C and 101.325 kPa, for gaseous fuel).

EF_{1i} = CH₄ or N₂O emission factor by fuel type “i” provided in Table 2-4 through Table 2-11, in energy units.

EF_{2i} = CH₄ or N₂O emission factor by fuel type “i” provided in Table 2-4 through Table 2-11, in physical units.

n = Number of measurement periods in calendar year.

10⁻⁶ = Conversion factor from grams to tonnes.

10⁻³ = Conversion factor from megajoules to gigajoules.

k = 10⁻³ for liquid and solid fuels, conversion factor from kilograms to tonnes.

k = 10⁻⁶ for gaseous fuels, conversion factor from grams to tonnes.

Table 2-4: CH₄ and N₂O Emission Factors for Natural Gas

Source	Natural Gas Emission Factor ¹			
	CH ₄ g/m ³	N ₂ O g/m ³	CH ₄ g/GJ	N ₂ O g/GJ
Electric Utilities	0.49	0.049	13	1.3
Industrial	0.037	0.033	0.98	0.87
Producer Consumption (Non-marketable) ²	6.4	0.06	140	1.3
Pipelines	1.9	0.05	50	1.3
Cement	0.037	0.034	0.98	0.90
Manufacturing Industries	0.037	0.033	0.98	0.87
Residential, Construction, Commercial/Institutional, Agriculture	0.037	0.035	0.98	0.92
On-site transportation ³	9	0.06	0.2	0.002
¹ SGA Energy (2000). ² Adapted from U.S. EPA (1996b) and CAPP (1999). ³ Adapted from IPCC (2006).				

Table 2-5: CH₄ and N₂O Emission Factors for Ethane, Propane and Butane

Fuel	Emission Factor ¹			
	CH ₄ kg/kl	N ₂ O kg/kl	CH ₄ g/GJ	N ₂ O g/GJ
Ethane	0.024	0.108	1.4	6.3
Propane				
Industry	0.024	0.108	0.95	4.3
On-site Transportation ^{2,3}	0.64	0.087	16	2.2
Butane	0.024	0.108	0.84	3.8
¹ SGA Energy (2000). ² Oak Leaf Environmental (2017). ³ Adapted from IPCC (2006)				

Table 2-6: CH₄ and N₂O Emission Factors for Refined Petroleum Products and Biofuels

Fuel by Source or by Technology	Emission Factor			
	CH ₄ kg/kl	N ₂ O kg/kl	CH ₄ g/GJ	N ₂ O g/GJ
Diesel ¹				
<19 kW	0.073	0.02	1.9	0.58
>=19 kW, Tier 1-3	0.073	0.02	1.9	0.58
>= 19 kW, Tier 4	0.073	0.23	1.9	5.9
Gasoline ¹				
2-stroke	10.6	0.013	300	0.36
4-stroke	5.08	0.064	150	1.8
Light Fuel Oil ²				
Utilities	0.18	0.031	4.6	0.80
Industrial	0.006	0.031	0.2	0.80
Forestry, Construction, Public Administration and Commercial/Institutional	0.026	0.031	0.67	0.80
Heavy Fuel Oil ²				
Utilities	0.034	0.064	0.80	1.5
Industrial	0.12	0.064	2.8	1.5
Forestry, Construction, Public Administration and Commercial/Institutional	0.057	0.064	1.3	1.5
Kerosene ²				
Electric Utilities	0.006	0.031	0.2	0.83
Industrial	0.006	0.031	0.2	0.83
Forestry, Construction, Public Administration and Commercial/Institutional	0.026	0.031	0.70	0.83
Ethanol	*	*	*	*
Biodiesel	**	**	**	**
¹ Oak Leaf Environmental (2017). ² SGA Energy (2000). * Gasoline CH ₄ and N ₂ O emission factors (by mode and technology) are used for ethanol. ** Diesel CH ₄ and N ₂ O emission factors (by mode and technology) are used for biodiesel.				

Table 2-7: CH₄ and N₂O Emission Factors for Coal, Coke and Coke Oven Gas

Source by Coal Type and by Region	Emission Factors ¹			
	CH ₄ g/kg	N ₂ O g/kg	CH ₄ g/GJ	N ₂ O g/GJ
Electric Utilities				
Anthracite	0.02	0.03	0.8	1
Canadian Bituminous	0.02	0.03	0.8	1
Foreign Bituminous	0.02	0.03	0.7	1
Lignite				
<i>Saskatchewan</i>	0.02	0.03	1	2
<i>All Other Provinces</i>	0.02	0.03	1	2
Sub-bituminous				
<i>Manitoba, Ontario</i>	0.02	0.03	1	1
<i>Alberta, British Columbia, Saskatchewan</i>	0.02	0.03	1	2
<i>All Other Provinces</i>	0.02	0.03	1	2
Industry and Heat & Steam Plants				
Anthracite	0.03	0.02	1	0.7
Canadian Bituminous	0.03	0.02	1	0.7
Foreign Bituminous	0.03	0.02	1	0.7
Lignite				
<i>Saskatchewan</i>	0.03	0.02	2	1
<i>All Other Provinces</i>	0.03	0.02	2	1
Sub-bituminous				
<i>Manitoba, Ontario</i>	0.03	0.02	1	1
<i>Alberta, British Columbia, Saskatchewan</i>	0.03	0.02	2	1
<i>All Other Provinces</i>	0.03	0.02	2	1

Source by Coal Type and by Region	Emission Factors ¹			
	CH ₄ g/kg	N ₂ O g/kg	CH ₄ g/GJ	N ₂ O g/GJ
Residential, Public Administration				
Anthracite	4	0.02	100	0.7
Canadian Bituminous	4	0.02	100	0.7
Foreign Bituminous	4	0.02	100	0.7
Lignite				
<i>Saskatchewan</i>	4	0.02	200	1
<i>All Other Provinces</i>	4	0.02	200	1
Sub-bituminous				
<i>MB, ON</i>	4	0.02	200	1
<i>AB, BC, SK</i>	4	0.02	200	1
<i>All Other Provinces</i>	4	0.02	200	1
Coke	0.03	0.02	1	0.7
Coke Oven Gas	g/m ³		g/GJ	
	0.04	0.04	2	2
¹ SGA Energy (2000).				

Table 2-8: CH₄ and N₂O Emission Factors for Petroleum Coke

Petroleum Coke	Emission Factors ¹			
	CH ₄		N ₂ O	
	kg/m ³	g/GJ	kg/m ³	g/GJ
Upgrading Facilities	0.12	3.0	0.024	0.59
Refineries & Others	0.12	2.6	0.028	0.59
¹ Adapted from IPCC (2006).				

Table 2-9: CH₄ and N₂O Emission Factors for Still Gas

Fuel	Emission Factors			
	CH ₄		N ₂ O	
	g/m ³	g/GJ	g/m ³	g/GJ
Still Gas ^{1,2}	0.031	0.91	0.02	0.6

¹ Adapted from IPCC (2006) and CIEEDAC (2014).
² SGA (2000).

Table 2-10: CH₄ and N₂O Emission Factors for Industrial Waste Fuel used by Cement Plants

Fuel	Emission Factors ¹	
	CH ₄	N ₂ O
	kg/GJ	kg/GJ
Waste	0.03	0.004

¹ Adapted from IPCC (2006).

Table 2-11: CH₄ and N₂O Emission Factors for Biomass Fuels

Biomass Fuel	Emission Factors			
	CH ₄ g/kg	N ₂ O g/kg	CH ₄ g/GJ	N ₂ O g/GJ
Wood Fuel / Wood Waste ¹	0.09	0.06	5	3
Spent Pulping Liquor ²	0.02	0.02	1	1

¹ Adapted from U.S. EPA (2003).
² Adapted from IPCC (2006).

(2) Use Equation 2-15, Equation 2-16 and Equation 2-17 to calculate the annual mass of CH₄ or N₂O emissions from on-site transportation for each fuel type and emission factors presented in Table 2-6.

Equation 2-15: On-Site Transportation by Type of Equipment in Energy Units

$$E_{gikq} = (h_{ik} \times hp_{ik} \times LF_{ik} \times BSFC_{ik}) \times HHV_{iq} \times EF_{1gi} \times 10^{-6}$$

or

Equation 2-16: On-Site Transportation by Type of Equipment in Physical Units

$$E_{gikq} = (h_{ik} \times hp_{ik} \times LF_{ik} \times BSFC_{ik}) \times EF_{2gi} \times 10^{-6}$$

Equation 2-17: On-site Transportation

$$E_{Totalgi} = \sum_{q=1}^4 \left(\sum_k E_{gikq} \right)$$

Where:

E_{gikq} = Quarterly “q” mass of greenhouse gas “g” (CH₄ or N₂O) emissions from each type of on-site transportation equipment “k” and fuel “i” (tonnes).

h_{ik} = Quarterly hours of operation for each type of on-site transportation equipment “k” and fuel “i” (hours).

hp_{ik} = Rated equipment horsepower for each type of on-site transportation equipment “k” and fuel “i” (horsepower).

LF_{ik} = Load factor for each type of on-site transportation equipment “k” and fuel “i” (dimensionless; ranges between 0 and 1).

BSFC_{ik} = Brake-specific fuel consumption for each type of on-site transportation equipment “k” and fuel “i” (litres/horsepower-hour).

HHV_{iq} = High heat value of fuel type “i” (MJ/kl) per quarterly period “q”, as specified in Sections 2.C.1 and 2.C.3.

EF_{1gi} = emission factor by CH₄ or N₂O “g” and by fuel type “i”, listed in Table 2-6, in energy units.

EF_{2gi} = emission factor by CH₄ or N₂O “g” and by fuel type “i”, listed in Table 2-6, in physical units.

E_{Totalgi} = Total annual mass of greenhouse gas “g” (CH₄ or N₂O) emissions by fuel type “i”, for all on-site transportation equipment “k” (tonnes).

10⁻⁶ = Conversion factor from grams to tonnes.

(3) On-site transportation facility specific method: If the variables required for Equation 2-15 and Equation 2-17 are not available for on-site transportation sources, calculate the annual mass of CH₄ or N₂O emissions using the following facility specific method. Conduct analysis of hourly fuel use from on-site transportation sources at the facility during a range of typical operations:

- (a) Document and analyze a range of typical operating conditions for the on-site transportation sources at the facility for each type of on-site transportation equipment in operation for the calendar year.
- (b) Calculate the average hourly fuel use rate for each range of typical operations.
- (c) Determine the number of hours of each type of operation at the facility in the calendar year.
- (d) Calculate the total annual mass of mobile emissions by multiplying the hours of operation with the average fuel use rate and the fuel-specific emission factor from for each of the typical operations.

This methodology, if used, shall be documented.

(4) Use Equation 2-18 to calculate the annual mass of CH₄ or N₂O emissions for each fuel type, if CH₄ or N₂O emission factors have been determined based on source tests. Method used to derive facility specific CH₄ and N₂O emission factors shall be documented.

Equation 2-18: CH₄ and N₂O Emission Factor Method

$$CH_{4\ i} \text{ or } N_{2O\ i} = \sum_{p=1}^n Fuel_{ip} \times EF_i \times 10^{-6}$$

Where:

CH₄_i or N₂O_i = Annual mass of CH₄ or N₂O emissions from a specific fuel type "i", tonnes CH₄ or N₂O per year.

Fuel_{ip} = Mass or volume of the fuel type "i" combusted during the measurement period "p" (mass in tonnes for solid fuel, volume in kilolitres for liquid fuel or volume in cubic meters, at 15°C and 101.325 kPa, for gaseous fuel), as specified in Section 2.C.

EF_i = CH₄ or N₂O emission factor for fuel type "i", measured directly or provided by the fuel supplier or equipment manufacturer (grams CH₄ or N₂O per unit of fuel).

n = Number of measurement periods in calendar year, as specified in Section 2.C.1.

10⁻⁶ = Conversion factor from grams to tonnes.

(5) Use Equation 2-19 to estimate CH₄ and N₂O emissions for biomass combustion.

Equation 2-19: CH₄ and N₂O Biomass Method

$$CH_4 \text{ or } N_2O = \text{Steam} \times B \times EF \times 10^{-6}$$

Where:

CH₄ or N₂O = Annual mass of CH₄ or N₂O emissions from the combustion of biomass (tonnes).

Steam = Total mass of steam generated by biomass combustion during the reporting year (tonnes steam).

B = Ratio of the boiler design rated heat input capacity to design rated steam output (MJ/tonne steam).

EF = Fuel-specific emission factor for CH₄ or N₂O from Table 2-11, as applicable (grams per MJ).

10⁻⁶ = Conversion factor from grams to tonnes.

(6) Calculate on-site transportation emissions for each liquid fuel not presented in Table 2-6 by deriving on-site transportation equipment specific CH₄ and N₂O emission factors to apply to Equation 2-18 or the approach in Sections 2.B0 and 2.B(3).

(a) Document the method used in deriving equipment specific CH₄ and N₂O emission factors.

(7) Use Equation 2-20 to estimate the annual mass of CH₄ and N₂O emissions for units that use Methodology 3 and for which the heat input is monitored on a year round basis.

(a) If only one type of fuel is combusted during normal operations, substitute the cumulative annual heat input from combustion of the fuel into Equation 2-20 of this section to calculate the annual CH₄ or N₂O emissions.

(b) If more than one type of fuel listed is combusted during normal operations, use Equation 2-20 of this section to calculate the annual CH₄ or N₂O emissions for each fuel.

Equation 2-20: CH₄ and N₂O CEM Methods

$$CH_{4i} \text{ or } N_{2O_i} = (HI)_{Ai} \times EF_i \times 10^{-6}$$

Where:

CH_{4i} or N₂O_i = Annual mass of CH₄ or N₂O emissions from the combustion of a specific type of fuel, expressed in tonnes.

(HI)_{Ai} = Cumulative annual heat input from the fuel (MJ), provided by fuel type "i".

EF_i = Fuel-specific emission factor for CH₄ or N₂O by fuel type "i", listed in Table 2-4 to Table 2-11 (grams/MJ or grams/kilogram of coal).

10⁻⁶ = Conversion factor from grams to tonnes.

- (8) When multiple fuels are combusted during the reporting year, use Equation 2-13 to Equation 2-20 in this section to obtain the total annual CH₄ and N₂O emissions by fuel type (tonnes).
- (9) Quantify CH₄ or N₂O emissions using available emission factors in Table 2-4 to Table 2-11, provided by the fuel supplier or equipment manufacturer, or measured source-specific emission factors conducted at least annually, with documented methodology of the source test plan.
- (10) Use Equation 2-13 to Equation 2-20 to calculate CH₄ and N₂O emissions as follows:
 - (a) Use Equation 2-13 for any type of fuel for which a CH₄ or N₂O emission factor is specified.
 - (b) Use Equation 2-18 to calculate CH₄ and N₂O emissions from any fuel type based on derived source-specific emission factors as noted in 2.B(4).
 - (c) Use Equation 2-19 only for biomass or municipal solid waste combustion that generates steam.
 - (d) Use Equation 2-20 for a unit of any size combusting any type of fuel, and for any units for which Methodology 3 (CEM) system is used to estimate CO₂ emissions and heat input is monitored on a year round basis.

2.C Sampling, Analysis and Measurement Requirements

2.C.1 Fuel Measurement and Sampling Requirements

Fuel sampling must be conducted, or fuel sampling results received from the fuel supplier, at the minimum frequency specified in paragraphs 2.C.1(1) to 2.C.1(7) of this section, subject to the requirements of Section 2.B(9). Take all fuel samples, at a location in the fuel handling system that is representative of the fuel combusted, as follows:

- (1) Once for each new fuel shipment or delivery for coal. If coal is delivered continuously, sample as often as necessary to capture variation in carbon content and heat value of coal feed to ensure a representative annual composition.
- (2) Once for each new fuel shipment or delivery of fuels, or quarterly for each of the fuels listed in Table 2-1 to Table 2-3.
- (3) Monthly for natural gas. If provided by fuel supplier, samples shall be taken monthly or, should that not be possible, as often as the supplier can provide, but no less than semi-annually.
- (4) Quarterly for liquid fuels and fossil fuel-derived gaseous fuels other than fuels listed in Table 2-1 and Table 2-2 (when these tables are used).
- (5) Quarterly for gases derived from biomass including landfill gas and biogas from wastewater treatment or agricultural processes.
- (6) For gaseous fuels, other than natural gas, gases derived from biomass and biogas, and if the necessary measurement equipment is in place, perform daily sampling and analysis to determine the carbon content and molecular weight of the fuel. If the necessary measurement equipment is not in place, perform weekly sampling and analysis. If using on-line instrumentation to perform daily sampling and analysis of carbon content and molecular weight the measurements shall be accurate to ±5 percent.

(7) Monthly for solid fuels other than coal and waste-derived fuels, as specified below:

- (a) The monthly solid fuel sample shall be a composite sample of weekly samples.
- (b) Sample the solid fuel at a location before fuel consumption but after all fuel treatment operations. The samples shall be representative of the fuel chemical and physical characteristics immediately prior to combustion.
- (c) Collect each weekly sub-sample at a time (day and hour) of the week when the fuel consumption rate is representative and unbiased.
- (d) Combine four weekly samples (or a sample collected during each week of operation during the month) of equal mass to form the monthly composite sample.
- (e) The monthly composite sample shall be homogenized and well mixed prior to withdrawing a sample for analysis.
- (f) Randomly select one in twelve composite samples for additional analysis of its discrete constituent samples. This information will be used to monitor the homogeneity of the composite.

(8) For biomass fuels and waste-derived fuels, the following may apply in lieu of paragraph 2.C.1(5):

- (a) If CO₂ emissions are calculated using Equation 2-3 in Section 2.A.1.b or Equation 2-7 in Section 2.A.2.a, determine the fuel-specific high heat value or carbon content annually. If CO₂ emissions are calculated using Equation 2-8 in Section 2.A.2.b for biomass fuels, adjust the emission factor, in kg CO₂/MJ not less frequently than every third year, through a stack test measurement of CO₂ and use of the applicable ASME Performance Test Code to determine heat input from all heat outputs, including the steam, flue gases, ash and losses.

2.C.2 Fuel Consumption Monitoring Requirements

- (1) Determine fuel consumption on the basis of direct measurement or recorded fuel purchase or sales invoices measuring any stock change using Equation 2-21. Follow the fuel measurement and sampling requirement in Section 2.C.1. Feedstock and non-energy use of fossil fuels are addressed in Sections 3 to 6.

Equation 2-21: Fuel Consumption

$$\mathbf{Fuel}_i = \mathbf{Purchases}_i - \mathbf{Sales}_i + \mathbf{Stored}_{SY\ i} - \mathbf{Stored}_{YE\ i} - \mathbf{Feedstock}_i$$

Where:

Fuel_i = total annual fuel combusted by type “i”, expressed in tonnes for solid fuel, kilolitres for liquid fuel or cubic meters, at 15°C and 101.325 kPa, for gaseous fuel.

Purchases_i = total annual fuel purchases by type “i”, expressed in tonnes (t), kilolitres (kL) or cubic metres (m³).

Sales_i = total annual fuel sales by type “i”, expressed in tonnes (t), kilolitres (kL) or cubic metres (m³).

Stored_{SY i} = quantity of fuel stored by type “i” at start of year, expressed in tonnes (t), kilolitres (kL) or cubic metres (m³).

Stored_{YE i} = quantity of fuel stored by type “i” at year end, expressed in tonnes (t), kilolitres (kL) or cubic metres (m³).

Feedstock_i = annual quantity feedstock or non-energy fuel use by type “i”, expressed in tonnes (t), kilolitres (kL) or cubic metres (m³).

- (2) Convert fuel consumption measured in MJ to the required mass or volume metrics using heat content values provided by the supplier or measured at the facility.
- (3) Calibrate all fuel oil and gas flow meters (except for gas billing meters) prior to the first year for which GHG emissions are reported, using procedures specified by the flow meter manufacturer. Recalibrate fuel flow meters once every three years, upon replacement of a previously calibrated meter or at the minimum frequency specified by the manufacturer. For orifice, nozzle, and venturi flow meters, the calibration shall consist of in-situ calibration of the differential pressure (delta-P), total pressure, and temperature transmitters. For flow meters used for natural gas, the facilities shall follow the requirements of Measurement Canada for Electricity and Gas.
- (4) For fuel oil, tank drop measurements may also be used.
- (5) Fuel volume flow meters may be used for liquid fuels, if appropriate fuel densities are used to convert volumetric flow rates to mass readings. Measure the density at the same frequency as the carbon content, using ASTM D1298-99 (Reapproved 2005) “Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method.”
- (6) Facilities using Calculation Methodology 1 for CO₂ emissions may use the default density values in Table 2-12 for fuel oil, in lieu of using the ASTM method in paragraph 2.C.2(5) of this section. These default densities may not be used for facilities using Calculation Method 2.

Table 2-12: Fuel Oil Default Density Values

Fuel Oil	No. 1 Oil	No. 2 Oil	No. 6 Oil
Default Density (kg/l)	0.81	0.86	0.97

2.C.3 Fuel Heat Content Monitoring Requirements

Base high heat values on the results of fuel sampling and analysis received from the fuel supplier or as determined using an applicable analytical method in 2.C.3(1) to 2.C.3(5) of this section. Follow the fuel measurement and sampling requirement in Section 2.C.1. For fuel heat content monitoring of natural gas, follow the requirements of Measurement Canada for Electricity and Gas.

- (1) For gases, use specific test procedures outlined in ASTM D1826 “Standard Test Method for Calorific (Heating) Value of Gases in Natural Gas Range by Continuous Recording Calorimeter”, ASTM D3588 “Standard Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels”, or ASTM D4891, GPA Standard 2261 “Analysis for Natural Gas and Similar Gaseous Mixtures by Gas Chromatography.”
- (2) For middle distillates and oil, or liquid waste-derived fuels, use the specific test procedures outlined in ASTM D240 “Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter” or ASTM D4809 “Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method).”
- (3) For solid biomass-derived fuels, use the specific test procedures outlined in ASTM D5865 “Standard Test Method for Gross Calorific Value of Coal and Coke.”
- (4) For waste-derived fuels, use the specific test procedures outlined in ASTM D5865 and ASTM D5468 “Standard Test Method for Gross Calorific and Ash Value of Waste Materials.” Persons combusting waste-derived fuels that are not pure biomass fuels shall determine the biomass fuel portion of CO₂ emissions.
- (5) Use Equation 2-22 to calculate the weighted annual heat content of the fuel, if the measured heat content is used to calculate CO₂ emissions.

Equation 2-22: High Heat Value

$$HHV_{Annual\ i} = \frac{\sum_{p=1}^n HHV_{i\ p} \times Fuel_{i\ p}}{\sum_{p=1}^n Fuel_{i\ p}}$$

Where:

HHV_{Annual i} = Weighted annual average high heat value of the fuel by type “i” (MJ per tonne for solid fuel, MJ per kilolitre for liquid fuel, or MJ per cubic meter for gaseous fuel).

HHV_{i p} = High heat value of the fuel by type “i”, for measurement period “p” (MJ per tonne for solid fuel, MJ per kilolitre for liquid fuel, or MJ per cubic meter for gaseous fuel).

Fuel_{i p} = Mass or volume of the fuel combusted by type “i” during measurement period “p” (mass in tonnes for solid fuel, volume in kilolitres for liquid fuel or volume in cubic meters, at 15°C and 101.325 kPa, for gaseous fuel).

n = Number of measurement periods per calendar year that fuel is burned by type “i” in the unit.

2.C.4 Fuel Carbon Content Monitoring Requirements

Base the fuel carbon content and either molecular weight or molar fraction for gaseous fuels on the results of fuel sampling and analysis received from the fuel supplier or as determined by the facility operator, using an applicable analytical method in paragraphs 2.C.4(1) to 2.C.4(4) of this section. Follow the fuel measurement and sampling requirement in Section 2.C.1. For carbon content monitoring of natural gas, use Measurement Canada requirements for Electricity and Gas.

- (1) For coal and coke, solid biomass fuels, and waste-derived fuels, use the specific test procedures outlined in ASTM 5373 “Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Laboratory Samples of Coal”.
- (2) For liquid fuels, use the following specific test procedures: For petroleum-based liquid fuels and liquid waste-derived fuels, ASTM D5291 “Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants,” ultimate analysis of oil or computations based on ASTM D3238, and either ASTM D2502 “Standard Test Method for Estimation of Mean Relative Molecular Mass of Petroleum Oils From Viscosity Measurements” or ASTM D2503 “Standard Test Method for Relative Molecular Mass (Molecular Weight) of Hydrocarbons by Thermoelectric Measurement of Vapor Pressure.”
- (3) For gaseous fuels, use test procedures outlined in ASTM D1945 “Standard Test Method for Analysis of Natural Gas by Gas Chromatography” or ASTM D1946 “Standard Practice for Analysis of Reformulated Gas by Gas Chromatography.”
- (4) Use Equation 2-23 to calculate the weighted annual average carbon content of the fuel, if the measured carbon content is used to calculate CO₂ emissions.

Equation 2-23: Annual Carbon Content

$$CC_{\text{Annual } i} = \frac{\sum_{p=1}^n CC_{ip} \times \text{Fuel}_{ip}}{\sum_{p=1}^n \text{Fuel}_{ip}}$$

Where:

CC_{Annual i} = Weighted annual average carbon content of the fuel by type “i”, percent carbon expressed as a decimal fraction.

CC_{i p} = Carbon content of the fuel by type “i”, for measurement period “p” (percent C per tonne for solid fuel, percent C per kilolitre for liquid fuel or percent C per cubic meter for gaseous fuel).

Fuel_{i p} = Mass or volume of the fuel combusted by type “i” during measurement period “p” (mass in tonnes for solid fuel, volume in kilolitres for liquid fuel or volume in cubic meters, at 15°C and 101.325 kPa, for gaseous fuel).

n = Number of measurement periods in calendar year that the fuel is burned type “i” in the unit.

2.C.5 Fuel Analytical Data Capture

When the applicable methodologies in Sections 2.A and 2.B require periodic collection of fuel analytical data for an emissions source, demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100 percent for each report year. In any case, fuel analytical data capture shall be 80 percent or more.

If the fuel analytical data capture rate is between 80 percent and 100 percent for any emissions source identified in Sections 2.A and 2.B, use the methods in paragraph 2.D(2) to substitute for the missing values for the period of missing data.

2.C.6 On-site Transportation Consumption of Biofuels

Determine the fuel use and emission factors as specified in this section.

- (1) For biofuels, the portion(s) of ethanol or biodiesel from vendor specifications.
- (2) Conventional fuels and biofuels have emission factors listed in Table 2-2.
- (3) Determine biofuel volumes from vendor receipts, dipstick measurement, on a quarterly basis, starting on January 1 of the calendar year.

2.D Procedures for Estimating Missing Analytical Data

Whenever a quality-assured value of a required parameter is unavailable (e.g., if a CEM system malfunctions during unit operation or if a required fuel sample is not taken), a substitute data value for the missing parameter shall be used in the calculations.

- (1) For sources subject to the requirements of Section 2 that monitor and report emissions using a CEM system, follow the missing data backfilling procedures in *Reference Method for Source Testing: Quantification of Carbon Dioxide Releases by Continuous Emission Monitoring Systems from Thermal Power Generation* (Environment Canada, June 2012, Cat. No.: En14-46/1-2012E-PDF) for CO₂ concentration, stack gas flow rate, fuel flow rate, high heat value, and fuel carbon content.
- (2) For sources using Methodologies 1, 2, or 3, perform the following missing data substitution for each parameter:
 - (a) For each missing value of the high heat value, carbon content, or molecular weight of the fuel, substitute the arithmetic average of the quality-assured values of that parameter immediately preceding and immediately following the missing data incident. If the “after” value has not been obtained by the time that the GHG emissions must be calculated, use the “before” value for missing data substitution or the best available estimate of the parameter, based on all available process data (e.g., electrical load, steam production, operating hours). If, for a particular parameter, no quality assured data are available prior to the missing data incident, substitute the first quality-assured value obtained after the missing data period.
 - (b) For missing records of CO₂ concentration, stack gas flow rate, moisture percentage, fuel usage, and sorbent usage, substitute the best available estimate of that parameter, based on all available process data (e.g., electrical load, steam production, operating hours, etc.). Document and retain records of the procedures used for all such estimates.
- (3) For missing data that concerns carbon content, temperature, pressure or gas concentration, determine the sampling or measurement rate using Equation 2-24 and, replace the missing data as follows:
 - (a) If $R \geq 0.9$: replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, use the first available data from after the missing data period;
 - (b) If $0.75 \leq R < 0.9$: replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
 - (c) If $R < 0.75$: replace the missing data by the highest data value sampled or analyzed during the 3 preceding years.

Equation 2-24

$$R = \frac{QS_{ACT}}{QS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

QS_{ACT} = Quantity of actual samples or measurements obtained by the facility operator.

QS_{REQUIRED} = Quantity of samples or measurements required for Section 2.

- (4) For missing data that concerns CEM systems, determine the replacement data using the procedure in EPS 1/PG/7 or using Equation 2-25:
- (a) If $R \geq 0.9$: replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, use the first available data from after the missing data period;
 - (b) If $0.75 \leq R < 0.9$: replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
 - (c) If $R < 0.75$: replace the missing data by the highest data value sampled or analyzed during the 3 preceding years.

Equation 2-25

$$R = \frac{HS_{ACT}}{HS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

HS_{ACT} = Quantity of actual samples or measurements obtained by the person.

HS_{REQUIRED} = Quantity of samples or measurements required for Section 2.

3 Quantification Methods for Lime Manufacturing

3.A CO₂ Emissions from Lime Production

Calculate the annual CO₂ emissions from lime production for all kilns combined using the methods in this section. Persons operating a facility with installed CEMS may calculate the annual CO₂ emissions from lime production as specified in Section 3.A.3 or using Equations 3-1 through 3-3.

Equation 3-1

$$E_{CO_2} = \sum_m^{12} \sum_i [QL_{mi} \times EFL_{mi}] + \sum_q^4 \sum_j [QCBW_{qj} \times EFCBW_{qj}]$$

Where:

E_{CO₂} = the total annual quantity of CO₂ emissions from lime production (tonnes).

m = month.

i = lime type.

q = quarter.

j = byproduct/waste type.

QL_{mi} = the total monthly quantity of each lime (tonnes).

EFL_{mi} = the monthly plant specific emission factor for each lime type (tonnes CO₂ / tonnes lime), using the method in Section 3.A.1.

QCBW_{qj} = the total quarterly quantity of calcined byproducts/wastes for each byproduct/waste type (tonnes byproduct/waste).

EFCBW_{qj} = the quarterly plant specific emission factor for each calcined byproduct/waste type (tonnes CO₂/tonnes byproduct/waste), using the method in Section 3.A.2.

3.A.1 Monthly Lime Emission Factor

Calculate the monthly plant specific emission factor for each lime type using Equation 3-2.

Equation 3-2

$$EFL_{mi} = [(fCaO_{mi} \times 0.785) + (fMgO_{mi} \times 1.092)]$$

Where:

EFL_{m i} = the monthly plant specific emission factor for each lime type (tonnes CO₂ / tonnes lime).

m = month.

i = lime type.

fCaO_{m i} = the monthly calcium oxide (CaO) content for each lime type, calculated by subtracting the total CaO content of feed material entering the kiln from CaO content of lime exiting the kiln, (tonnes CaO / tonnes lime).

0.785 = ratio of molecular weights of CO₂ to CaO.

fMgO_{m i} = the monthly magnesium oxide (MgO) content for each lime type, calculated by subtracting the total MgO content of feed material entering the kiln from MgO content of lime exiting the kiln (tonnes MgO / tonne lime).

1.092 = ratio of molecular weights of CO₂ to MgO.

3.A.2 Quarterly Calcined Byproduct/Waste Emission Factor

Calculate the quarterly calcined byproduct/waste plant emission factor for each calcined/byproduct waste type using Equation 3-3.

Equation 3-3

$$EFCBW_{qj} = [(fCaO_{qj} \times 0.785) + (fMgO_{qj} \times 1.092)]$$

Where:

EFCBW_{q j} = the quarterly plant specific emission factor (tonnes CO₂ / tonnes calcined byproduct/waste).

q = quarter.

j = calcined byproduct/waste type.

fCaO_{q j} = CaO content of byproduct/waste, calculated by subtracting CaO content of byproduct/waste in uncalcined CaCO₃ remaining in calcined byproduct/waste from total CaO content of byproduct/waste (tonnes CaO / tonnes byproduct/waste).

fMgO_{q j} = the quarterly magnesium oxide (MgO) content of calcined byproduct/waste, calculated by subtracting MgO content of byproduct/waste in uncalcined MgCO₃ remaining in byproduct/waste from total MgO content of byproduct/waste (tonnes MgO / tonnes byproduct/waste).

0.785 = ratio of molecular weights of CO₂ to CaO.

1.092 = ratio of molecular weights of CO₂ to MgO.

3.A.3 CO₂ Emissions from Lime Production using CEMS

Persons operating a facility with installed CEMS may calculate CO₂ emissions from lime production using Equation 3-4.

Equation 3-4

$$E_{CO_2} = E_{CO_2\ CEMS} - E_{CO_2\ FC}$$

Where:

E_{CO₂} = the total annual quantity of CO₂ emissions for lime production from all kilns combined (tonnes), calculated by subtracting CO₂ fuel combustion emissions as specified in Section 2 from the total annual CO₂ quantity measured using CEMS.

E_{CO₂ CEMS} = the total annual quantity of CO₂ emissions from CEMS including fuel combustion and lime production emissions from all kilns (tonnes).

E_{CO₂ FC} = the total annual CO₂ fuel combustion emissions from all kilns, calculated as specified in Section 2.

3.B Sampling, Analysis and Measurement Requirements

Use the testing methods provided in this section to determine the chemical composition of CaO and MgO contents of each lime type and each calcined byproduct/waste type. Samples for analysis of the calcium oxide and magnesium oxide content of each lime type and each calcined byproduct/waste type shall be collected during the same month or quarter as the production data. At least one sample shall be collected monthly for each lime type that is produced monthly and, at least one sample shall be collected quarterly for each calcined byproduct/waste type that is produced quarterly.

- (1) ASTM C25-06 Standard Test Methods for Chemical Analysis of Limestone, Quicklime and Hydrated Lime.
- (2) Analytical Methods section of the National Lime Association "CO₂ Emissions Calculation Protocol for the Lime Industry English Units Version".
- (3) ASM CS-104 UNS No. G10460 "Carbon Steel of Medium Carbon Content".
- (4) ASME Performance Test Codes.
- (5) ASTM C25—Standard Test Method for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime.
- (6) ASTM D70—Standard Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method).
- (7) ASTM C114—Standard Test Methods for Chemical Analysis of Hydraulic Cement.
- (8) ASTM D240—Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimetre.
- (9) ASTM D1298—Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method.

- (10) ASTM D1826—Standard Test Method for Calorific (Heating) Value of Gases in Natural Gas Range by Continuous Recording Calorimetre.
- (11) ASTM D1945—Standard Test Method for Analysis of Natural Gas by Gas Chromatography.
- (12) ASTM D1946—Standard Practice for Analysis of Reformed Gas by Gas Chromatography.
- (13) ASTM D2013—Standard Practice of Preparing Coal Samples for Analysis.
- (14) ASTM D2163—Standard Test Method for Determination of Hydrocarbons in Liquefied Petroleum (LP) Gases and Propane/Propene Mixtures by Gas Chromatography.
- (15) ASTM D2234/D2234M—Standard Practice for Collection of a Gross Sample of Coal.
- (16) CO₂ Emissions Calculation Protocol for the Lime Industry—English Units Version, February 5, 2008 Revision—National Lime Association.

3.B.1. Determine the quantity of lime produced and sold monthly using direct measurements (i.e.: rail and truck scales) of lime sales for each lime type, and adjusted to take into account the difference in the beginning- and end-of-period inventories of each lime type. The inventory period shall be annual at a minimum.

3.B.2. Determine the quantity of calcined byproduct/waste sold monthly using direct measurements (i.e.: rail and truck scales) of calcined byproduct/waste sales for each calcined byproduct/waste type, and adjusted to take into account the difference in the beginning- and end-of-period inventories of each calcined byproduct/waste type. The inventory period shall be annual at a minimum. Determine the quantity of unsold calcined byproduct/waste annually at a minimum for each calcined/byproduct waste type using direct measurements (i.e.: rail and truck scales), or a calcined byproduct/waste generation rate (i.e. calcined byproduct produced as a factor of lime production).

3.B.3. Follow the quality assurance/quality control procedures (including documentation) in National Lime Association's CO₂ Emissions Calculation Protocol for the Lime Industry (English Units Version, February 5, 2008 Revision – National Lime Association).

3.C Procedures for Estimating Missing Analytical Data

Use the methods prescribed in this section to re-analyze the original sample, a backup sample or a replacement sample for the same measurement and sampling period for missing analytical data.

3.C.1. Whenever sampling, analysis and measurement data required for Section 3.A for the calculation of emissions is missing, a person shall ensure the data is replaced using the missing data procedures specified in this section.

- (a) For missing data that concerns carbon content, temperature, pressure or gas concentration, determine the sampling or measurement rate using Equation 3-5 and, replace the missing data as specified in paragraphs (b) to (d) of this section.
- (b) If $R \geq 0.9$: a person shall replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, a person shall use the first available data from after the missing data period;

- (c) If $0.75 \leq R < 0.9$: a person shall replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
- (d) If $R < 0.75$: a person shall replace the missing data by the highest data value sampled or analyzed during the 3 preceding years.

Equation 3-5

$$R = \frac{QS_{ACT}}{QS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

QS_{ACT} = Quantity of actual samples or measurements obtained by the person.

QS_{REQUIRED} = Quantity of samples or measurements required for Section 3.

3.C.2. For missing data that concerns lime production or missing calcined byproduct/waste production; the replacement data shall be generated from the best available estimate based on all available process data.

3.C.3. For missing data that concerns missing values related to the CaO and MgO content; a new composition test shall be conducted.

3.C.4. For all units that monitor and report emissions using CEMS; the missing data backfilling procedures in EPS 1/PG/7 can be used or Equation 3-6 to determine CO₂ concentration, stack gas flow rate, fuel flow rate, high heating value, and fuel carbon content.

- (a) If $R \geq 0.9$: a person shall replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, a person shall use the first available data from after the missing data period;
- (b) If $0.75 \leq R < 0.9$: a person shall replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
- (c) If $R < 0.75$: a person shall replace the missing data by the highest data value sampled or analyzed during the 3 preceding years.

Equation 3-6

$$R = \frac{HS_{ACT}}{HS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

HS_{ACT} = Quantity of actual samples or measurements obtained by the person.

HS_{REQUIRED} = Quantity of samples or measurements required for Section 3.

4 Quantification Methods for Cement Manufacturing

4.A CO₂ Emissions from Cement Production

Calculate the annual CO₂ emissions from clinker production for all kilns combined using the methods in this section. Persons operating a facility with installed CEMS may calculate the annual CO₂ emissions from clinker production as specified in Equation 4-6 or using Equations 4-1 through 4-5.

Equation 4-1

$$E_{CO_2} = E_{CO_2\ CLI} + E_{CO_2\ CKD} + E_{CO_2\ RM}$$

Equation 4-2

$$E_{CO_2} = \sum_m^{12} [Q_{CLI\ m} \times EF_{CLI\ m}] + \sum_q^4 [Q_{CKD\ q} \times EF_{CKD\ q}] + [TOC_{RM} \times RM \times 3.664]$$

Where:

E_{CO₂} = the total annual quantity of CO₂ emissions from cement production (tonnes).

E_{CO₂ CLI} = the total annual quantity of CO₂ emissions from clinker production (tonnes).

E_{CO₂ CKD} = the total annual quantity of CO₂ emissions from cement kiln dust (CKD) (tonnes).

E_{CO₂ RM} = the total annual quantity of CO₂ emissions from organic carbon oxidation (tonnes).

m = month.

q = quarter.

Q_{CLI m} = the total monthly quantity of clinker (tonnes).

EF_{CLI m} = the monthly plant specific emission factor of clinker (tonnes CO₂ / tonnes clinker), using Equation 4-3.

Q_{CKD q} = the total quarterly quantity of cement kiln dust not recycled back to the kiln (tonnes).

EF_{CKD q} = the quarterly plant specific emission factor of cement kiln dust not recycled back to the kiln (tonnes CO₂ / tonnes cement kiln dust), using Equation 4-4.

TOC_{RM} = the measured annual organic carbon content in raw material, or using a default value of 0.002 (0.2%).

RM = the total annual quantity of raw material consumption (tonnes).

3.664 = ratio of molecular weights of CO₂ to C.

4.A.1 Monthly Clinker Emission Factor

Calculate the monthly plant specific emission factor for clinker using Equation 4-3. The monthly clinker emission factor is calculated using monthly measurements of the weight fractions of calcium oxide (CaO) and magnesium oxide (MgO) content in clinker and in the non-carbonate raw materials entering the kiln.

Equation 4-3

$$EF_{CLI\ m} = [CaO_{CLI\ m} - fCaO_m] \times 0.785 + [MgO_{CLI\ m} - fMgO_m] \times 1.092$$

Where:

$EF_{CLI\ m}$ = the monthly plant specific emission factor of clinker (tonnes CO₂ / tonnes clinker).

m = month.

$CaO_{CLI\ m}$ = the monthly total calcium oxide (CaO) content of clinker (tonnes CaO / tonnes clinker).

$fCaO_m$ = the monthly non-calcined calcium oxide (CaO) content of clinker (tonne CaO / tonne clinker).

$MgO_{CLI\ m}$ = the monthly total magnesium oxide (MgO) content of clinker (tonne MgO / tonne clinker).

$fMgO_m$ = the monthly non-calcined magnesium oxide (MgO) content of clinker (tonne MgO / tonne clinker).

0.785 = ratio of molecular weights of CO₂ to CaO.

1.092 = ratio of molecular weights of CO₂ to MgO.

4.A.2 Quarterly CKD Emission Factor

Calculate the quarterly CKD emission factor using Equation 4-4. The quarterly plant specific CKD emission factor shall be calculated only if it is not recycled back to the kiln. The CKD emission factor is calculated using quarterly measurements of the weight fractions of calcium oxide (CaO) and magnesium oxide (MgO) content in CKD not recycled back to the kiln.

Equation 4-4

$$EF_{CKD\ q} = [CaO_{CKD\ q} - fCaO_q] \times 0.785 + [MgO_{CKD\ q} - fMgO_q] \times 1.092$$

Where:

$EF_{CKD\ q}$ = the quarterly plant specific emission factor of CKD not recycled back to the kiln (tonnes CO₂ / tonnes CKD).

$CaO_{CKD\ q}$ = the quarterly total calcium (expressed as CaO) content of CKD not recycled back to the kiln (tonnes CaO / tonnes CKD).

$fCaO_q$ = the quarterly non-calcined calcium oxide (CaO) content of CKD not recycled back to the kiln (tonne CaO / tonne clinker).

$MgO_{CKD\ q}$ = the quarterly total magnesium (expressed as MgO) content of CKD not recycled back to the kiln (tonne MgO / tonne clinker).

$fMgO\ q$ = the quarterly non-calcined magnesium oxide (MgO) content of CKD not recycled back to the kiln (tonne MgO / tonne clinker).

0.785 = ratio of molecular weights of CO₂ to CaO.

1.092 = ratio of molecular weights of CO₂ to MgO.

4.A.3 Organic Carbon Oxidation Emissions

Calculate the annual CO₂ emissions from total organic content in raw materials using Equation 4-5.

Equation 4-5

$$E_{CO_2RM} = [TOC_{RM} \times RM \times 3.664]$$

Where:

E_{CO_2RM} = the total annual quantity of CO₂ emissions from organic carbon oxidation (tonnes).

TOC_{RM} = the measured annual organic carbon content in raw material, or using a default value of 0.002 (0.2%).

RM = the total annual quantity of raw material consumption (tonnes).

3.664 = ratio of molecular weights of CO₂ to C.

4.A.4 CO₂ Emissions from Cement Production using CEMS

Persons operating a facility with installed CEMS may calculate CO₂ emissions from cement production using Equation 4-6.

Equation 4-6

$$E_{CO_2} = E_{CO_2\ CEMS} - E_{CO_2\ FC}$$

Where:

E_{CO_2} = the total annual quantity of CO₂ emissions from cement production from all kilns combined (tonnes), calculated by subtracting fuel combustion emissions for CO₂ as specified in Section 2 from the total annual CO₂ quantity measured using CEMS.

$E_{CO_2\ CEMS}$ = the total annual quantity of CO₂ emissions from CEMS including fuel combustion and cement production emissions from all kilns (tonnes).

$E_{CO_2\ FC}$ = the total annual CO₂ fuel combustion emissions from all kilns, calculated as specified in Section 2.

4.B Sampling, Analysis and Measurement Requirements

Use the testing methods provided in this section to determine the monthly plant specific weight fractions of total calcium oxide (CaO) and total magnesium oxide (MgO) in clinker using ASTM C114-Standard Test Methods for Chemical Analysis of Hydraulic Cement. The monitoring shall be conducted either daily from clinker drawn from the exit of the kiln or monthly from clinker drawn from bulk storage.

4.B.1. Determine the quarterly plant specific weight fractions of total calcium oxide (CaO) and total magnesium oxide (MgO) in CKD using ASTM C114-Standard Test Methods for Chemical Analysis of Hydraulic Cement. The monitoring shall be conducted either daily from CKD samples drawn from the exit of the kiln or quarterly from CKD samples drawn from bulk storage.

4.B.2. Determine the monthly plant specific weight fractions of calcium oxide (CaO) and magnesium oxide (MgO) that enter the kiln as non-carbonate species to clinker, by chemical analysis of feed material using a documented analytical method or a value of 0.0.

4.B.3. Determine the quarterly plant specific weight fractions of calcium oxide (CaO) and magnesium oxide (MgO) that enter the kiln as a non-carbonate species to CKD, by chemical analysis of feed material using a documented analytical method or a value of 0.0.

4.B.4. Determine the monthly plant specific weight fractions of calcium oxide (CaO) and magnesium oxide (MgO) that remain in clinker, by chemical analysis of feed material using a documented analytical method or a value of 0.0.

4.B.5. Determine the plant specific weight fractions of calcium oxide (CaO) and magnesium oxide (MgO) that remain in CKD, by chemical analysis of feed material using a documented analytical method or a value of 0.0.

4.B.6. Determine the total annual organic carbon content in raw material using ASTM C114 or a default value of 0.002. The analysis shall be conducted on samples drawn from bulk raw material storage for each category of raw material.

4.B.7. Determine the monthly quantity of clinker production using one of the following procedures:

- (a) Direct weight measurement using the same plant instruments used for accounting purposes, such as reconciling measurements using weigh hoppers or belt weigh feeders against inventory measurements, or
- (b) Direct measurement of raw kiln feed and application of a kiln specific feed to clinker factor. A person that chooses to use a feed to clinker factor, shall verify the accuracy of this factor on a monthly basis.

4.B.8. Determine the quarterly quantity of CKD not recycled back to the kiln using the same plant techniques used for accounting purposes, such as direct weight measurement using weigh hoppers or belt weigh feeders, and/or material balances.

4.B.9. Determine the monthly total quantity of raw materials consumed (i.e. limestone, sand, shale, iron oxide, alumina, and non-carbonate raw material) by direct weight measurement using the same plant instruments used for accounting purposes, such as reconciling weigh hoppers or belt weigh feeders.

4.C Procedures for Estimating Missing Analytical Data

Use the methods prescribed in this section to re-analyze the original sample, a backup sample or a replacement sample for the same measurement and sampling period for missing analytical data.

4.C.1. Whenever sampling, analysis and measurement data required for Section 4.A for the calculation of emissions is missing, a person shall ensure the data is replaced using the missing data procedures specified in this section.

- (a) For missing data that concerns carbon content, temperature, pressure or gas concentration, determine the sampling or measurement rate using Equation 4-7 and, replace the missing data as specified in paragraphs (b) to (d) of this section.
- (b) If $R \geq 0.9$: a person shall replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, a person shall use the first available data from after the missing data period;
- (c) If $0.75 \leq R < 0.9$: a person shall replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
- (d) If $R < 0.75$: a person shall replace the missing data by the highest data value sampled or analyzed during the three preceding years.

Equation 4-7

$$R = \frac{QS_{ACT}}{QS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

QS_{ACT} = Quantity of actual samples or measurements obtained by the person.

QS_{REQUIRED} = Quantity of samples or measurements required for Section 4.

4.C.2. For missing data that concerns clinker production, use the first data estimated after the period for which the data is missing or use the maximum daily production capacity and multiply it by the number of days in the month.

4.C.3. For missing data that concerns raw material consumption, use the first data estimated after the period for which the data is missing or use the maximum rate of raw materials entering the kiln and multiply by the number of days in the month.

4.C.4. For missing data that concerns the quantity of dust, or the quantity of limestone, the replacement data shall be generated from best estimates based on all of the data relating to the processes.

4.C.5. For all units that monitor and report emissions using CEMS; the missing data backfilling procedures in EPS 1/PG/7 can be used or Equation 4-8 to determine CO₂ concentration, stack gas flow rate, fuel flow rate, high heating value, and fuel carbon content.

- (a) If $R \geq 0.9$: a person shall replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, a person shall use the first available data from after the missing data period;
- (b) If $0.75 \leq R < 0.9$: a person shall replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
- (c) If $R < 0.75$: a person shall replace the missing data by the highest data value sampled or analyzed during the three preceding years.

Equation 4-8

$$R = \frac{HS_{ACT}}{HS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

HS_{ACT} = Quantity of actual samples or measurements obtained by the person.

HS_{REQUIRED} = Quantity of samples or measurements required for Section 4.

5 Quantification Methods for Aluminium Manufacturing

5.A CO₂ Emissions from Aluminium Production

Calculate the annual CO₂, CF₄, C₂F₆ and SF₆ emissions from aluminium production using the methods specified in this section.

5.A.1 CO₂ Emissions from Prebaked Anode Consumption

Calculate the total annual CO₂ emissions from prebaked anodes consumption using Equation 5-1.

Equation 5-1

$$E_{CO_2 PA} = \sum_{i=1}^{12} [NAC \times MP \times (1 - S_a - Ash_a) \times 3.664]_i$$

Where:

E_{CO₂ PA}

 = the total annual quantity of CO₂ emissions from the consumption of prebaked anodes (tonnes).

i = month.

NAC = the monthly net anode consumption for liquid aluminium production (tonnes anodes/tonnes liquid aluminium).

MP = the monthly total quantity of liquid aluminium production (tonnes).

S_a = the monthly sulphur content in prebaked anodes (kg S / kg prebaked anodes).

Ash_a = the monthly ash content in prebaked anodes (kg ash / kg prebaked anodes).

3.664 = ratio of molecular weights of CO₂ to C.

5.A.2 CO₂ Emissions from Anode Consumption from Söderberg Electrolysis Cells

Calculate the total annual CO₂ emissions from anode consumption from Söderberg electrolysis cells using Equation 5-2.

Equation 5-2

$$E_{CO_2 AS} = \sum_{i=1}^{12} \left[(PC \times MP) - \left(CSM \times \frac{MP}{1000} \right) - (BC \times PC \times MP \times (S_p + Ash_p + H_p)) \right. \\ \left. - ((1 - BC) \times PC \times MP \times (S_c + Ash_c)) - (MP \times CP) \right]_i \times 3.664$$

Where:

E_{CO₂ AS} = the total annual quantity of CO₂ emissions attributable to anode consumption from Söderberg electrolysis cells (tonnes).

i = month.

PC = the total monthly quantity of anode paste consumption (tonnes paste / tonnes liquid aluminium).

MP = the total monthly quantity of liquid aluminium production (tonnes).

CSM = emissions from cyclohexane-soluble matter (CSM) (tonnes) or the International Aluminium Institute factor used Table 5-1 (kg CSM / tonnes liquid aluminium).

BC = the monthly average pitch content or other binding agent in paste (kg pitch or other binding agent / kg paste).

S_p = the monthly sulphur content or other binding agent in pitch (kg S or other binding agent / kg pitch).

Ash_p = the ash content or other binding agent in pitch (kg ash / kg pitch).

H_p = the hydrogen content or other binding agent in pitch or the International Aluminium Institute factor used, listed in Table 5-1 (kg H₂ or other binding agent / kg pitch).

S_c = the sulphur content in calcinated coke (kg S / kg calcinated coke).

Ash_c = the ash content in calcinated coke (kg ash / kg calcinated coke).

CP = the carbon content in dust from Söderberg electrolysis cells (kg C / kg liquid aluminium, or a value of 0).

3.664 = ratio of molecular weights, CO₂ to C.

5.A.3 CO₂ Emissions from Anode and Cathode Baking

Calculate the total annual CO₂ emissions from anode and cathode baking using Equation 5-3.

Equation 5-3

$$E_{CO_2 AC} = E_{CO_2 PM} + E_{CO_2 P}$$

Where:

E_{CO₂ AC}

 = the total annual quantity of CO₂ emissions from anode and cathode baking (tonnes).

E_{CO₂ PM}

 = the total annual quantity of CO₂ emissions from packing material, as specified in Equation 5-4.

E_{CO₂ P}

 = the total annual quantity of CO₂ emissions from the coking of pitch or another binding agent, as specified in Equation 5-5.

5.A.4 CO₂ Emissions from Packing Material

Calculate the total annual CO₂ emissions from packing material using Equation 5-4.

Equation 5-4

$$E_{CO_2 PM} = \sum_{i=1}^{12} \left(CPM \times BAC \times (1 - Ash_{pm} - S_{pm}) \right)_i \times 3.664$$

Where:

E_{CO₂ PM}

 = the total annual quantity of CO₂ emissions from packing material consumption (tonnes).

i = month.

CPM = the monthly quantity of packing material consumption (tonnes packing material / tonnes baked anodes or cathodes).

BAC = the monthly quantity of baked anodes or cathodes removed from furnace (tonnes).

Ash_{pm} = the monthly ash content of packing material (kg ash / kg packing material).

S_{pm} = the monthly sulphur content of packing material (kg S / kg packing material).

3.664 = ratio of molecular weights, CO₂ to C.

5.A.5 CO₂ Emissions from Coking of Pitch or Other Binding Agent

Calculate the total annual CO₂ emissions from coking of pitch or other binding using Equation 5-5.

Equation 5-5

$$E_{CO_2 P} = \sum_{i=1}^{12} (GAC - BAC - (H_p \times PC \times GAC) - RT)_i \times 3.664$$

Where:

E_{CO₂ P} = the total annual quantity of CO₂ emissions from coking of pitch or other binding agent (tonnes).

i = month.

GAC = the total monthly quantity of green anodes or cathodes put into furnace (tonnes).

BAC = the total monthly quantity of baked anodes or cathodes removed from furnace (tonnes).

H_p = the monthly hydrogen content in pitch or other binding agent or the International Aluminium Institute factor used, listed in Table 5-1 (kg H₂ / kg pitch or other binding agent).

PC = the monthly pitch or other binding agent content in green anodes or cathodes (kg pitch or other binding agent / kg anodes or cathodes).

RT = the total monthly quantity of recovered tar (tonnes).

3.664 = ratio of molecular weights, CO₂ to carbon.

5.A.6 CO₂ Emissions from Green Coke Calcination

Calculate the total annual CO₂ emissions from green coke calcination using Equation 5-6.

Equation 5-6

$$E_{CO_2 GC} = \sum_{i=1}^{12} [(GC \times (1 - H_2O_{GC} - V_{GC} - S_{GC}) - (CC + UCC + ED) \times (1 - S_{cc})) \times 3.664 + (GC \times 0.035 \times 2.75)]_i$$

Where:

E_{CO₂ GC} = the total annual quantity of CO₂ emissions from green coke calcination (tonnes).

i = month.

GC = the total monthly quantity of green coke consumption (tonnes).

H₂O_{GC} = the monthly water content in green coke (kg H₂O / kg green coke).

V_{GC} = the monthly volatiles content in green coke (kg volatiles / kg green coke).
S_{GC} = the monthly sulphur content in green coke (kg S / kg green coke).
CC = the total monthly quantity of calcinated coke production (tonnes).
UCC = the total monthly quantity of under-calcinated coke production (tonnes).
ED = the total monthly quantity of emissions from coke dust (tonnes).
S_{CC} = the monthly sulphur content in calcinated coke (kg S / kg calcinated coke).
3.664 = ratio of molecular weights, CO₂ to carbon.
0.035 = CH₄ and tar content in coke volatiles contributing to CO₂ emissions.
2.75 = Conversion factor, CH₄ to CO₂.

5.A.7 CF₄ and C₂F₆ Emissions from Anode Effects

Calculate the total annual CF₄ and C₂F₆ emissions from anode effects for each series of pots using the same technology as specified in this section. Persons who operate a facility with CEMS shall calculate the annual CF₄ and C₂F₆ emissions as specified in Section 5.B.1.

5.A.7.a The Slope Method for CF₄ Emissions from Anode Effects

Calculate the total annual CF₄ emissions from anode effects using Equation 5-7.

Equation 5-7

$$E_{CF_4} = \sum_{i=1}^{12} [Slope_{CF_4} \times AED \times MP]_i$$

Where:

E_{CF₄} = the total annual quantity of CF₄ emissions from anode effects (tonnes).

i = month

Slope_{CF₄} = the monthly slope for series of pots *j* (tonnes CF₄ / tonnes liquid aluminium / anode effect minute / pot-day).

AED = the monthly anode effect duration (anode effect minutes / pot-day calculated per month and obtained by multiplying the anode effects frequency, in number of anode effects per pot-day, by the average duration of anode effects, in minutes).

MP = the monthly production of liquid aluminium (tonnes).

5.A.7.b The Overvoltage Coefficient Method for CF₄ Emissions from Anode Effects

Calculate the total annual CF₄ emissions from anode effects using Equation 5-8.

Equation 5-8

$$E_{CF_4} = \sum_{j=1}^m \left[\sum_{i=1}^{12} \left[OVC_{CF_4} \times \frac{AEO}{CE} \times MP \right]_i \right]_j$$

Where:

E_{CF₄} = the total annual quantity of CF₄ emissions from anode effects (tonnes).

m = number of a series of pots.

j = series of pots.

i = month.

OVC_{CF₄} = the overvoltage coefficient (tonnes of CF₄ / tonnes liquid aluminium/millivolt).

AEO = the monthly anode effect overvoltages (millivolts / pot).

CE = the current efficiency of the aluminium production process (fraction).

MP = the monthly production of liquid aluminium (tonnes).

5.A.7.c Calculation Method for C₂F₆ Emissions from Anode Effects

Calculate the total annual C₂F₆ emissions from anode effects using Equation 5-9.

Equation 5-9

$$E_{C_2F_6} = \sum_{i=1}^{12} [E_{CF_4} \times F]_i$$

Where:

E_{C₂F₆} = the total annual quantity of C₂F₆ emissions (tonnes).

E_{CF₄} = the total monthly quantity of CF₄ emissions (tonnes).

i = month.

F = the weight fraction of C₂F₆ / CF₄ determined by the emitter or selected from Table 5-2 (kg C₂F₆ / kg CF₄).

5.A.8 Emissions from SF₆ Used as a Cover Gas

Calculate the total annual emissions from SF₆ used as a cover gas using Equation 5-10 if based on the change in inventory or using Equation 5-11 if based on direct measurement.

Equation 5-10

$$E_{SF_6} = (S_{Inv-Begin} - S_{Inv-End}) + (S_{Purchased} - S_{Shipped})$$

Where:

E_{SF₆}

 = the total annual quantity of SF₆ emissions used as a cover gas (tonnes).

S_{Inv-Begin} = the total annual quantity of SF₆ in storage at the beginning of the year (tonnes).

S_{Inv-End} = the total annual quantity of SF₆ in storage at the end of the year (tonnes).

S_{Purchased} = the total annual quantity of SF₆ purchases for the year (tonnes).

S_{Shipped} = the total annual quantity of SF₆ shipped out of the facility during the year (tonnes).

Equation 5-11

$$E_{SF_6} = \sum_{i=1}^{12} [(Q_{Input} \times C_{Input}) - (Q_{Output} \times C_{Output})]_i$$

Where:

E_{SF₆}

 = the total annual quantity of SF₆ emissions used as a cover gas (tonnes).

i = month.

Q_{Input} = the total monthly quantity of cover gas entering the electrolysis cells (tonnes).

C_{Input} = the monthly concentration of SF₆ in the cover gas entering the electrolysis cells (tonnes SF₆ / tonnes input gas).

Q_{Output} = the monthly quantity of gas containing SF₆ collected and shipped out of the facility (tonnes).

C_{Output} = the monthly concentration of SF₆ in the gas collected and shipped out of the facility (tonnes SF₆ / tonnes gas collected and shipped out of the facility).

5.B Sampling, Analysis and Measurement Requirements

Measure all parameters monthly, subject to the exceptions specified in this section. Where a method provides the option to use a default value versus a measured parameter, a person who operates a facility that currently measures these parameters, shall continue to measure these parameters. Where measured data for a parameter is unavailable, a person shall use the provided default values.

- (a) for emissions of cyclohexane-soluble matter used in Equation 5-2, a person shall measure the emissions monthly or use International Aluminium Institute factors.
- (b) for the carbon present in dust from Søderberg electrolysis cells used in the calculation in Equation 5-2, a person shall measure the carbon monthly or use the value of 0.
- (c) for the hydrogen content in pitch used in the calculation in Equation 5-2 and Equation 5-5, a person shall measure the content monthly or use the International Aluminium Institute factors.
- (d) for the parameters concerning the use of SF₆ as a cover gas, a person shall measure the parameters in accordance with paragraph (b).
- (e) in the case of the quantity of calcinated coke, a person shall directly measure that quantity or determine it by multiplying the recovery factor by the quantity of green coke consumed in accordance with Equation 5-6:

Equation 5-12

$$CCP_M = RF \times CGC$$

Where:

CCP_M = the calcinated coke produced and measured during the measurement period (tonnes).

RF = the recovery factor determined annually during a measurement period (tonnes calcinated coke / tonnes green coke).

CGC = the consumption of green coke measured during the measurement period (tonnes).

5.B.1. Persons using CEMS for CF₄ and C₂F₆ emissions from anode effects must comply with the guidelines in the document “*Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*” published by the Intergovernmental Panel on Climate Change.

5.B.2. Persons using the slope method or the overvoltage coefficient method shall conduct performance tests to calculate the slope or overvoltage coefficients for each technology used in a series of pots using the Protocol for Measurement of Tetrafluoromethane and Hexafluoroethane Emissions from Primary Aluminum Production published in April 2008 by the U.S. Environmental Protection Agency (USEPA) and the International Aluminium Institute. The performance tests shall be conducted whenever:

- (a) 36 months have passed since the last tests or a series of pots is started up;
- (b) a change occurs in the control algorithm that affects the intensity or duration of the anode effects or the nature of the anode effect termination routine; or

(c) changes occur in the distribution or duration of anode effects: for example when the percentage of manual kills changes or when, over time, the number of anode effects decreases and results in anode effects of shorter duration, or when the algorithm for bridge movements and anode effect overvoltage accounting changes.

5.B.3. The slope or the overvoltage coefficient calculated following the performance tests specified in 5.B.2 shall be used beginning on the date of the change; or the 1st of January immediately following the measurements.

5.B.4. Persons who use the direct measurement method in Equation 5-11 to calculate SF₆ emissions from the consumption of a cover gas shall, measure monthly the quantity of SF₆ entering the electrolysis cells and the quantity and SF₆ concentration of any residual gas collected and shipped out of the facility.

5.C Procedures for Estimating Missing Analytical Data

Use the methods prescribed in this section to re-analyze the original sample, a backup sample or a replacement sample for the same measurement and sampling period for missing analytical data.

5.C.1. Whenever sampling, analysis and measurement data required for Section 5 for the calculation of emissions is missing, a person shall ensure the data is replaced using the missing data procedures specified below:

- (a) For missing data that concerns carbon content, sulphur content, ash content, hydrogen content, water content, CSM emissions, pitch content, carbon present in skimmed dust from electrolysis cells, volatiles content, data for slope calculations, frequency and duration of anode effects, overvoltage, SF₆ concentration or data to calculate current efficiency, determine the sampling or measurement rate using Equation 5-13 and, replace the missing data as specified in paragraphs (b) to (d) of this section.
- (b) If $R \geq 0.9$: a person shall replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, a person shall use the first available data from after the missing data period;
- (c) If $0.75 \leq R < 0.9$: a person shall replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
- (d) If $R < 0.75$: a person shall replace the missing data by the highest data value sampled or analyzed during the three preceding years.

Equation 5-13

$$R = \frac{QS_{ACT}}{QS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

QS_{ACT} = Quantity of actual samples or measurements obtained by the person.

QS_{REQUIRED} = Quantity of samples or measurements required for Section 5.

5.C.2. For missing data that concerns net anode consumption, anode paste consumption, packing material consumption, green anode or cathode consumption, quantity of tar recovered, green coke consumption, liquid aluminium production, aluminium hydrate production, baked anode or cathode production, calcinated and under-calcinated coke production, coke dust quantity or SF₆ quantity, the replacement data must be estimated on the basis of all the data relating to the processes used.

5.C.3. For all units that monitor and report emissions using CEMS; the missing data backfilling procedures in EPS 1/PG/7 can be used or Equation 5-14 to determine CO₂ concentration, stack gas flow rate, fuel flow rate, high heating value, and fuel carbon content.

- (a) If $R \geq 0.9$: a person shall replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, a person shall use the first available data from after the missing data period;
- (b) If $0.75 \leq R < 0.9$: a person shall replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
- (c) If $R < 0.75$: a person shall replace the missing data by the highest data value sampled or analyzed during the three preceding years.

Equation 5-14

$$R = \frac{HS_{ACT}}{HS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

HS_{ACT} = Quantity of actual samples or measurements obtained by the person.

HS_{REQUIRED} = Quantity of samples or measurements required for Section 5.

Table 5-1: Default Factors for Parameters Used to Quantify CO₂ Emissions

Parameters ¹	Default Factors
CSM: emissions of cyclohexane soluble matter (kg per tonne aluminium)	Horizontal stud Søderberg: 4.0 Vertical stud Søderberg: 0.5
Hp: Hydrogen content in pitch (wt %)	3.3
¹ International Aluminium Institute. 2006. The Aluminium Sector Greenhouse Gas Protocol (Addendum to WRI/WBCSD Gas Protocol). International Aluminium Institute.	

Table 5-2: C₂F₆ / CF₄ Weight Fractions Based on the Technology Used

Technology used	Weight fraction (kg C ₂ F ₆ / kg CF ₄)
Centre-worked prebaked anodes (CWPB)	0.121
Side-worked prebaked anodes (SWPB)	0.252
Vertical stud Søderberg (VSS)	0.053
Horizontal stud Søderberg (HSS)	0.085

6 Quantification Methods for Iron and Steel Manufacturing

6.A CO₂ Emissions from Iron and Steel Production

The total annual CO₂ emissions from iron and steel production shall be calculated using the methods specified in this section, depending on the process used. Specific process inputs or outputs that contribute less than 1% of the total mass of carbon into or out of the process do not have to be included in Equation 6-1 to Equation 6-10. Persons who operate a facility with CEMS, may calculate the annual CO₂ emissions from iron and steel production as specified in Equation 6-11 or using Equation 6-1 to Equation 6-10. Where a method provides the option to use a default value versus a measured parameter, a person who operates a facility that currently measures these parameters shall continue to measure these parameters. Where measured data for a parameter is unavailable, a person shall use the provided default values.

6.A.1 Taconite Indurating Furnace

Equation 6-1

Calculate the total annual CO₂ emissions from the taconite indurating furnace using either Equation 6-1 or Equation 6-2.

$$E_{CO_2 T} = [(T \times C_T) - (P \times C_P) - (R \times C_R)] \times 3.664$$

Where:

$E_{CO_2 T}$ = the total annual quantity of emissions from taconite indurating furnace (tonnes).

T = the total annual quantity of greenball (taconite) pellets fed to the furnace (tonnes).

C_T = the annual weighted average carbon content of greenball (taconite) pellets fed to the furnace (tonnes C / tonnes taconite pellets).

P = the total annual quantity of fired pellets produced by the furnace (tonnes).

C_P = the annual weighted average carbon content of fired pellets produced by the furnace (tonnes C / tonnes taconite pellets).

R = the annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average carbon content of air pollution control residue collected (tonnes C / tonnes residue).

3.664 = conversion factor from tonnes of C to tonnes of CO₂.

Equation 6-2

$$E_{CO_2 IP} = \left[\sum_j^n (AD_j \times C_{ADj}) + (IRC \times C_{IRC}) - (P \times C_P) - (R \times C_R) \right] \times 3.664$$

Where:

E_{CO₂ IP} = the total annual quantity of emissions from taconite indurating furnace (tonnes).

n = number of additives.

j = type of additive, such as limestone, dolomite or bentonite.

AD_j = the total annual quantity of additive material consumed by the furnace (tonnes).

C_{ADj} = the annual weighted average carbon content of additive material consumed by the furnace (tonnes C / additive material).

IRC = the total annual quantity of iron ore pellets fed to the furnace (tonnes).

C_{IRC} = the annual weighted average carbon content of iron ore pellets fed to the furnace (tonnes C / tonnes iron ore pellets).

P = the total annual quantity of fired pellets produced by the furnace (tonnes).

C_P = the annual weighted average carbon content of fired pellets produced by the furnace (tonnes C / tonnes taconite pellets).

R = the annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average carbon content of air pollution control residue collected (tonnes C / tonnes residue).

3.664 = conversion factor from tonnes of C to tonnes of CO₂.

6.A.2 Basic Oxygen Furnace

Calculate the total annual CO₂ emissions from the basic oxygen furnace using Equation 6-3.

Equation 6-3

$$E_{CO_2 BOF} = \left[(I \times C_I) + (SC \times C_{SC}) + \sum_{t=1}^n (FL_t \times C_{FL_t}) + \sum_{i=1}^m (CAR_i \times C_{CAR_i}) - (ST \times C_{ST}) - (SL \times C_{SL}) - (BOG \times C_{BOG}) - (R \times C_R) \right] \times 3.664$$

Where:

E_{CO₂ BOF}

 = the total annual quantity of emissions from basic oxygen furnace (tonnes).

n = number of flux materials.

t = type of flux material, such as limestone, dolomite or bentonite.

m = number of carbonaceous materials.

i = type of carbonaceous material, such as coal, coke etc.

I = the total annual quantity of molten iron charged to furnace (tonnes).

C_I = the annual weighted average carbon content of molten iron charged to furnace (tonnes of C / tonnes of molten iron).

SC = the total annual quantity of ferrous scrap charged to furnace (tonnes).

C_{SC} = the annual weighted average carbon content of ferrous scrap charged to furnace (tonnes C / tonnes ferrous scrap).

FL_t = the total annual quantity of non-biomass flux material charged to the furnace (tonnes).

C_{FL_t} = the annual weighted average carbon content of non-biomass flux material charged to the furnace (tonnes C / flux material).

CAR_i = the total annual quantity of non-biomass carbonaceous material consumed by the furnace (tonnes).

C_{CAR_i} = the annual weighted average carbon content of non-biomass carbonaceous material consumed by the furnace (tonnes C / tonnes carbonaceous material).

ST = the total annual quantity of molten raw steel produced by the furnace (tonnes).

C_{ST} = the annual weighted average carbon content of molten raw steel produced by the furnace (tonnes C / tonnes molten raw steel).

SL = the total annual quantity of slag produced by the furnace (tonnes).

C_{SL} = the annual weighted average carbon content of slag produced by the furnace (tonnes C / tonnes slag).

BOG = the total annual quantity of furnace gas transferred off site (tonnes).

C_{BOG} = the annual weighted average carbon content of furnace gas transferred off site (tonnes C / tonnes furnace gas transferred).

R = the annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average carbon content of air pollution control residue collected (tonnes C / tonnes residue).

3.664 = conversion factor from tonnes of C to tonnes of CO₂.

6.A.3 Coke Oven Battery

Calculate the total annual CO₂ emissions from the coke oven battery using Equation 6-4.

Equation 6-4

$$E_{CO_2 \text{ COKE}} = [(C_C \times C_{CC}) - (CO \times C_{CO}) - (BY \times C_{BY}) - (COG \times C_{COG}) - (R \times C_R)] \times 3.664$$

Where:

E_{CO₂ COKE} = the total annual quantity of emissions from coke production (tonnes).

C_C = the total annual quantity of non-biomass coking coal charged to battery (tonnes).

C_{CC} = the annual weighted average carbon content of non-biomass coking coal charged to battery (tonnes of C / tonnes of coking coal).

CO = the total annual quantity of coke produced (tonnes).

C_{CO} = the annual weighted average carbon content of coke produced (tonnes C / tonnes coke).

BY = the total annual quantity of byproduct, from non-biomass byproduct coke oven battery (tonnes).

C_{BY} = the annual weighted average carbon content of non-biomass byproduct, from byproduct coke oven battery (tonnes C / tonnes byproduct).

COG = the total annual quantity of coke oven gas transferred off site (tonnes).

C_{COG} = the annual weighted average carbon content of coke oven gas transferred off site (tonnes C / tonnes coke oven gas).

R = the annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average carbon content of air pollution control residue collected (tonnes C / tonnes residue).

3.664 = conversion factor from tonnes of C to tonnes of CO₂.

6.A.4 Sinter

Calculate the total annual CO₂ emissions from sinter production using Equation 6-5.

Equation 6-5

$$E_{CO_2 \text{ SINTER}} = \left[\sum_{i=1}^m (CAR_i \times C_{CAR_i}) + (FE \times C_{FE}) - (S \times C_S) - (R \times C_R) \right] \times 3.664$$

Where:

E_{CO₂ SINTER} = the total annual quantity of emissions from sinter production (tonnes).

m = number of carbonaceous materials.

i = type of carbonaceous material, such as coal, coke etc.

CAR_i = the total annual quantity of non-biomass carbonaceous material consumed by the furnace (tonnes).

C_{CAR i} = the annual weighted average carbon content of non-biomass carbonaceous material consumed by the furnace (tonnes C / tonnes carbonaceous material).

FE = the total annual quantity of sinter feed material (tonnes).

C_{FE} = the annual weighted average carbon content of sinter feed material (tonnes C / tonnes sinter feed).

S = the total annual quantity of sinter production (tonnes).

C_S = the annual weighted average carbon content of sinter production (tonnes C / tonnes sinter production).

R = the annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average carbon content of air pollution control residue collected (tonnes C / tonnes residue).

3.664 = conversion factor from tonnes of C to tonnes of CO₂.

6.A.5 Electric Arc Furnace

Calculate the total annual CO₂ emissions from electric arc furnace using Equation 6-6.

Equation 6-6

$$E_{CO_2 EAF} = \left[\sum_{i=1}^m (CAR_i \times C_{CAR_i}) + \sum_{t=1}^n (FL_t \times C_{FL_t}) + (I \times C_I) + (SC \times C_{SC}) + (EL \times C_{EL}) - (ST \times C_{ST}) - (SL \times C_{SL}) - (R \times C_R) \right] \times 3.664$$

Where:

E_{CO₂ EAF}

 = the total annual quantity of emissions from electric arc furnace (tonnes).

n

 = number of flux materials.

t

 = type of flux material, such as limestone, dolomite or bentonite.

m

 = number of carbonaceous materials.

i

 = type of carbonaceous material, such as coal, coke etc.

I

 = the total annual quantity of direct reduced iron charged to furnace (tonnes).

C_I

 = the annual weighted average carbon content of direct reduced iron charged to the furnace (tonnes C / tonnes direct reduced iron).

SC

 = the total annual quantity of ferrous scrap consumed by the furnace (tonnes).

C_{SC}

 = the annual weighted average carbon content of ferrous scrap consumed by the furnace (tonnes C / tonnes ferrous scrap).

FL_t

 = the total annual quantity of non-biomass flux material charged to the furnace (tonnes).

C_{FL_t}

 = the annual weighted average carbon content of non-biomass flux material charged to the furnace (tonnes C / flux material).

EL

 = the total annual quantity of non-biomass carbon electrodes consumed by the furnace (tonnes).

C_{EL}

 = the annual weighted average carbon content of non-biomass carbon electrodes consumed by the furnace (tonnes C / tonnes carbon electrode).

CAR_i

 = the total annual quantity of non-biomass carbonaceous material consumed by the furnace (tonnes).

C_{CAR_i}

 = the annual weighted average carbon content of non-biomass carbonaceous material consumed by the furnace (tonnes C / tonnes carbonaceous material).

ST

 = the total annual quantity of molten raw steel produced by the furnace (tonnes).

C_{ST}

 = the annual weighted average carbon content of molten raw steel produced by the furnace (tonnes C / tonnes molten raw steel).

SL

 = the total annual quantity of slag produced by the furnace (tonnes).

C_{SL}

 = the annual weighted average carbon content of slag produced by the furnace (tonnes C / tonnes slag).

R = the annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average carbon content of air pollution control residue collected (tonnes C / tonnes residue).

3.664 = conversion factor from tonnes of C to tonnes of CO₂.

6.A.6 Argon-oxygen Decarburization Vessels

Calculate the total annual CO₂ emissions from argon-oxygen decarburization vessels shall be calculated using Equation 6-7.

Equation 6-7

$$E_{CO_2 AOD} = [Steel \times (C_{In} - C_{Out}) - (R \times C_R)] \times 3.664$$

Where:

E_{CO₂ AOD}

 = the total annual quantity of emissions from argon-oxygen decarburization vessels (tonnes).

Steel = the total annual quantity of molten steel charged to the vessel (tonnes).

C_{In} = the annual weighted average carbon content of molten steel before decarburization (tonnes C / tonnes molten steel).

C_{Out} = the annual weighted average carbon content of molten steel after decarburization (tonnes C / tonnes molten steel).

R = the total annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average annual carbon content of air pollution control residue collected or a default value of 0 (tonnes C / tonnes residue).

3.664 = conversion factor from tonnes of C to tonnes of CO₂.

6.A.7 Iron Production from Direct Reduction Furnace

Calculate the total annual CO₂ emissions from direct reduction furnace using Equation 6-8.

Equation 6-8

$$E_{CO_2 DR} = \left[\sum_{k=1}^n (RM_k \times C_{RM k}) + \sum_{i=1}^m (CAR_i \times C_{CAR i}) + (Ore \times C_{Ore}) - (I \times C_I) - (NM \times C_{NM}) - (R \times C_R) \right] \times 3.664$$

Where:

E_{CO₂ DR}

 = the total annual quantity of emissions from direct reduction furnace (tonnes).

n = number of raw materials, other than carbonaceous materials and ore.

k = type of raw material other than carbonaceous materials and ore.

m = number of carbonaceous materials.

i = type of carbonaceous material, such as coal, coke etc.

Ore = the total annual quantity of iron ore or iron ore pellets fed to the furnace (tonnes).

C_{Ore} = the annual weighted average carbon content of iron ore or iron ore pellets fed to the furnace (tonnes C / tonnes iron or iron ore pellets).

RM_k = the total annual consumed raw material other than carbonaceous material and ore (tonnes).

C_{RM k} = the annual weighted average carbon content of raw material, other than carbonaceous material and ore (tonnes C / tonnes raw material).

CAR_i = the total annual quantity of non-biomass carbonaceous material consumed by the furnace (tonnes).

C_{CAR i} = the annual weighted average carbon content of non-biomass carbonaceous material consumed by the furnace (tonnes C / tonnes carbonaceous material).

I = the total annual quantity of iron produced by the furnace (tonnes).

C_I = the annual weighted average carbon content of iron produced by the furnace (tonnes C / tonnes iron).

NM = the total annual quantity of non-metallic material produced by the furnace (tonnes).

C_{NM} = the annual weighted average carbon content of non-metallic material produced by the furnace (tonnes C / tonnes non-metallic material).

R = the total annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average annual carbon content of air pollution control residue collected or a default value of 0 (tonnes C / tonnes residue).

3.664 = conversion factor from tonnes of C to tonnes of CO₂.

6.A.8 Iron Production from Blast Furnace

Calculate the total annual CO₂ emissions from the blast furnace using Equation 6-9.

Equation 6-9

$$E_{CO_2 BF} = \left[\sum_{k=1}^n (RM_k \times C_{RM k}) + \sum_{i=1}^m (CAR_i \times C_{CAR i}) + \sum_{t=1}^p (FL_t \times C_{FL t}) + (Ore \times C_{Ore}) - (I \times C_I) - (NM \times C_{NM}) - (BG \times C_{BG}) - (R \times C_R) \right] \times 3.664$$

Where:

E_{CO₂ BF}

 = the total annual quantity of emissions from blast furnace (tonnes).

n = number of raw materials, other than carbonaceous materials and ore.

k = type of raw material other than carbonaceous materials and ore.

m = number of carbonaceous materials.

i = type of carbonaceous material, such as coal, coke etc.

p = number of flux materials.

t = type of flux material, such as limestone, dolomite or bentonite.

Ore = the total annual quantity of iron ore or iron ore pellets fed to the furnace (tonnes).

C_{Ore} = the annual weighted average carbon content of iron ore or iron ore pellets fed to the furnace (tonnes C / tonnes iron or iron ore pellets).

RM_k = the total annual quantity of consumed raw material other than carbonaceous material and ore (tonnes).

C_{RM k} = the annual average carbon content of raw material, other than carbonaceous material and ore (tonnes C / tonnes raw material).

CAR_i = the total annual quantity of non-biomass carbonaceous material consumed by the furnace (tonnes).

C_{CAR i} = the annual weighted average carbon content of non-biomass carbonaceous material consumed by the furnace (tonnes C / tonnes carbonaceous material).

FL_t = the total annual quantity of non-biomass flux material charged to the furnace (tonnes).

C_{FL t} = the annual weighted average carbon content of non-biomass flux material charged to the furnace (tonnes C / flux material).

I = the total annual quantity of iron produced by the furnace (tonnes).

C_I = the annual weighted average carbon content of iron produced by the furnace (tonnes C / tonnes iron).

NM = the total annual quantity of non-metallic material produced by the furnace (tonnes).

C_{NM} = the annual weighted average carbon content of non-metallic material produced by the furnace (tonnes C / tonnes non-metallic material).

BG = the total annual quantity of blast furnace gas transferred off site (tonnes).

C_{BG} = the annual weighted average carbon content of blast furnace gas transferred off site (tonnes C / tonnes blast furnace gas).

R = the total annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average annual carbon content of air pollution control residue collected or a default value of 0 (tonnes C / tonnes residue).

3.664 = conversion factor from tonnes of C to tonnes of CO₂.

6.A.9 Molten Steel Production from Ladle Furnace

Calculate the total annual CO₂ emissions from the ladle furnace using Equation 6-10.

Equation 6-10

$$E_{CO_2 LF} = \left[(MS_{FED} \times C_{MS_{FED}}) + \sum_{j=1}^m (AD_j \times C_{AD_j}) + (EL \times C_{EL}) - (MS_{prod} \times C_{MS_{prod}}) - (SL \times C_{SL}) - (R \times C_R) - (Rp \times C_{Rp}) \right] \times 3.664$$

Where:

$E_{CO_2 LF}$ = the total annual quantity of emissions from ladle furnace (tonnes).

m = number of additives.

j = type of additive, such as limestone, dolomite or bentonite.

MS_{FED} = the total annual quantity of molten steel fed to the furnace (tonnes).

$C_{MS_{FED}}$ = the annual weighted average carbon content of molten steel fed to the furnace (tonnes C / tonnes molten steel).

AD_j = the total annual quantity of additive material consumed by the furnace (tonnes).

C_{AD_j} = the annual weighted average carbon content of additive material consumed by the furnace (tonnes C / tonnes additive material).

EL = the total annual carbon electrodes consumed by the furnace (tonnes).

C_{EL} = the annual weighted average carbon content of carbon electrodes consumed by the furnace (tonnes C / tonnes carbon electrodes).

MS_{prod} = the total annual quantity of molten steel produced by the furnace (tonnes).

$C_{MS\ prod}$ = the annual weighted average carbon content of molten steel produced by the furnace (tonnes C / tonnes molten steel).

SL = the total annual quantity of slag produced by the furnace (tonnes).

C_{SL} = the annual weighted average carbon content of slag produced by the furnace, or a default value of 0 (tonnes C / tonnes slag).

R = the total annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average carbon content of air pollution control residue collected or a default value of 0 (tonnes C / tonnes residue).

R_p = the total annual quantity of other residue produced (tonnes).

C_{Rp} = the annual weighted average carbon content of other residue produced or a default value of 0 (tonnes of C / tonnes of residue).

3.664 = Conversion factor from tonnes of C to tonnes of CO₂.

6.A.10 CO₂ Emissions from Iron and Steel Production Using CEMS

Persons operating a facility with installed CEMS shall calculate CO₂ emissions from iron and steel production using Equation 6-11.

Equation 6-11

$$E_{CO_2} = E_{CO_2\ CEMS} - E_{CO_2\ FC}$$

Where:

E_{CO_2} = the total annual quantity of CO₂ emissions from iron and steel production (tonnes) calculated by subtracting fuel combustion emissions for CO₂ as specified in Section 2 from the total annual CO₂ quantity measured using CEMS.

$E_{CO_2\ CEMS}$ = the total annual quantity of CO₂ emissions from CEMS including fuel combustion and iron and steel production emissions (tonnes).

$E_{CO_2\ FC}$ = the total annual CO₂ fuel combustion emissions, calculated as specified in Section 2.

6.B CO₂ Emissions from Iron and Steel Powder Production

Calculate the total annual CO₂ emissions from iron and steel powder production using the methods in this section depending on the process used. Specific process inputs or outputs that contribute less than 0.5 % of the total mass of carbon into or out of the process do not have to be included in equations Equation 6-12 to Equation 6-16 by mass balance. Persons operating a facility with CEMS, shall calculate the annual CO₂ emissions from iron and steel powder production as specified in Equation 6-17. Where a method provides the option to use a default value versus a measured parameter, persons who operates a facility that currently measures these parameters, shall continue to measure these parameters. Where measured data for a parameter is unavailable, persons shall use the provided default values.

Equation 6-12

$$E_{CO_2} = E_{CO_2 A} + E_{CO_2 D} + E_{CO_2 SG} + E_{CO_2 SA}$$

Where:

E_{CO₂} = the total annual quantity of CO₂ emissions from iron and steel powder production (tonnes).

E_{CO₂ A} = the total annual quantity of CO₂ emissions from the atomization of molten cast iron (tonnes).

E_{CO₂ D} = the total annual quantity of CO₂ emissions from the decarburization of iron powder (tonnes).

E_{CO₂ SG} = the total annual quantity of CO₂ emissions from molten steel grading (tonnes).

E_{CO₂ SA} = the total annual quantity of CO₂ emissions from steel powder annealing.

6.B.1 CO₂ Emissions from the Atomization of Molten Cast Iron

Calculate the total annual CO₂ emissions from the atomization of molten cast iron using Equation 6-13.

Equation 6-13

$$E_{CO_2 A} = \left[(MI \times C_{MI}) + \sum_{k=1}^p (M_k \times C_{Mk}) - (AI \times C_{AI}) - \sum_{j=1}^m (BP_j \times C_{BPj}) \right] \times 3.664$$

Where:

E_{CO₂A} = the total annual quantity of CO₂ emissions from the atomization of molten cast iron (tonnes).

p = number of materials used other than molten cast iron.

k = material used other than molten cast iron.

m = number of byproducts.

j = byproduct type.

MI = the total annual quantity of molten cast iron fed into the process (tonnes).

C_{MI} = the annual weighted average carbon content of molten cast iron fed into the process (tonnes C / tonnes molten cast iron).

M_k = the total annual quantity of other material used in the process (tonnes).

C_{Mk} = the annual weighted average carbon content of other material used in the process (tonnes C / tonnes other material).

AI = the total annual quantity of atomized cast iron production (tonnes).

C_{AI} = the annual weighted average carbon content of atomized cast iron (tonnes C / tonnes atomized cast iron).

BP_j = the total annual quantity of byproduct (tonnes).

C_{BPj} = the annual weighted average carbon content of byproduct, or a default value of 0 (tonnes C / tonnes byproduct).

3.664 = Ratio of molecular weights, CO₂ to carbon.

6.B.2 CO₂ Emissions from the Decarburization of Iron Powder

Calculate the total annual CO₂ emissions from the decarburization of iron powder using Equation 6-14.

Equation 6-14

$$E_{CO_2 D} = \left[(IP_f \times C_{IP_f}) - (IP_d \times C_{IP_d}) - \sum_{j=1}^m (BP_j \times C_{BP_j}) \right] \times 3.664$$

Where:

E_{CO₂D} = the total annual quantity of CO₂ emissions from the decarburization of iron powder (tonnes).

m = number of byproducts.

j = byproduct type.

IP_f = the total annual quantity of iron powder fed into the process (tonnes).

C_{IP_f} = the annual weighted average carbon content of iron powder fed into the process (tonnes C / tonnes iron powder).

IP_d = the total annual quantity of decarburized iron powder (tonnes).

C_{IP_d} = the annual weighted average carbon content of decarburized powder production (tonnes C / tonnes decarburized powder production).

BP_j = the total annual quantity of byproduct (tonnes).

C_{BP_j} = the annual weighted average carbon content of byproduct, or a default value of 0 (tonnes C / tonnes byproduct).

3.664 = ratio of molecular weights, CO₂ to carbon.

6.B.3 CO₂ Emissions from Steel Grading

Calculate the total annual CO₂ emissions from steel grading using Equation 6-15.

Equation 6-15

$$E_{CO_2 SG} = \left[(MI_f \times C_{MI_f}) + \sum_{j=1}^m (AD_j \times C_{AD_j}) + (EL \times C_{EL}) - (MS \times C_{MS}) - (SL \times C_{SL}) - (R \times C_R) - (Rp \times C_{Rp}) \right] \times 3.664$$

Where:

E_{CO₂ SG} = the total annual quantity of CO₂ emissions from steel grading (tonnes).

m = number of additives.

j = type of additive.

MI_f = the total annual quantity of molten steel fed into the process (tonnes).

C_{MI_f} = the annual weighted average carbon content of molten steel fed into the process (tonnes C / tonnes molten steel).

AD_j = the total annual quantity of additive used in the process (tonnes).

C_{AD_j} = the annual weighted average carbon content of additive used in the process (tonnes C / tonnes additive).

EL = the total annual carbon electrodes consumption (tonnes).

C_{EL} = the annual weighted average carbon content of carbon electrodes consumption (tonnes C / tonnes carbon electrodes).

MS = the total annual quantity of molten steel production (tonnes).

C_{MS} = the annual weighted average carbon content of molten steel production (tonnes C / tonnes molten steel).

SL = the total annual quantity of slag production (tonnes).

C_{SL} = the annual weighted average carbon content of slag production, or a default value of 0 (tonnes C / tonnes slag).

R = the total annual quantity of air pollution control residue collected (tonnes).

C_R = the annual weighted average annual carbon content of air pollution control residue collected or a default value of 0 (tonnes C / tonnes residue).

Rp = the total annual quantity of other residue production (tonnes).

C_{Rp} = the annual weighted average annual carbon content of other residue production or a default value of 0 (tonnes C / tonnes other residue).

3.664 = ratio of molecular weights, CO₂ to carbon.

6.B.4 CO₂ Emissions from Steel Powder Annealing

Calculate the total annual CO₂ emissions from steel powder annealing using Equation 6-16.

Equation 6-16

$$E_{CO_2 SA} = \left[(P_a \times C_{Pa}) - (SP_p \times C_{SPp}) - \sum_{j=1}^m (BP_j \times C_{BPj}) \right] \times 3.664$$

Where:

E_{CO₂ SA} = the total annual quantity of CO₂ emissions from steel powder annealing (tonnes).

m = number of byproducts.

j = byproduct type.

P_a = the total annual quantity of steel powder fed into the process (tonnes).

C_{Pa} = the annual weighted average carbon content of steel powder fed into the process (tonnes C / tonnes steel powder).

SP_p = the total annual quantity of steel powder production (tonnes).

C_{SPp} = the annual weighted average carbon content of steel powder production (tonnes C / tonnes steel powder).

BP_j = the total annual quantity of byproduct (tonnes).

C_{BPj} = the annual weighted average carbon content of byproduct, or a default value of 0 (tonnes C / tonnes byproduct).

3.664 = ratio of molecular weights, CO₂ to carbon.

6.B.5 CO₂ Emissions from Iron and Steel Powder Production Using CEMS

Persons operating a facility with installed CEMS shall calculate CO₂ emissions from iron and steel production using Equation 6-17.

Equation 6-17

$$E_{CO_2} = E_{CO_2\ CEMS} - E_{CO_2\ FC}$$

Where:

E_{CO₂} = the total annual quantity of CO₂ emissions from iron and steel powder production (tonnes) calculated by subtracting fuel combustion emissions for CO₂ as specified in Section 2, from the total annual CO₂ quantity measured using CEMS.

E_{CO₂ CEMS} = the total annual quantity of CO₂ emissions from CEMS including fuel combustion and iron and steel powder production emissions (tonnes).

E_{CO₂ FC} = the total annual CO₂ fuel combustion emissions, calculated as specified in Section 2.

6.C Sampling, Analysis and Measurement Requirements

The annual mass of each material used in Sections 6.A and 6.B mass balance methodologies shall be determined using plant instruments used for accounting purposes, including either direct measurement of the quantity of material used in the process or by calculations using process operating information.

6.C.1 Carbon Content for Materials in Iron and Steel Production

Persons who operate a facility that uses calculations specified Sections 6.A and 6.B shall, for materials that contribute 1% or more of the total carbon in the process, use the data provided by the supplier or determine the carbon content by analyzing a minimum of 3 representative samples per year, using the following analysis methods:

- (a) For iron ore, taconite pellets, and other iron-bearing materials, use ASTM E1915.
- (b) For iron and ferrous scrap, use ASTM E1019.
- (c) For coal, coke, and other carbonaceous materials (e.g., electrodes, etc.), use ASTM D5373 or ASTM D5142.
- (d) For petroleum liquid based fuels and liquid waste-derived fuels, use ASTM D5291 and either ASTM D2502 or ASTM D2503.
- (e) For steel, use any of the following analyses methods:
 - i. ASM CS-104 UNS No. G10460
 - ii. ISO/TR 15349-1: 1998
 - iii. ISO/TR 15349-3: 1998

iv. ASTM E415

v. ASTM E1019

(f) For flux (i.e., limestone or dolomite) and slag, use ASTM C25.

(g) For steel production by-products (e.g., blast furnace gas, coke oven gas, coal tar, light oil, sinter off gas, slag dust, etc.); use an online instrument that determines carbon content to $\pm 5\%$; or any of the other analytical methods listed in this section; or methodologies using plant instruments used for accounting purposes.

6.C.2 Iron and Steel Powder Production

Person who operate a facility that produces iron powder and steel powder shall determine annually the carbon content of each material or product that contributes 0.5% or more of the total carbon in the process, either by using the data provided by the supplier, or by using the following methods:

(a) for iron or iron powder, a person shall use any of the following analyses methods:

i. ASTM E1019

ii. ASTM E415

(b) for steel or steel powder, a person shall use any of the following methods:

i. ASM CS-104 UNS G10460

ii. ISO/TR 15349-1

iii. ISO/TR 15349-3

iv. ASTM E415

(c) For carbon electrodes, a person shall use ASTM D5373.

6.D Procedures for Estimating Missing Analytical Data

Use the methods prescribed in this section to re-analyze the original sample, a backup sample or a replacement sample for the same measurement and sampling period for missing analytical data.

6.D.1. Whenever sampling, analysis and measurement data required for Section 6 for the calculation of emissions is missing, a person shall ensure the data is replaced using the missing data procedures specified in this section.

(a) For missing data that concerns carbon content, temperature, pressure or gas concentration, determine the sampling or measurement rate using Equation 6-18 and, replace the missing data as specified in paragraphs (b) to (d) of this section.

(b) If $R \geq 0.9$: a person shall replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, a person shall use the first available data from after the missing data period;

- (c) If $0.75 \leq R < 0.9$: a person shall replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
- (d) If $R < 0.75$: a person shall replace the missing data by the highest data value sampled or analyzed during the 3 preceding years.

Equation 6-18

$$R = \frac{QS_{ACT}}{QS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

QS_{ACT} = Quantity of actual samples or measurements obtained by the person.

QS_{REQUIRED} = Quantity of samples or measurements required for Section 6.

6.D.2. For missing data that concerns the following in iron and steel production: the quantity of carbonaceous raw material, quantity of ferrous scrap, quantity of molten iron, quantity of coking coal, quantity of flux material, quantity of direct reduced iron pellets, quantity of carbon electrodes, quantity of iron ore or iron ore pellets, production of slag, quantity of greenball pellets, production of fired pellets, production of coke oven gas, production of coke, quantity of air pollution control residue collected, quantity of other coke oven byproducts, the quantity of steel consumption or production, quantity of gas from basic oxygen furnace transferred off site, production of sinter, production of iron or the quantity of nonmetallic byproducts, the replacement data shall be generated from best estimates based on all of the data relating to the processes.

6.D.3. For missing data that concerns the following in iron and steel powder production: the quantity of molten cast iron, consumption of carbon electrodes, quantity of molten steel, quantity of additive, quantity of iron or steel powder, production of atomized cast iron, quantity of slag, quantity of byproducts, quantity of residue or the quantity of other materials, the replacement data shall be generated from best estimates based on all of the data relating to the processes.

6.D.4. For all units that monitor and report emissions using CEMS; the missing data backfilling procedures in EPS 1/PG/7 can be used or Equation 6-19 to determine CO₂ concentration, stack gas flow rate, fuel flow rate, high heating value, and fuel carbon content.

- (a) If $R \geq 0.9$: a person shall replace the missing data by the arithmetic mean of the sampling or measurement data from immediately before and after the missing data period. If no data is available from before the missing data period, a person shall use the first available data from after the missing data period;
- (b) If $0.75 \leq R < 0.9$: a person shall replace the missing data by the highest data value sampled or analyzed during the reporting period for which the calculation is made;
- (c) If $R < 0.75$: a person shall replace the missing data by the highest data value sampled or analyzed during the 3 preceding years.

Equation 6-19

$$R = \frac{HS_{ACT}}{HS_{REQUIRED}}$$

Where:

R = Sampling or measurement rate that was used (%).

HS_{ACT} = Quantity of actual samples or measurements obtained by the person.

HS_{REQUIRED} = Quantity of samples or measurements required for Section 6.

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Technical Testing and Analysis Standards

- ASM CS-104 UNS G10460: Carbon steel of medium carbon content
- ASTM C25: Standard Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime.
- ASTM C114: Standard Test Methods for Chemical Analysis of Hydraulic Cement.
- ASTM D70: Standard Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method).
- ASTM D240: Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter.
- ASTM D1298: Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method.
- ASTM D1826: Standard Test Method for Calorific (Heating) Value of Gases in Natural Gas Range by Continuous Recording Calorimeter.
- ASTM D1945: Standard Test Method for Analysis of Natural Gas by Gas Chromatography.
- ASTM D1946: Standard Practice for Analysis of Reformed Gas by Gas Chromatography.
- ASTM D2013 / D2013M: Standard Practice for Preparing Coal Samples for Analysis.
- ASTM D2163: Standard Test Method for Determination of Hydrocarbons in Liquefied Petroleum (LP) Gases and Propane/Propene Mixtures by Gas Chromatography.
- ASTM D2234 / D2234M: Standard Practice for Collection of a Gross Sample of Coal.
- ASTM D2502: Standard Test Method for Estimation of Mean Relative Molecular Mass of Petroleum Oils from Viscosity Measurements.
- ASTM D2503: Standard Test Method for Relative Molecular Mass (Molecular Weight) of Hydrocarbons by Thermoelectric Measurement of Vapor Pressure.
- ASTM D3238: Standard Test Method for Calculation of Carbon Distribution and Structural Group Analysis of Petroleum Oils by the n-d-M Method.
- ASTM D4809: Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method).
- ASTM D4891: Standard Test Method for Heating Value of Gases in Natural Gas and Flare Gases Range by Stoichiometric Combustion.
- ASTM D5142: Standard Test Methods for Proximate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures.
- ASTM D5291: Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants.
- ASTM D5373: Standard Test Methods for Determination of Carbon, Hydrogen and Nitrogen in Analysis Samples of Coal and Carbon in Analysis Samples of Coal and Coke.
- ASTM D5468: Standard Test Method for Gross Calorific and Ash Value of Waste Materials.
- ASTM D5865: Standard Test Method for Gross Calorific Value of Coal and Coke.

- ASTM D6866: Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis.
- ASTM D7459: Standard Practice for Collection of Integrated Samples for the Speciation of Biomass (Biogenic) and Fossil-Derived Carbon Dioxide Emitted from Stationary Emissions Sources.
- ASTM E415: Standard Test Method for Analysis of Carbon and Low-Alloy Steel by Spark Atomic Emission Spectrometry.
- ASTM E1019: Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques.
- ASTM E1915: Standard Test Methods for Analysis of Metal Bearing Ores and Related Materials for Carbon, Sulfur, and Acid-Base Characteristics.
- ISO/TR 15349-1:1998: Unalloyed steel – Determination of low carbon content – Part 1: Infrared absorption method after combustion in an electric resistance furnace (by peak separation).
- ISO/TR 15349-3: Unalloyed steel – Determination of low carbon content – Part 3: Infrared absorption method after combustion in an electric resistance furnace (with preheating).

Additional information can be obtained at:

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