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GLOSSARY

"*2018 GHGRP Notice*" means the *Notice with respect to reporting of greenhouse gases (GHGs) for 2018, Canada Gazette*, Part I.

"*aluminium production*" 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.

"*ammonia production*" means processes in which ammonia is manufactured from fossil-based feedstock produced by steam reforming of a hydrocarbon. This also includes processes where ammonia is manufactured through the gasification of solid and liquid raw material.

"*base metal production*" means the primary and secondary production processes that are used to recover copper, nickel, zinc, lead, and cobalt. Primary production includes the smelting or refining of base metals from feedstock that comes primarily from ore. Secondary production processes includes the recovery of base metals from various feedstock materials, such as recycled metals. Process activities may include the removal of impurities using carbonate flux reagents, the use of reducing agents to extract metals or slag cleaning, and the consumption of carbon electrodes.

"*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.

"*bone dry tonne*" means a mass of one tonne of solid material that contains no, i.e. zero percent (0%) moisture.

"*carbon dioxide equivalent (CO_2 eq.)*" means a unit of measure for comparison between greenhouse gases that have different global warming potentials (GWPs).

"*cement production*" 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.

"*CO_2 capture*" means the capture of CO_2 at an integrated facility that would otherwise be directly released to atmosphere.

"*CO_2 emissions from biomass decomposition*" means releases of CO_2 resulting from aerobic decomposition of biomass and from the fermentation of biomass.

"*CO_2 injection*" means an activity that places captured CO_2 into, a long-term geological storage site or an enhanced fossil fuel recovery operation.

"*CO_2 recovered*" means the recovery/capture of CO_2 at a hydrogen plant that would typically be delivered for downstream use in other manufacturing industries, used in on-site production or sent to permanent storages.

"*CO_2 storage*" means a long-term geological formation where CO_2 is stored.

"*CO_2 transport system*" means transport of captured CO_2 by any mode.

"*cogeneration unit*" means a fuel combustion device which simultaneously generates electricity and other useful heat and/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.

"*dry reference condition*" (dR) means gases measured at 101.325 kPa, 25°C and 0% moisture.

"*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 to the atmosphere 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; CO_2 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 the primary purpose of which is to produce a non-fuel product, as opposed to useful heat or work. This does not include process vents (i.e. hydrogen production) from fossil fuel production and processing.

"*industrial product use emissions*" means releases from the use of a product, in an industrial process, that is not involved in a chemical or physical reaction and does not react in the process. This includes releases from the use of SF_6, 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 production, fire extinguishing, solvents, aerosols and SF_6 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 production*" 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; CO_2 capture, transport, injection and storage infrastructure.

"*lime production*" 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.

"*nitric acid production*" means the use of one or more trains to produce nitric acid through the catalytic oxidation of ammonia.

"*non-variable fuels*" means fuels with consistent properties and hydrocarbon 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.

"*petroleum refineries*" means processes used to produce gasoline, aromatics, kerosene, distillate fuel oils, residual fuel oils, lubricants, asphalt, or other products through the distillation of petroleum or through redistillation, cracking, rearrangement or reforming of unfinished petroleum derivatives. This includes catalytic cracking units; fluid coking units; delayed coking units; catalytic reforming units; coke calcining units; asphalt blowing operations; blowdown systems; storage tanks; process equipment components (i.e., compressors, pumps, valves, pressure relief devices, flanges, and connectors) in gas service; marine vessel, barge, tanker truck, and similar loading operations; flares; sulphur recovery plants; and non-merchant hydrogen plants that are owned or under the direct control of the refinery owner and operator. This does not include facilities that distill only pipeline transmix.

"*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 CO_2 or processed natural gas and their associated installations, including meter sets and storage installations but excluding straddle plants or other processing installations.

"*pulp and paper production*" means separating cellulose fibres from other materials in fibre sources to produce pulp, paper and paper products. This includes converting paper into paperboard products, or operating coating and laminating processes.

"*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 CO_2 emitted from geological formations used for long term storage of CO_2.

"*variable fuels*" means fuels of variable composition.

"*venting emissions*" means controlled releases of a process or waste gas, including releases of CO_2 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:

- **2019-05-13**. In Table 2-11 (Biomass Fuel), emission factors given in energy units were corrected. Emission factors were adjusted to match the units provided (g/GJ).
- **2019-08-13**. In Table 2-9 (CH_4 and N_2O Emission factors for Still Gas), the N_2O 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 18 of the 2018 GHGRP Notice. The 2018 GHGRP Notice shall prevail over this document, should any inconsistencies be found between them. Note that this document is based upon updates made to *Canada's Greenhouse Gas Quantification Requirements, December 2017*.

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.
- Section 7 deals with generation of electricity and/or heat
- Section 8 deals with industrial processes in ammonia production (including associated hydrogen production)
- Section 9 deals with industrial processes in nitric acid production
- Section 10 deals with industrial processes (or venting) in hydrogen production (outside of ammonia production)
- Section 11 deals with petroleum refineries
- Section 12 deals with industrial processes in pulp and paper production
- Section 13 deals with industrial processes in lead, zinc, copper, nickel, and cobalt production (smelting or refining)

Separate guidance is available in the GHGRP Technical Guide for those persons to whom Schedules 6 through 18 of the 2018 Gazette Notice do not apply.

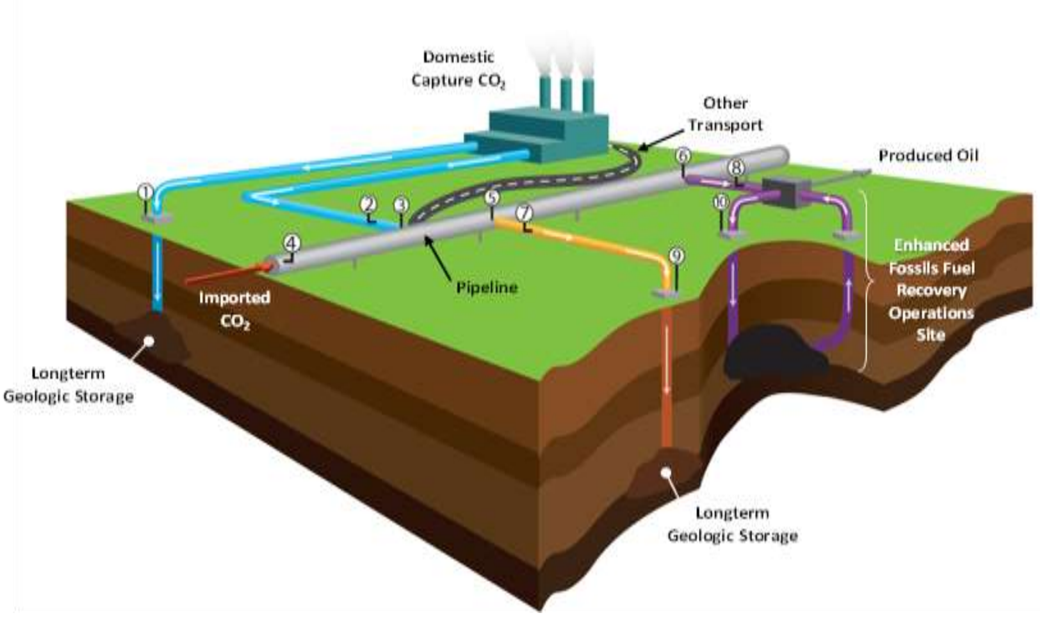
1 Quantification Methods for Carbon Capture, Transport and Storage

A CO_2 carbon capture, transport and storage facility (CCTS system) consists of some, or all, of the following components:

- A CO_2 capture facility including all infrastructures, equipment and process modifications designed to capture otherwise vented CO_2 emissions. Calculate the total annual quantity of captured CO_2 using Equation 1-1 or Equation 1-2.
- A CO_2 pipeline, or other system, used to transport CO_2, within Canada, from the capture facility to the injection facility. Calculate the total annual quantity of CO_2 transported using Equation 1-3 or Equation 1-4.
- A long-term geological storage facility, including sites injecting CO_2 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 CO_2 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 CO_2 Quantities**

To measure annual concentrations, densities, masses and volumes of any CO_2 quantity captured, transported, or injected, 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 CO_2 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, or alternate methods proposed in the appropriate sections below.

1.A.1 **CO_2 Capture Facility**

Calculate the annual mass of CO_2 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 CO_2 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:

$\mathbf{CO_2}$ = Annual mass of CO_2 measured by the outgoing custody transfer point flow meter (tonnes).

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

$\mathbf{C_{CO2\,p}}$ = Weighted average CO_2 concentration at the outgoing custody transfer point flow meter, for specified measurement period “p”, expressed as a decimal fraction.

$\mathbf{n}$ = Number of measurement periods in calendar year.

1.A.1.b Volumetric Flow Approach

Calculate the annual mass of CO_2 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:

CO_2 = Annual mass of CO_2 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 (m^3).

D_p = Weighted average density of volumetric flow, for specified measurement period “p”, at stated temperature and pressure (tonnes per m^3).

$C_{CO2\,p}$ = Weighted average CO_2 concentration at the outgoing custody transfer flow meter, for specified measurement period “p” (expressed as a decimal fraction).

n = Number of measurement periods in calendar year.

If CO_2 is delivered through more than one flow meter, calculate the sum of the annual mass delivered through all meters.

1.A.2 **CO_2 Transport System**

Calculate the annual mass of CO_2 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 CO_2 pipeline or other transport system, using the equations specified in this section.

1.A.2.a Mass Flow Approach

Calculate the annual mass of CO_2 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:

$\mathbf{CO_2}$ = Annual mass of CO_2 measured by the incoming custody transfer flow meter or the outgoing custody transfer flow meter attached to the CO_2 pipeline or other transport mode (tonnes).

$\mathbf{M_p}$ = Total flow mass measured by the incoming custody transfer flow meter, or the outgoing custody transfer flow meter, for specified measurement period "p" (tonnes).

$\mathbf{C_{CO2\,p}}$ = Weighted average CO_2 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.

$\mathbf{n}$ = Number of measurement periods in calendar year.

1.A.2.b Volumetric Flow Approach

Calculate the annual mass of CO_2, 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:

$\mathbf{CO_2}$ = Annual mass of CO_2 measured by the incoming custody transfer flow meter or the outgoing custody transfer flow meter attached to the CO_2 pipeline or other transport mode (tonnes).

$\mathbf{Q_p}$ = 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 (m^3).

$\mathbf{D_p}$ = Weighted average density of flow at stated temperature and pressure, for specified measurement period "p" (tonnes per m^3).

$\mathbf{C_{CO2\,p}}$ = Weighted average CO_2 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).

$\mathbf{n}$ = Number of reporting periods in calendar year.

If CO_2 arrives through more than one incoming custody transfer flow meter, or is delivered through more than one outgoing custody transfer flow meter, sum the annual mass of all CO_2 received or delivered.

1.A.3 CO_2 Injection Site

For all sites, calculate the annual mass of CO_2 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 CO_2 into long-term geologic storage, calculate the annual mass of CO_2 measured by the injection point flow meter (Figure 1-1, Meters 1 and 9), using Equation 1-5.

For sites injecting CO_2 at enhanced fossil fuel recovery operations, with the final goal of long-term storage, calculate the annual mass of CO_2 measured by the injection point flow meter (Figure 1-1, Meter 10), including all recycled CO_2 volumes or masses, using Equation 1-5.

1.A.3.a Mass Flow Approach

Calculate the annual mass of CO_2 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:

$\mathbf{CO_2}$ = Annual mass of CO_2 measured by the incoming custody transfer or injection flow meter (tonnes).

$\mathbf{M_p}$ = Total mass flow measured by the incoming custody transfer or injection flow meter, for specified measurement period “p” (tonnes).

$\mathbf{C_{CO2\,p}}$ = Weighted average CO_2 concentration at the incoming custody transfer or injection flow meter, for specified measurement period “p” , expressed as a decimal fraction.

$\mathbf{n}$ = Number of measurement periods in calendar year.

1.A.3.b Volumetric Flow Approach

Calculate the annual mass of CO_2 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:

CO_2 = Annual mass of CO_2 measured by the incoming custody transfer or injection flow meter associated with CO_2 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 (m^3).

D_p = Weighted average density of flow at stated temperature and pressure, for specified measurement period “p” (tonnes per m^3).

$C_{CO2\,p}$ = Weighted average CO_2 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.

If CO_2 is received or injected by more than one incoming custody transfer or injection flow meter, sum the annual mass of all CO_2 received or injected.

1.A.4 **CCTS Fugitive Emissions**

1.A.4.a CO_2 Capture

Calculate the annual mass of CO_2 fugitive emissions from equipment leaks, and venting from equipment located between the capture infrastructure (Figure 1-1, labelled Domestic Capture CO_2) and the outgoing custody transfer flow meters or on-site injection wellhead (Figure 1-1, Meters 1 and 2), 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, or alternatively report the mass difference between the metered captured CO_2 and the CO_2 measured at the outgoing custody transfer meter, as fugitive emissions associated with CO_2 capture.

1.A.4.b CO_2 Transport System

Calculate the annual mass of CO_2 from equipment leaks and venting from pipelines, or other methods used to transport the liquefied CO_2 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 the Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry, A.P.I., 2009, Section 2.2.5, or alternativelyreport the mass difference between the annual mass at receipt transfer point flow meters and the annual mass at the delivery transfer point meters as fugitive emissions associated with CO_2 transport.

1.A.4.c CO_2 Injection

Calculate the annual mass of CO_2 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, or alternatively report the mass difference between the incoming custody transfer point flow meters and the injection wellhead meters as fugitive emissions associated with CO_2 injection.

1.A.4.d Surface Leakage from Stored CO_2

Calculate the annual mass of CO_2 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 and Flaring

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, process heaters, on-site transportation equipment and any other combustion devices. Section 0 presents CO_2 estimation methods, while Section 2.B presents methods to estimate CH_4 and N_2O for fuel combustion sources.

Fuel Combustion de minimus

If the sum of CO_2, CH_4 and N_2O emissions (excluding CO_2 from biomass), in CO_2 equivalent, from the combustion of one or more fuels does not exceed 0.5% of the total facility GHG emissions from all fuels combusted (excluding CO_2 from biomass combustion), these fuels and their emissions are not required to be reported.

Burning waste materials in flares releases fugitive emissions. Section 2.C presents methods to estimate emissions from flaring.

2.A CO_2 Emissions from Fuel Combustion

To calculate the annual mass of CO_2 emissions from fuel combustion sources, facility operators can use one or a combination of the quantification methodologies specified in Sections 2.A.1 to 2.A.3 for each fuel type. Facilities with Continuous Emission Monitoring (CEM) systems are not obligated to use the CEM system method (Methodology 3) and instead can apply the Non-Variable (Methodology 1) and the Variable (Methodology 2) fuels methods. Specification on fuel sampling, analysis and measurement requirements are in Section 2.D and guidance for the handling of mixtures of biomass and fossil fuels is in Section 2.A.4.

Methodology 1: Non-Variable Fuels Method

The method in Section 2.A.1 applies to non-variable fuels that have consistent composition with applicable CO_2 emission factors.

(a) Use Equation 2-1 and Equation 2-2 for non-variable fuels with CO_2 emission factors listed in Table 2-1 and Table 2-2.

(b) Use Equation 2-3, Equation 2-4, and Equation 2-5 or the facility-specific methodology in Section 2.A.1.a(3) with appropriate documentation for on-site transportation, only when information required for Equation 2-1 or Equation 2-2 is unavailable.

Methodology 2: Variable Fuels Method

The variable fuels method in Section 2.A.2 applies to fuels whose variable properties and composition require the determination of facility specific carbon content with the exception of biofuels presented in Table 2-3. A variable fuel is any fuel not included in Table 2-1 and Table 2-2.

(a) Use Equation 2-6, Equation 2-7, and Equation 2-8 for fuels not listed in Table 2-1 to Table 2-3. Apply Equation 2-9 for natural gas where carbon content is not obtainable from fuel supplier or routinely measured.

(b) Use Equation 2-1 and Equation 2-2 for biomass fuels listed in Table 2-3 or apply Equation 2-11 for biomass fuels used to produce steam.

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 CO_2 concentration monitor. Determine CO_2 emissions data from CEM systems using the prescribed method in Section 2.A.3.

Key Notes

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

For internally generated and consumed [biomass] fuel mixtures, determination of the portion of each fuel type in the mixture is not required. Facilities have the option to consider it as a combined fuel type or to separate by fuel type.

Facilities producing steam to generate electricity and heat, and 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. When a facility specific method is used to determine the quantity of fuel used for each purpose, supporting documentation of approach is required (refer to Appendix A for detail).

Use any applicable 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 Fuels Method for the diesel oil, even though the Non-Variable Fuels Method was employable for both fuels.

Apply facility specific oxidation factor to CO_2 emission estimates from fuel combustion, where such factor is available with supporting documentation and information to be provided.

Document for consideration the method and information used to derive any facility specific fuel properties (for example; carbon content and higher heating values) and emission factors when these approaches necessarily differ from those specified in Section 2 Quantification Methods for Fuel Combustion and Flaring. An outline of contents to be considered are included in Appendix A.

2.A.1 **Methodology 1: Non-variable Fuels Method**

This method uses higher heating values (HHV) provided by the supplier or measured at the facility. Non-variable fuels consist of propane, ethane, butane, gasoline, diesel, ethanol, and biodiesel - all other fuels are variable (see section 2.A.2: Methodology 2: Variable Fuels Method).

Use Equation 2-1 or Equation 2-2 to calculate the annual mass of CO_2 emissions from non-variable fuels, using CO_2 emission factors presented in Table 2-1 and Table 2-2.

For on-site transportation, if parameters required for Equation 2-1 or Equation 2-2 are not available, calculate CO_2 emissions using either Equation 2-3, Equation 2-4 and Equation 2-5, or site-specific method in Section 2.A.1.a(3).

Equation 2-1: Energy-based Emissions Equation

$$CO_{2\,i} = \sum_{p=1}^{n} Fuel_{e\,p} \times EF_{1\,e} \times 10^{-6}$$

or

Equation 2-2: Volume- or Mass-based Emissions Equation

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

Where:

$\mathbf{CO_{2\,i}}$ = Annual mass of CO_2 emissions for a specific fuel type “i” (tonnes).

$\mathbf{n}$ = Number of fuel heat content measurements for the calendar year, as specified in Section 2.D.

$\mathbf{Fuel_{i\,p}}$ = Mass or volume of fuel type “i” combusted in measurement or delivery 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.D.1 and 2.D.2.

$\mathbf{Fuel_{e\,p}}$ = Energy quantity of fuel type “e” combusted in measurement or delivery period “p” (in MJ), as specified in Sections 2.D.1 and 2.D.2.

$\mathbf{EF_{1e}}$ = Fuel type “e” specific CO_2 emission factors listed in Table 2-1 and Table 2-2, energy units.

$\mathbf{EF_{2\,i}}$ = Fuel type “i” specific CO_2 emission factors listed in Table 2-1 and Table 2-2, physical units.

$\mathbf{10^{-3}}$ = Conversion factor from kilograms to tonnes.

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

Table 2-1: CO_2 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: CO_2 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).

2.A.1.a On-site Transportation (Non-variable Fuels)

Calculate the annual mass of CO_2 emissions from on-site transportation using the method described in paragraph 2.A.1.a(1) or calculate emissions using the method described in either paragraph 2.A.1.a(2) or 2.A.1.a(3).

(1) Calculate CO_2 emissions from on-site transportation as described under Section 2.A.1 Methodology 1: Non-variable fuels method.

(2) When fuel consumption data is unavailable, calculate CO_2 emissions from on-site transportation using Equation 2-3 or Equation 2-4 (based on fuel volume) and Equation 2-5.

Equation 2-3: On-Site Transportation by Equipment Type—HHV

$$E_{CO_2\,i\,k\,q} = (h_{i\,k} \times hp_{i\,k} \times LF_{i\,k} \times BSFC_{i\,k} \times 10^{-3}) \times HHV_{i\,q} \times EF_{1\,i} \times 10^{-6}$$

or

Equation 2-4: On-Site Transportation by Equipment Type—EF

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

Equation 2-5: On-site Transportation

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

Where:

$E_{CO2\,i\,k\,q}$ = Quarterly "q" mass of CO_2 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).

$HHV_{i\,q}$ = Higher heating value of fuel type "i" (MJ/kl) per quarterly period "q", as specified in Sections 2.D.1 and 2.D.3.

$EF_{1\,i}$ = Emission factor by fuel type "i" (g CO_2/MJ) listed in Table 2-2, energy units.

$EF_{2\,i}$ = Emission factor by fuel type "i" (kg CO_2/kl) listed in Table 2-2, physical units.

$E_{Total\,CO2}$ = Total annual mass of CO_2 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.

(3) On-site transportation equipment-specific method: If the variables required for Equation 2-3, Equation 2-4 and Equation 2-5 are not available for on-site transportation sources, calculate mass of CO_2 emissions using the following equipment-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 rate of fuel use and the fuel-specific emission factor for each of the typical operations.

  (E) Document and report the methodology used, following the content outline in Appendix A.

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

Calculate the annual mass of CO_2 emissions for each type of variable fuel, using measurements of fuel carbon content conducted on site, or provided by the fuel supplier, and the quantity of fuel combusted. There is an alternative methodology for calculating CO_2 emissions from natural gas combustion when carbon content data is not obtainable.

2.A.2.a Solid Fuels

Use Equation 2-6 to calculate annual mass of CO_2 emissions from each type of solid fuel combusted. The fuel quantity applied and carbon content must be based on or adjusted to the same percent moisture content.

Equation 2-6: 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 CO_2 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.D 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.D.1 and 2.D.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.D.4. The applied CC_{ip} must be adjusted based on percent moisture content of Fuel $_{ip}$.

3.664 = Ratio of molecular weights, CO_2 to carbon.

2.A.2.b Liquid fuels

Use Equation 2-7 to calculate annual mass of CO_2 emission from each type of liquid fuel combusted.

Equation 2-7: Liquid 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 CO_2 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.D.

$Fuel_{i\,p}$ = Volume of liquid fuel type "i" combusted in measurement period "p" (kilolitres), as specified in Sections 2.D.1 and 2.D.2.

$CC_{i\,p}$ = 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.D.4.

3.664 = Ratio of molecular weights, CO_2 to carbon.

2.A.2.c Gaseous Fuels

Use Equation 2-8 to calculate the annual mass of CO_2 emissions from each type of gaseous fuel combusted. For natural gas only, use Equation 2-9 when carbon content needed for Equation 2-8 is not obtainable. For these equations, give fuel volumes at standard conditions (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 law presented in Equation 2-10. For conversion from other temperatures and pressures or for converting from liquid quantities to gaseous volumes, provide a brief summary of the method used.

Equation 2-8: All Gaseous Fuels

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

Where:

$CO_{2\,i}$ = Annual mass of CO_2 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.D for gaseous fuel type "i".

$\mathbf{Fuel}_{\mathbf{i\ p}}$ = Volume of gaseous fuel type “i” combusted in period “p” (cubic meters at 15°C and 101.325 kPa), Section 2.D.1 and Section 2.D.2.

$\mathbf{CC}_{\mathbf{i\ p}}$ = 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.D.1 and 2.D.4.

$\mathbf{3.664}$ = Ratio of molecular weights, CO_2 to carbon.

$\mathbf{10^{-3}}$ = Conversion factor from kilograms to tonnes.

Equation 2-9: Natural Gas

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

Where:

$\mathbf{CO_{2\ NG}}$ = Annual mass of CO_2 emissions from combustion of natural gas expressed in tonnes.

$\mathbf{n}$ = Number of fuel heat content measurements for the calendar year, as specified in Section 2.D.1.

$\mathbf{Fuel}_{\mathbf{p}}$ = Volume of natural gas fuel combusted during measurement period “p” (cubic meters at 15°C and 101.325 kPa), as specified in Sections 2.D.1 and 2.D.2.

$\mathbf{HHV}_{\mathbf{p}}$ = Higher heating value of natural gas for the measurement period “p” (MJ/cubic meter, at 15°C and 101.325 kPa), as specified in Sections 2.D.1 and 2.D.3.

$\mathbf{(60.554 \times HHV_p - 404.15)}$ = Empirical equation (g of CO_2/cubic meter of natural gas) representing a very close relationship between carbon dioxide and volume of natural gas determined through higher heating value with a discreet set of available data where, 60.554 is the slope and 404.15 the intercept.

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

Equation 2-10: 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).

$\mathbf{P_m}$ = Measured pressure of gas volume, in kPa.

$Fuel_m$ = Measured volume of gaseous fuel, at $\mathbf{P_m}$, in cubic meters.

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

$\mathbf{T_m}$ = Measured temperature of gas volume $\mathbf{Fuel_m}$, in degrees Kelvin.

$\mathbf{P_{STP}}$ = Standard pressure, 101.325 kPa.

2.A.2.d Variable Biomass Fuels

This section describes methods for calculating CO_2 emissions from biomass fuels not contained in either Table 2-1 or Table 2-2. For these variable biomass fuels, apply methods provided in section 2.A.2.a Solid Fuels, 2.A.2.b Liquid fuels, and 2.A.2.c Gaseous Fuels for each biomass type.

Alternatively, for biomass fuels listed in Table 2-3 the methodology in Section 2.A.1 Methodology 1: *Non-variable fuels* may be applied. Table 2-3 presents the required emission factors on a dry basis, therefore, the solid biomass fuel quantity applied must be based on or adjusted to a 0% moisture content,

When biomass fuel is used to produce steam use Equation 2-11: Biomass Fuels to calculate the mass of CO_2 emissions when information on the quantity and type of biomass fuel is not available.

Equation 2-11: Biomass Fuels

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

Where:

$CO_{2\,i}$ = Annual mass of CO_2 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: CO_2 Emission Factors for Biomass, as applicable (g CO_2/MJ) or site-specific emission factor determined through measurements and updated no less than every third year as provided in Section 2.D.1, paragraph (8).

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

Table 2-3: CO_2 Emission Factors for Biomass

Biomass Fuel	CO_2 Emission Factor	
	g/kg	g/MJ
Wood Fuel / Wood Waste[1]	1560	76
Spent Pulping Liquor—softwood[2]	1270	89.5
Spent Pulping Liquor—hardwood[2]	1230	88.8
Spent Pulping Liquor—straw[2]	1320	90.1

[1] Adapted from U.S. EPA (2003), assuming 0% moisture content and a higher heating value of 20.44 MJ/kg.
[2] Adapted from NCASI (2010). Based on dry solids content (0% moisture) and assuming a higher heating value of 13.7 MJ/kg

2.A.2.e On-site Transportation (Variable Fuels)

Where variable fuels are used, calculate the annual mass of CO_2 emissions from on-site transportation using Equation 2-7. If fuel carbon content information required for Equation 2-7 is not obtainable, derive on-site transportation equipment specific emission factors and follow the approach in Section 2.A.1.a. Document and report the approach and information used to derive any on-site transportation equipment specific emission factors, refer to Appendix A for detail.

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

Calculate the annual mass of CO_2 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 CO_2 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 CO_2 or O_2 concentrations and flue gas flow measurements to determine hourly CO_2 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 CO_2 emissions for the reporting year, expressed in tonnes, based on the sum of hourly CO_2 mass emissions for the calendar year.

(3) Facility operators may use an oxygen (O_2) concentration monitor in place of a CO_2 concentration monitor in a CEM system installed before January 1, 2012, to determine the hourly CO_2 concentrations, under two conditions. One, if the effluent gas stream monitored by the CEM system consists solely of combustion products (i.e. no process CO_2 emissions or CO_2 emissions from acid gas control are mixed with the combustion products). Two, if only 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 O_2 concentrations.

(b) Facilities combusting biomass fuels and using O_2 concentrations to calculate CO_2 concentrations, should demonstrate, using annual source testing, that calculated CO_2 concentrations compared to measured CO_2 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 CO_2 mass emissions separately, as described in Section 2.A.4.

(5) For any units using CEM system data, provide industrial process and stationary combustion CO_2 emissions separately. Determine the annual quantities of each type of fossil fuel and biomass consumed, using the fuel sampling approach in Sections 2.D.1 and 2.D.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 CO_2 concentrations or flue gas flow, select and operate the added devices using appropriate requirements for the facility, as applicable in Canada.[1,2]

(7) If a facility does not have a CEM system and chooses to add one in order to measure CO_2 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 **CO_2 Emissions from Combustion of Mixtures of Biomass and Fossil Fuels**

Use the procedures in this section to estimate biogenic CO_2 emissions from units that combust a combination of biomass and fossil fuels, including combustion of waste-derived fuels (e.g. wood waste and tires) that are partially biomass.

(1) If a CEM system is not used to measure CO_2 and the facility combusts biomass fuels that does not include waste-derived fuels, use Methodology 1 or 2, as applicable, to calculate the annual biogenic CO_2 mass emissions from the combustion of biomass fuels. Determine the quantity 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 CO_2 (or O_2 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 CO_2 mass emissions from the combustion of fossil fuels. Calculate biomass fuel emissions by subtracting the fossil fuel-related emissions from the total CO_2 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., tire-derived fuel), or biomass fuels with no CO_2 emission factor provided in Table 2-2 and Table 2-3, use the following to estimate biogenic CO_2 emissions:

  (A) Methodology 2 or Methodology 3 to calculate the total annual CO_2 mass emissions, as applicable.

  (B) Determine the biogenic portion of the CO_2 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

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

[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.

fuels combusted in the emissions reporting year, except, if a person wishes to report a biomass fuel fraction of CO_2 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 CO_2 emissions between biomass fuel emissions and non-biomass fuel emissions using the average proportions of the samples analyzed in the reporting year.

(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.B **CH_4 and N_2O Emissions from Fuel Combustion**

Calculate the annual mass of CH_4 and N_2O emissions from fuel combustion sources, for each fuel type, using methods specified in this section.

(1) If directly measured, or fuel supplier provided, higher heating values (HHVs) are available, calculate annual CH_4 and N_2O emissions using Equation 2-12.

Equation 2-12: CH_4 and N_2O HHV Methods, in Energy Units

$$CH_{4\,e} \text{ or } N_2O_e = \sum_{p=1}^{n} Fuel_{e\,p} \times EF_e \times k$$

Where:

$CH_{4\,e}$ or N_2O_e = Annual mass of CH_4 or N_2O emissions for fuel type “e”, tonnes CH_4 or N_2O per year.

$Fuel_{e\,p}$ = Energy quantity of fuel type “e” combusted in measurement or delivery period “p” (in MJ), as specified in Sections 2.D.1 and 2.D.2.

EF_e = CH_4 or N_2O emission factor by fuel type “e” provided in Table 2-4 through Table 2-11 or provided by the fuel supplier or equipment manufacturer, in energy units.

n = Number of measurement periods in calendar year.

$k =$ The appropriate conversion factor to tonnes CH_4 or N_2O, depending on the units of the EF either obtained from Table 2-4 to Table 2-11, from the fuel supplier or equipment manufacturer, or derived at the facility. The majority of energy based EFs in Table 2-4 to Table 2-11 (g/GJ) require conversion factor of 10^{-9}.

(2) Where HHV is not available from fuel supplier or routinely measured, use Equation 2-13 to calculate the annual CH_4 and N_2O emissions.

Equation 2-13: CH_4 and N_2O HHV Value Methods, in Physical Units

$$CH_{4\,i} \; or \; N_2O_i \; = \; \sum_{p=1}^{n} Fuel_{i\,p} \times EF_i \times k$$

Where:

$\mathbf{CH_{4\,i}}$ or $\mathbf{N_2O_i}$ = Annual mass of CH_4 or N_2O emissions for fuel type “i”, tonnes CH_4 or N_2O per year.

$\mathbf{Fuel_{i\,p}}$ = Mass or volume of fuel type “i” combusted in measurement or delivery 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.D.1 and 2.D.2.

$\mathbf{EF_i}$ = CH_4 or N_2O emission factor by fuel type “i” provided in Table 2-4 through Table 2-11, provided by the fuel supplier or equipment manufacturer, or facility derived, in physical units.

$\mathbf{n}$ = Number of measurement periods in calendar year.

$\mathbf{k = 10^{-3}}$ for liquid and solid fuels; $\mathbf{10^{-6}}$ for gaseous fuels; or otherwise, the appropriate conversion factor to tonnes CH_4 or N_2O, depending on the units of the EF either obtained from the fuel supplier or equipment manufacturer or derived at the facility.

(3) Facility or equipment specific emission factors may also be determined based on source tests or from equipment manufacturer for use in quantifying CH_4 and N_2O emissions using Equation 2-13. Document the method used to derive facility specific CH_4 and N_2O emission factors.

(4) CEMS. Estimate the annual mass of CH_4 and N_2O emissions, for units using Methodology 3 (CEMS) and with year round monitored heat input, using Equation 2-14.

Equation 2-14: CH_4 and N_2O CEM Methods

$$CH_{4\,i} \; or \; N_2O_i \; = \; (HI)_{A\,i} \times EF_i \times 10^{-6}$$

Where:

$\mathbf{CH_{4i}}$ or $\mathbf{N_2O_i}$ = Annual mass of CH_4 or N_2O emissions from the combustion of a specific type of fuel “i”, expressed in tonnes.

$\mathbf{(HI)_{A\,i}}$ = Cumulative annual heat input from the fuel (MJ), provided by fuel type “i”.

$\mathbf{EF_i}$ = Fuel-specific emission factor for CH_4 or N_2O by fuel type “i”, listed in Table 2-4 to Table 2-11 (grams/MJ or grams/kilogram of coal).

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

Table 2-4: CH_4 and N_2O Emission Factors for Natural Gas

Source	Natural Gas Emission Factor[1]			
	CH_4 g/m^3	N_2O g/m^3	CH_4 g/GJ	N_2O 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: CH_4 and N_2O Emission Factors for Ethane, Propane and Butane

Fuel	Emission Factor[1]			
	CH_4 kg/kl	N_2O kg/kl	CH_4 g/GJ	N_2O 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: CH_4 and N_2O Emission Factors for Refined Petroleum Products and Biofuels

Fuel by Source or by Technology	Emission Factor			
	CH_4 kg/kl	N_2O kg/kl	CH_4 g/GJ	N_2O g/GJ
Diesel				
All industry—stationary combustion[2]	0.133	0.4	3.5	10
Upgraders—stationary combustion[3]	0.151	1.0	3.9	27
Onsite Transportation, <19kW[1]	0.073	0.02	1.9	0.58
Onsite Transportation, >=19kW, Tier 1-3[1]	0.073	0.02	1.9	0.58
Onsite Transportation, >= 19kW, Tier 4[1]	0.073	0.23	1.9	5.9
Gasoline[1]				
All industry—stationary combustion[3]	0.1	0.02	3.0	0.6
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	0.15	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	0.16	0.83
Industrial	0.006	0.031	0.16	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).
[3] Adapted from IPCC (2006)
* Ethanol uses gasoline CH_4 and N_2O emission factors (by mode and technology).
** Biodiesel uses diesel CH_4 and N_2O emission factors (by mode and technology).

Table 2-7: CH_4 and N_2O Emission Factors for Coal, Coke and Coke Oven Gas

Source by Coal Type and by Region	Emission Factors[1]			
	CH_4 g/kg	N_2O g/kg	CH_4 g/GJ	N_2O g/GJ
Electric Utilities				
Anthracite	0.022	0.032	0.79	1.2
Canadian Bituminous	0.022	0.032	0.78	1.1
Foreign Bituminous	0.022	0.032	0.74	1.1
Lignite				
Saskatchewan	*0.022*	*0.032*	*1.4*	2.0
All Other Provinces	*0.022*	*0.032*	*1.4*	2.0
Sub-bituminous				
Manitoba, Ontario	*0.022*	*0.032*	*1.1*	1.5
Alberta, British Columbia, Saskatchewan	*0.022*	*0.032*	*1.2*	1.7
All Other Provinces	*0.022*	*0.032*	*1.1*	1.7
Industry and Heat & Steam Plants				
Anthracite	0.03	0.02	1.1	0.72
Canadian Bituminous	0.03	0.02	1.1	0.70
Foreign Bituminous	0.03	0.02	1.0	0.67
Lignite				
Saskatchewan	0.03	0.02	*1.8*	*1.2*
All Other Provinces	0.03	0.02	*1.9*	*1.2*
Sub-bituminous				
Manitoba, Ontario	0.03	0.02	*1.4*	*1.0*
Alberta, British Columbia, Saskatchewan	0.03	0.02	*1.6*	*1.1*
All Other Provinces	0.03	0.02	*1.6*	*1.0*

Source by Coal Type and by Region	Emission Factors[1]			
	CH_4 g/kg	N_2O g/kg	CH_4 g/GJ	N_2O g/GJ
Residential, Public Administration				
Anthracite	4	0.02	100	0.72
Canadian Bituminous	4	0.02	100	0.70
Foreign Bituminous	4	0.02	100	0.67
Lignite				
Saskatchewan	4	0.02	200	1.2
All Other Provinces	4	0.02	200	1.2
Sub-bituminous				
MB, ON	4	0.02	200	1.0
AB, BC, SK	4	0.02	200	1.1
All Other Provinces	4	0.02	200	1.0
Coke	0.03	0.02	1.0	0.69
Coke Oven Gas	g/m³		g/GJ	
	0.037	0.035	1.9	1.8

[1] SGA Energy (2000).

Table 2-8: CH_4 and N_2O Emission Factors for Petroleum Coke

Petroleum Coke	Emission Factors[1]			
	CH_4		N_2O	
	kg/m³	g/GJ	kg/m³	g/GJ
Upgrading Facilities	0.12	3.0	0.024	0.59
Refineries & Others	0.12	2.6	0.0275	0.593

[1] Adapted from IPCC (2006).

Table 2-9: CH_4 and N_2O Emission Factors for Still Gas

Fuel	Emission Factors			
	CH_4		N_2O	
	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: CH_4 and N_2O Emission Factors for Industrial Waste Fuel used by Cement Plants

Fuel	Emission Factors[1]	
	CH_4	N_2O
	kg/GJ	kg/GJ
Waste	0.03	0.004

[1] Adapted from IPCC (2006).

Table 2-11: CH_4 and N_2O Emission Factors for Biomass Fuels

Biomass Fuel	Emission Factors			
	CH_4 g/kg	N_2O g/kg	CH_4 g/GJ	N_2O g/GJ
Wood Fuel / Wood Waste[1]	0.18	0.11	8.81	5.38
Spent Pulping Liquor[2]	0.033	0.027	2.41	1.97

[1] Adapted from U.S. EPA (2003), assuming 0% moisture content and a higher heating value of 20.44 MJ/kg.
[2] Adapted from IPCC (2006). Based on dry solids content (0% moisture) and assuming a higher heating value of 13.7 MJ/kg

(5) On-Site Transportation. Calculate the annual mass of CH_4 or N_2O emissions from on-site transportation using the method described in paragraph 2.B(1) or 2.B(2) with the emission factors presented in Table 2-6. If Table 2-6 does not present the required emission factor, derive on-site transportation equipment specific CH_4 and N_2O emission factors and document and report the methods used. If fuel consumption data is notobtainable from fuel supplier or routinely measured, calculate emissions using either of the alternative calculation methods described in paragraphs 2.B(5)(A) or 2.B(5)(B).

(A) Alternative calculation. Calculate the annual mass of CH_4 or N_2O emissions from on-site transportation for each fuel type using Equation 2-15 and Equation 2-17. Use Equation 2-16 in place of Equation 2-15, if the HHV is not obtainable from fuel supplier or routinely measured.

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

$$\boldsymbol{E_{g\,i\,k\,q} = (h_{i\,k} \times hp_{i\,k} \times LF_{i\,k} \times BSFC_{i\,k}) \times HHV_{i\,q} \times EF_{1\,g\,i} \times 10^{-6}}$$

or

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

$$\boldsymbol{E_{g\,i\,k\,q} = (h_{i\,k} \times hp_{i\,k} \times LF_{i\,k} \times BSFC_{i\,k}) \times EF_{2\,g\,i} \times 10^{-3}}$$

Equation 2-17: On-site Transportation

$$\boldsymbol{E_{Total\,g\,i} = \sum_{q=1}^{4}\left(\sum_{k} E_{g\,i\,k\,q}\right)}$$

Where:

$\mathbf{E}_{g\,i\,k\,q}$ = quarterly “q” mass of greenhouse gas “g” (CH_4 or N_2O) emissions from each type of on-site transportation equipment “k” and fuel “i” (tonnes).

$\mathbf{h}_{i\,k}$ = quarterly hours of operation for each type of on-site transportation equipment “k” and fuel “i” (hours).

$\mathbf{hp}_{i\,k}$ = rated equipment horsepower for each type of on-site transportation equipment “k” and fuel “i” (horsepower).

$\mathbf{LF}_{i\,k}$= load factor for each type of on-site transportation equipment “k” and fuel “i” (dimensionless; ranges between 0 and 1).

$\mathbf{BSFC}_{i\,k}$ = brake-specific fuel consumption for each type of on-site transportation equipment “k” and fuel “i” (litres/horsepower-hour).

$\mathbf{HHV}_{i\,q}$ = higher heating value of fuel type “i” (MJ/kl) per quarterly period “q”, as specified in Sections 2.D.1 and 2.D.3.

$\mathbf{EF}_{1\,g\,i}$ = emission factor by CH_4 or N_2O “g” and by fuel type “i”, listed in Table 2-6, in energy units.

$\mathbf{EF}_{2\,g\,i}$ = emission factor by CH_4 or N_2O “g” and by fuel type “i”, listed in Table 2-6, in physical units.

$\mathbf{E}_{\mathbf{Total}\,g\,i}$ = total annual mass of greenhouse gas “g” (CH_4 or N_2O) emissions by fuel type “i”, for all on-site transportation equipment “k” (tonnes).

$\mathbf{10^{-3}} =$ conversion factor from kilograms to tonnes.

$\mathbf{10^{-6}} =$ conversion factor from grams to tonnes.

(B) Alternative calculation. Calculate the annual mass of CH_4 or N_2O 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:

(i) 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.

(ii) Calculate the average hourly fuel use rate for each range of typical operations.

(iii) Determine the number of hours of each type of operation at the facility in the calendar year.

(iv) 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.

(v) Document and report the methodology used.

(6) Biomass. Use Equation 2-18 to estimate CH_4 and N_2O emissions for biomass combustion based on quanity of steam generated when unable to determine the quantity of biomass fuel to apply Equation 2-12 or Equation 2-13.

Equation 2-18: CH_4 and N_2O Biomass Method

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

Where:

$\mathbf{CH_4}$ or $\mathbf{N_2O}$ = Annual mass of CH_4 or N_2O emissions from the combustion of biomass (tonnes).

$\mathbf{Steam}$ = Total mass of steam generated by biomass combustion during the reporting year (tonnes steam).

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

$\mathbf{EF}$ = Fuel-specific emission factor for CH_4 or N_2O from Table 2-11, as applicable (grams per MJ).

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

2.C **Fugitive Emissions from Flaring**

Calculate and report CO_2, CH_4 and N_2O emissions resulting from the combustion of flare pilot and hydrocarbons routed to flares for destruction using the appropriate method(s) specified.

Flaring de minimus

If the sum of CO_2, CH_4 and N_2O emissions, in CO_2 equivalent (CO_2 eq.) from any flare(s) does not exceed 0.5% of the facility total flaring GHG emissions, or 0.05% of facility total combustion GHG emissions, whichever is larger, then these flaring emissions are not required to be reported.

2.C.1 **CO_2 Emissions from Flaring**

(1) Heat value or carbon content measurement. If continuously monitoring HHV or gas composition at the flare or if monitoring these parameters at least weekly, use the measured HHV or carbon content value in calculating the CO_2 emissions from the flare using the applicable methods in paragraphs (A) and (B) of this section.

(A) For monitored gas composition, calculate the CO_2 emissions from the flare using Equation 2-19 of this section.

Equation 2-19: CO_2 from Flaring—CC

$$\boldsymbol{CO_{2i} = CE \times 10^{-3} \times (\sum_{p=1}^{n}[3.664 \times (Flare)_p \times \frac{(MW)_p}{MVC} \times (CC)_p])}$$

Where:

CO_{2i} = Annual CO_2 emissions for a specific fuel type "i" (tonnes).

CE = Flare combustion efficiency measured at the facility. Assume a 0.98 flare combustion efficiency if facility efficiency data is unavailable.

10^{-3} = Conversion factor from kilograms to tonnes.

n = Number of measurement periods as specified in Section 2.C.1(1).

3.664 = Ratio of molecular weights, CO_2 to carbon

$(Flare)_p$ = Volume of flare gas combusted during measurement period "p" at 15°C and 101.325 kPa for gaseous fuels (m^3/period) or, specific to petroleum refineries, at dry reference condition at 25°C, 101.325 kPa and 0% moisture (dRm^3/period). If a mass flow meter is used, measure flare gas flow rate in kg/period and set $(MW)_p/MVC = 1$.

$(\mathbf{MW})_p$ = Average molecular weight of the flare gas combusted during measurement period "*p*" (kg/kg-mole). If measurements are more frequent than daily, use the arithmetic average of measurement values within the day.

MVC = Molar volume conversion factor at the same reference conditions as the above $(\text{Flare})_p$ (m^3/kg-mole).
= 8.3145 * [273.16 + reference temperature in °C]/[reference pressure in kilopascal].

$(\mathbf{CC})_p$ = Average carbon content of the flare gas combusted during measurement period "*p*" (kg C per kg flare gas) as specified in Section 2.D.4. If measurements are more frequent than daily, use the arithmetic average of measurement values within the day.

(B) For monitored heat content, when gas composition is not obtainable, calculate the CO_2 emissions from the flare using Equation 2-20 of this section.

Equation 2-20: CO_2 from Flaring—HHV

$$\boldsymbol{CO_{2i} = CE \times 10^{-3} \times \sum_{p=1}^{n} [(Flare)_p \times (HHV)_p \times EF]}$$

Where:

$\mathbf{CO_{2i}}$ = Annual CO_2 emissions for a specific fuel type "i" (tonnes).

CE = Flare combustion efficiency measured at the facility. Assume a 0.98 flare combustion efficiency if facility efficiency data is unavailable.

$\mathbf{10^{-3}}$ = Conversion factor from kilograms to tonnes.

n = Number of measurement periods as specified in Section 2.C.1(1).

$(\mathbf{Flare})_p$ = Volume of flare gas combusted during measurement period "*p*" at reference temperature and pressure conditions as used by the facility (m^3/period). If a mass flow meter is used, also measure molecular weight and convert the mass flow to a volumetric flow as follows: Flare[m^3] = Flare[kg] ×MVC/$(MW)_p$, where MVC is the molar volume conversion factor at the same reference conditions as $(\text{Flare})_p$,15°C and 101.325 kPa for gaseous fuels (m^3/ kg-mole) or, specific to petroleum refineries, dry reference condition, 25°C, 101.325 kPa and 0% moisture (dRm^3/kg-mole), and $(MW)_p$ is the average molecular weight of the flare gas combusted during measurement period *p* (kg/kgmole).

$(\mathbf{HHV})_p$ = High heat value for the flare gas combusted during measurement period "*p*" (GJ per m^3). For measurement frequencies greater than daily, use the arithmetic average of measurement values within the day.

EF = Apply facility specific CO_2 emission factor. When facility specific factor is not available assume default CO_2 emission factor of 62.4 kg CO_2/GJ[3] (HHV basis).

---

[3] Default CO_2 flaring emission factor is based on the 1990-2016 National Inventory Report's Table A6-5, Still Gas Refineries & Others 2015-2016 value of 2123 g CO_2/l of fuel and a HHV conversion factor of 34.02 GJ/m^3 from CIEEDAC. Assumed refinery fuel/still gas is used to support flaring activities. ECCC 20017, National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, Gatineau, April 2018. CIEEDAC 2014, Energy Use and CO_2 Emissions in Canadian Oil Refineries 1990, 1994-2013, Simon Fraser University, March 2014

(2) Alternative Method. For startup, shutdown, and malfunctions during which there are no measured parameters required by Equation 2-19 and Equation 2-20 of this section, determine the quantity of gas discharged to the flare separately for each start-up, shutdown, or malfunction, and calculate the CO_2 emissions as specified in paragraphs (A) and (B).

   (A) For periods of start-up, shutdown, or malfunction, use engineering calculations and process knowledge to estimate the carbon content of the flared gas for each start-up, shutdown, or malfunction event.

   (B) Calculate the CO_2 emissions using Equation 2-21 of this section.Equation 2-21

Equation 2-21

$$\boldsymbol{CO_{2i} = CE \times 10^{-3} \times (\sum_{p=1}^{n}[3.664 \times (Flare_{SSM})_p \times \frac{(MW)_p}{MVC} \times (CC)_p])}$$

Where:

CO_{2i} = Annual CO_2 emissions for a specific fuel type "i" (tonnes).

CE = Flare combustion efficiency measured at the facility. Assume a 0.98 flare combustion efficiency, if facility efficiency data is unavailable.

10^{-3} = Conversion factor from kilograms to tonnes.

n = Number of start-up, shutdown, and malfunction events during the reporting year.

$(Flare_{SSM})_p$ = Volume of flare gas combusted during start-up, shutdown, or malfunction event "*p*" from engineering calculations, at 15°C and 101.325 kPa (m^3/ event) or specific to petroleum refineries at dry reference conditions 25°C, 101.325 kPa and 0% moisture (dRm^3/event). If a mass flow meter is used, measure the flare gas combusted in kg per event and set $(MW)_p/MVC = 1$.

$(MW)_p$ = Average molecular weight of the flare gas, from the analysis results or

engineering calculations for the event "*p*" (kg/kg-mole).

MVC = Molar volume conversion factor at the same reference conditions as the above $(Flare_{SSM})_p$ (m^3/kg-mole).
= 8.3145 * [273.16 + reference temperature in °C]/[reference pressure in kilopascal].

$(CC)_p$ = Average carbon content of the flare gas, from analysis results or engineering calculations for the event "*p*" (kg C per kg flare gas).

3.664 = Ratio of molecular weights, CO_2 to carbon.

2.C.2 CH_4 and N_2O Emissions from Flaring

Calculate and report CH_4 and N_2O emissions resulting from the combustion of hydrocarbons routed to flares for destruction using the methods specified in paragraphs (1) and (2):

(1) Calculate CH_4 emissions using Equation 2-22 of this section.

Equation 2-22

$$CH_4 = \left(CO_2 \times \frac{EF_{CH4}}{EF}\right) + CO_2 \times \frac{1-CE}{CE} \times \frac{16}{44} \times f_{CH4}$$

Where:

CH_4 = Annual methane emissions from flared gas (tonnes).

CO_2 = Emissions of CO_2 from flared gas calculated in paragraph 2.C.1 (tonnes).

EF_{CH4} = Apply facility specific CH_4 emission factor. When facility specific factor is not available assume default CH_4 emission factor of 0.91×10^{-3} kg/GJ[4].

EF = Apply facility specific CO_2 emission factor. When facility specific factor is not available assume default CO_2 emission factor for flare gas of 62.4kilograms CO_2/GJ (HHV basis).

CE = Flare combustion efficiency measured at the facility. Assume a 0.98 flare combustion efficiency if facility efficiency data is unavailable.

$(1 - CE)/CE$ = Correction factor for flare combustion efficiency.

$16/44$ = Ratio of molecular weights, CH_4 to CO_2

f_{CH4} = Weight fraction of carbon in the flare gas prior to combustion that is contributed by methane from measurement values or engineering calculations (kg C in methane in flare gas/kg C in flare gas); default is 0.4.

---

[4] Default CH_4 flaring emission factor is based on the 1990-2016 National Inventory Report's Table A6-7, Still Gas Refineries & Others 2015-2016 value of 31.0 g CH_4/m^3 of fuel and a HHV conversion factor of 34.02 GJ/m^3 from CIEEDAC. Assumed refinery fuel gas/still gas is used to support flaring activities. ECCC 2017, National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, Gatineau, April 2018. CIEEDAC 2014, Energy Use and CO_2 Emissions in Canadian Oil Refineries 1990, 1994-2013, Simon Fraser University, March 2014

(2) Calculate N_2O emissions using Equation 2-23 of this section.

Equation 2-23

$$N_2O = (CO_2 \times \frac{EF_{N2O}}{EF})$$

Where:

N_2O = Annual nitrous oxide emissions from flared gas (tonnes).

CO_2 = Emission rate of CO_2 from flared gas calculated in paragraph 2.C.1 (tonnes).

EF_{N2O} = Apply facility specific N_2O emission factor. When facility specific factor is not available assume default N_2O emission factor for petroleum products of 0.6 x 10^{-6} kg N_2O/GJ[5].

EF = Apply facility specific CO_2 emission factor. When facility specific factor is not available assume default CO_2 emission factor for flare gas of 62.4 kilograms CO_2/GJ (HHV basis).

2.C.3 **Other CO_2 Emissions**

Where low Btu gases (e.g. coker flue gas, gases from vapor recovery systems, casing vents and product storage tanks) are destroyed using methods other than flares (e.g. incineration, combustion as a supplemental fuel in heaters or boilers) calculate CO_2 emissions using Equation 2-24. Determine CC_A and MW_A quarterly using methods specified in Section 2.D and use the annual average values of CC_A and MW_A to calculate CO_2 emissions.

---

[5] Default N_2O flaring emission factor is based on the 1990-2016 National Inventory Report's Table A6-4, Still Gas Refineries & Others 2015-2016 value of 0.00002 g N_2O /l of fuel and a HHV conversion factor of 34.02 GJ/m^3 from CIEEDAC. Assumed refinery fuel gas/still gas is used to support flaring activities. ECCC 20017, National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada, Environment and Climate Change Canada, Gatineau, April 2018. CIEEDAC 2014, Energy Use and CO_2 Emissions in Canadian Oil Refineries 1990, 1994-2013, Simon Fraser University, March 2014

Equation 2-24

$$CO_2 = GV_A \times CC_A \times \frac{MW_A}{MVC} \times 3.664 \times 10^{-3}$$

Where:

$\mathbf{CO_2}$ = Annual CO_2 emissions from destruction methods other than flares (tonnes).

$\mathbf{GV_A}$ = Annual volume of gas *A* destroyed at 15°C and 101.325 kPa (m^3) or specific to petroleum refineries at reference conditions of 25°C and 101.325 kPa ($dRm^{3)}$. When using a mass flow meter, measure the gas destroyed in kg and replace the term "MW_A/MVC" with "1".

$\mathbf{CC_A}$ = Carbon content of gas *A* (kg C/kg fuel).

$\mathbf{MW_A}$ = Molecular weight of gas *A*.

MVC = Molar volume factor at the same reference conditions as the GV_A variable (m^3/kg-mole).
= 8.3145 * [273.16 + reference temperature in °C]/[reference pressure in kilopascal].

3.664 = Ratio of molecular weights, CO_2 to carbon.

$\mathbf{10^{-3}}$ = Conversion factor from kilograms to tonnes.

2.D **Sampling, Analysis and Measurement Requirements**

2.D.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.D.1(1) to 2.D.1(7) of this section, when sampling frequencies are not specified in Section 0, 2.B and 2.C. 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. Sample continuously delivered coal, such as, from conveyor systems or on-going truck deliveries, as often as necessary to capture variations in carbon content and heat value and to ensure a representative annual composition, but no less than quarterly.

(2) Once for each new fuel shipment or delivery of fuels, or quarterly for each of the fuels listed in Table 2-1, Table 2-2 or Table 2-3.

(3) Monthly for natural gas. The fuel supplier should provide monthly analysis or, should that not be possible, as often as the supplier can provide, but no less than semi-annually.

(4) Quarterly for all liquid fuels including renewables and biomass except for fuels listed in Table 2-1 and Table 2-2 (when these tables are used).

(5) Quarterly for renewable and biomass gaseous fuels derived from biomass including landfill gas and biogas from wastewater treatment or agricultural processes.

(6) For all other gaseous fuels including renewables and biomass (other than natural gas, and 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 all other solid fuels including renewables and biomass except for 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, for use in monitoring the homogeneity of the composite.

(8) For all other biomass fuels and waste-derived fuels, the following may apply in lieu of paragraph 2.D.1(4) to 2.D.1(7)

(A) If calculating CO_2 emissions using equations requiring HHV or carbon content, determine the fuel-specific HHV or carbon content annually. If CO_2 emissions are calculated using Equation 2-11 and a site-specific emission factor, adjust the emission factor, in kg CO_2/MJ, at least every third year. Use a stack test measurement of CO_2 and the applicable ASME Performance Test Code to determine heat input from all heat outputs, including the steam, flue gases, ash and losses.

2.D.2 **Fuel Consumption Monitoring Requirements**

(1) Determine fuel consumption based on direct measurement or recorded fuel purchase or sales invoices measuring any stock change using Equation 2-25. Follow the fuel measurement and sampling requirement in Section 2.D.1. For feedstock and non-energy use of fossil fuels, consult sections according to the specific sector or activity.

Equation 2-25: Fuel Consumption

$$\boldsymbol{Fuel_i = Purchases_i - Sales_i + Stored_{SY\,i} - Stored_{YE\,i} - Feedstock_i}$$

Where:

$\mathbf{Fuel}_{\mathrm{i}}$ = 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.

$\mathbf{Purchases}_{\mathrm{i}}$ = Total annual fuel purchases by type "i", expressed in tonnes (t), kilolitres (kL) or cubic metres (m^3).

$\mathbf{Sales}_{\mathrm{i}}$ = Total annual fuel sales by type "i", expressed in tonnes (t), kilolitres (kL) or cubic metres (m^3).

$\mathbf{Stored}_{\mathrm{SY\,i}}$ = Quantity of fuel stored by type "i" at start of year, expressed in tonnes (t), kilolitres (kL) or cubic metres (m^3).

$\mathbf{Stored}_{\mathrm{YE\,i}}$ = Quantity of fuel stored by type "i" at year-end, expressed in tonnes (t), kilolitres (kL) or cubic metres (m^3).

$\mathbf{Feedstock}_{\mathrm{i}}$ = Annual quantity feedstock or non-energy fuel use by type "i", expressed in tonnes (t), kilolitres (kL) or cubic metres (m^3).

(2) Convert fuel consumption measured in MJ to the required mass or volume metrics, or vice versa, using heat content values provided by the supplier or measured at the facility, when applicable.

(3) Calibrate all fuel oil and gas flow meters (except for gas billing meters) 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 the *Weights and Measures Act*.

(4) For fuel oil, tank drop measurements may also be used.

(5) Use fuel volume flow meters for liquid fuels, if appropriate fuel densities are available 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 CO_2 emissions may use the default density values in Table 2-12 for fuel oil, in lieu of using the ASTM method in paragraph 2.D.2(5) of this section. Do not use these default densities 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

(7) Determine annual mass of spent liquor solids using one of the methods specified in subparagraph (A) or (B)

(A) Measure mass of annual spent liquor solids using TAPPI T650 om-15 "Solids Content of Black Liquor".

(B) Determine mass of annual spent liquor solids based on records of measurements made with an online measurement system that determines the mass of spent liquor solids fired in a chemical recovery furnace or chemical recovery combustion unit. Measure the quantity of black liquor produced each month.

2.D.3 **Fuel Heat Content Monitoring Requirements**

Base higher heating values on the results of fuel sampling and analysis received from the fuel supplier or as determined using an applicable analytical method in paragraphs (1) to (6) of this section. Follow the fuel measurement and sampling requirement in Section 2.D.1. For fuel heat content monitoring of natural gas, follow the requirements of the *Weights and Measures Act*.

(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, and 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*. Determine the biomass fuel portion of CO_2 emissions, if combusting waste-derived fuels that are not pure biomass.

(5) For black liquor, use Technical Association of the Pulp and Paper Industry (TAPPI) *T684 om-15 - Gross High Heating Value of Black Liquor*.

(6) When using measured heat content to calculate CO_2 emissions, use Equation 2-26 to develop the weighted annual heat content of the fuel.

Equation 2-26: HHV

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

Where:

$\mathbf{HHV}_{\mathrm{Annual\ i}}$ = weighted annual average higher heating 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).

$\mathbf{HHV}_{\mathrm{i\ p}}$ = higher heating 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).

$\mathbf{Fuel}_{\mathrm{i\ p}}$ = 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).

$\mathbf{n}$ = number of measurement periods per calendar year that fuel is burned by type "i" in the unit.

2.D.4 **Fuel Carbon Content Monitoring Requirements**

Base the fuel carbon content 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.D.4(1) to 2.D.4(5) of this section. Follow the fuel measurement and sampling requirement in Section 2.D.1. For carbon content monitoring of natural gas, follow the requirements of the *Weights and Measures Act*.

(1) For coal and coke, solid biomass fuels, and waste-derived fuels, use the specific test procedures in ASTM 5373 "Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Laboratory Samples of Coal".

(2) For petroleum-based liquid fuels and liquid waste-derived fuels, use *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 refinery fuel gas and flexigas, use either *ASTM D1945-03 (Reapproved 2006)* or *ASTM D1946-90 (Reapproved 2006)*. Alternatively, the results of chromatographic analysis of the fuel gas may be used, provided that the gas chromatograph is operated, maintained, and calibrated according to manufacturer instructions; and the methods used for operation, maintenance, and calibration of the gas chromatograph are documented in a plan.

(4) For other gaseous fuels, use *ASTM D1945 - Standard Test Method for Analysis of Natural Gas by Gas Chromatography* or *ASTM D1946 - Standard Practice for Analysis of Reformed Gas by Gas Chromatography*.

(5) When using measured carbon content to calculate CO_2 emissions, use Equation 2-27 to develop the weighted annual average carbon content of the fuels.

Equation 2-27: Annual Carbon Content

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

Where:

$CC_{\text{Annual i}}$ = Weighted annual average carbon content of the fuel type “i”, expressed as tonnes C per tonne solid fuel, tonnes C per kilolitre liquid fuel, or tonnes C per cubic meter gaseous fuel.

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

$Fuel_{\text{i p}}$ = Mass or volume of the 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).

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

2.D.5 **Fuel Analytical Data Capture**

When the applicable methodologies in Sections 0 and 2.B require periodic collection of fuel analytical data for an emissions source, demonstrate every 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 0 and 2.B, use the methods in paragraph 2.E(2) to substitute for the missing values for the period of missing data.

2.D.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.7 **Flares and Other Control Devices**

(1) Where a continuous flow monitor on the flare exists, use the measured flow rates when the monitor is operational and the flow rate is within the calibrated range of the measurement device to calculate the flare gas flow. Where no continuous flow monitor on the flare exists and for periods when the monitor is not operational or the flow rate is outside the calibrated range of the measurement device, use engineering calculations, company records, or similar estimates of volumetric flare gas flow.

(2) If using the method specified in section 2.C.1(1)(A), monitor the carbon content of the flare gas daily if the flare is already equipped with the necessary measurement devices (at least weekly if not).

(3) If using the method specified in section 2.C.1(1)(B), monitor the HHV of the flare gas daily if the flare is already equipped with the necessary measurement devices (at least weekly if not).

2.E **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 a required fuel sample 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 CO_2 concentration, stack gas flow rate, fuel flow rate, HHV, 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 HHV, 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 CO_2 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 2-28 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 2-28

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

Where:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

$\mathbf{QS}_{\mathbf{ACT}}$ = Quantity of actual samples or measurements obtained by the facility operator.

$\mathbf{QS}_{\mathbf{REQUIRED}}$ = 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 2-29:

- (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 2-29

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

Where:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

$\mathbf{HS}_{\mathbf{ACT}}$ = Quantity of actual samples or measurements obtained by the person.

$\mathbf{HS}_{\mathbf{REQUIRED}}$ = Quantity of samples or measurements required for Section 2.

3 Quantification Methods for Lime Production

3.A CO_2 Emissions from Lime Production

Calculate the annual CO_2 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 CO_2 emissions from lime production as specified in Section 3.A.3 or using Equation 3-1 through Equation 3-3. For emissions from lime kilns at a pulp and paper production facility, refer to section 12.

Equation 3-1

$$E_{CO_2} = \sum_{m}^{12}\sum_{i}[QL_{m\,i} \times EFL_{m\,i}] + \sum_{q}^{4}\sum_{j}[QCBW_{q\,j} \times EFCBW_{q\,j}]$$

Where:

E_{CO2} = the total annual quantity of CO_2 emissions from lime production (tonnes).

$QL_{m\,i}$ = the total quantity of each lime type "i" in month "m" (tonnes).

$EFL_{m\,i}$ = the plant specific emission factor for each lime type "i" in month "m" (tonnes CO_2 / tonnes lime), using the method in Section 3.A.1.

$QCBW_{q\,j}$ = the total quantity of calcined byproducts/wastes for each byproduct/waste type "j" in quarter "q" (tonnes byproduct/waste).

$EFCBW_{q\,j}$ = the plant specific emission factor for each calcined byproduct/waste type "j" in quarter "q" (tonnes CO_2/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

$$EFL_{m\,i} = [(fCaO_{m\,i} \times 0.785) + (fMGO_{m\,i} \times 1.092)]$$

Where:

$EFL_{m\,i}$ = the plant specific emission factor for each lime type "i" in month "m" (tonnes CO_2 / tonnes lime).

$fCaO_{m\,i}$ = the calcium oxide (CaO) content for each lime type "i" in month "m", 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).

$\mathbf{0.785}$ = ratio of molecular weights of CO_2 to CaO.

$\mathbf{fMgO}_{\mathbf{m\,i}}$ = the magnesium oxide (MgO) content for each lime type "i" in month "m", 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).

$\mathbf{1.092}$ = ratio of molecular weights of CO_2 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

$$\boldsymbol{EFCBW_{q\,j} = \left[\left(fCaO_{q\,j} \times 0.785\right) + \left(fMGO_{q\,j} \times 1.092\right)\right]}$$

Where:

$\mathbf{EFCBW}_{\mathbf{q\,j}}$ = the plant specific emission factor for each calcined byproduct/waste type "j" in quarter "q" (tonnes CO_2 / tonnes calcined byproduct/waste).

$\mathbf{fCaO}_{\mathbf{q\,j}}$ = the calcium oxide (CaO) content of each byproduct/waste type "j" in quarter "q", calculated by subtracting CaO content of byproduct/waste in uncalcined $CaCO_3$ remaining in calcined byproduct/waste from total CaO content of byproduct/waste (tonnes CaO / tonnes byproduct/waste).

$\mathbf{fMgO}_{\mathbf{q\,j}}$ = the magnesium oxide (MgO) content of each calcined byproduct/waste "j" in quarter "q", calculated by subtracting MgO content of byproduct/waste in uncalcined $MgCO_3$ remaining in byproduct/waste from total MgO content of byproduct/waste (tonnes MgO / tonnes byproduct/waste).

$\mathbf{0.785}$ = ratio of molecular weights of CO_2 to CaO.

$\mathbf{1.092}$ = ratio of molecular weights of CO_2 to MgO.

3.A.3 CO_2 Emissions from Lime Production Using CEMS

Persons operating a facility with installed CEMS may calculate CO_2 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 CO_2 emissions for lime production from all kilns combined (tonnes), calculated by subtracting CO_2 fuel combustion emissions as specified in Section 2 from the total annual CO_2 quantity measured using CEMS.

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

$E_{CO2\,FC}$ = the total annual CO_2 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 "CO_2 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) CO_2 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 CO_2 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 CO_2 concentration, stack gas flow rate, fuel flow rate, HHV, 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

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

Where:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

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

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

4 Quantification Methods for Cement Production

4.A CO_2 Emissions from Cement Production

Calculate the annual CO_2 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 CO_2 emissions from clinker production as specified in Equation 4-6 or using Equation 4-1 through Equation 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 CO_2 emissions from cement production (tonnes).

$E_{CO2\,CLI}$ = the total annual quantity of CO_2 emissions from clinker production (tonnes).

$E_{CO2\,CKD}$ = the total annual quantity of CO_2 emissions from cement kiln dust (CKD) (tonnes).

$E_{CO2\,RM}$ = the total annual quantity of CO_2 emissions from organic carbon oxidation (tonnes).

$Q_{CLI\,m}$ = the total quantity of clinker in month "m" (tonnes).

$EF_{CLI\,m}$ = the plant specific emission factor of clinker in month "m" (tonnes CO_2 / tonnes clinker), using Equation 4-3.

$Q_{CKD\,q}$ = the total quantity of cement kiln dust not recycled back to the kiln in quarter "q" (tonnes).

$EF_{CKD\,q}$ = the plant specific emission factor of cement kiln dust not recycled back to the kiln in quarter "q" (tonnes CO_2 / 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 CO_2 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

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

Where:

$\mathbf{EF}_{\mathrm{CLI\ m}}$ = the plant specific emission factor of clinker in month “m” (tonnes CO_2 / tonnes clinker).

$\mathbf{CaO}_{\mathrm{CLI\ m}}$ = the total calcium oxide (CaO) content of clinker in month “m” (tonnes CaO / tonnes clinker).

$\mathbf{fCaO}_{\mathrm{m}}$ = the non-calcined calcium oxide (CaO) content of clinker in month “m” (tonne CaO / tonne clinker).

$\mathbf{MgO}_{\mathrm{CLI\ m}}$ = the total magnesium oxide (MgO) content of clinker in month “m” (tonne MgO / tonne clinker).

$\mathbf{fMgO}_{\mathrm{m}}$ = the non-calcined magnesium oxide (MgO) content of clinker in month “m” (tonne MgO / tonne clinker).

$\mathbf{0.785}$ = ratio of molecular weights of CO_2 to CaO.

$\mathbf{1.092}$ = ratio of molecular weights of CO_2 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

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

Where:

$\mathbf{EF}_{\mathrm{CKD\ q}}$ = the plant specific emission factor of CKD not recycled back to the kiln in quarter “q” (tonnes CO_2 / tonnes CKD).

$\mathbf{CaO}_{\mathrm{CKD\ q}}$ = the total calcium (expressed as CaO) content of CKD not recycled back to the kiln in quarter “q” (tonnes CaO / tonnes CKD).

$\mathbf{fCaO}_{\mathrm{q}}$ = the non-calcined calcium oxide (CaO) content of CKD not recycled back to the kiln in quarter “q” (tonne CaO / tonne clinker).

$\mathbf{MgO}_{\mathbf{CKD\ q}}$ = the total magnesium (expressed as MgO) content of CKD not recycled back to the kiln in quarter “q” (tonne MgO / tonne clinker).

$\mathbf{fMgO}_{\mathbf{q}}$ = the non-calcined magnesium oxide (MgO) content of CKD not recycled back to the kiln in quarter “q” (tonne MgO / tonne clinker).

$\mathbf{0.785}$ = ratio of molecular weights of CO_2 to CaO.

$\mathbf{1.092}$ = ratio of molecular weights of CO_2 to MgO.

4.A.3 **Organic Carbon Oxidation Emissions**

Calculate the annual CO_2 emissions from total organic content in raw materials using Equation 4-5.

Equation 4-5

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

Where:

$\mathbf{E}_{\mathbf{CO2\ RM}}$ = the total annual quantity of CO_2 emissions from organic carbon oxidation (tonnes).

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

$\mathbf{RM}$ = the total annual quantity of raw material consumption (tonnes).

$\mathbf{3.664}$ = ratio of molecular weights of CO_2 to C.

4.A.4 **CO_2 Emissions from Cement Production Using CEMS**

Persons operating a facility with installed CEMS may calculate CO_2 emissions from cement production using Equation 4-6.

Equation 4-6

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

Where:

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

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

$\mathbf{E}_{\mathbf{CO2\ FC}}$ = the total annual CO_2 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 CO_2 concentration, stack gas flow rate, fuel flow rate, HHV , 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 Production

5.A CO$_2$ Emissions from Aluminium Production

Calculate the annual CO$_2$, CF$_4$, C$_2$F$_6$ and SF$_6$ emissions from aluminium production using the methods specified in this section.

5.A.1 CO$_2$ Emissions from Prebaked Anode Consumption

Calculate the total annual CO$_2$ emissions from prebaked anodes consumption using Equation 5-1.

Equation 5-1

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

Where:

$E_{CO2\,PA}$ = the total annual quantity of CO$_2$ emissions from the consumption of prebaked anodes (tonnes).

NAC = the net anode consumption for liquid aluminium production in month “m” (tonnes anodes/tonnes liquid aluminium).

MP = the total quantity of liquid aluminium production in month “m” (tonnes).

S_a = the sulphur content in prebaked anodes in month “m” (kg S / kg prebaked anodes).

Ash_a = the ash content in prebaked anodes in month “m” (kg ash / kg prebaked anodes).

3.664 = ratio of molecular weights of CO$_2$ to C.

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

Calculate the total annual CO_2 emissions from anode consumption from Søderberg electrolysis cells using Equation 5-2.

Equation 5-2

$$E_{CO_2\,AS} = \sum_{m=1}^{12} \Big[(PC \times MP) - \Big(CSM \times \frac{MP}{1000}\Big) - \Big(BC \times PC \times MP \times \big(S_p + Ash_p + H_p\big)\Big) - \big((1 - BC) \times PC \times MP \times (S_c + Ash_c)\big) - (MP \times CP)\Big]_m \times 3.664$$

Where:

$E_{CO2\,AS}$ = the total annual quantity of CO_2 emissions attributable to anode consumption from Søderberg electrolysis cells (tonnes).

PC = the total quantity of anode paste consumption in month "m" (tonnes paste / tonnes liquid aluminium).

MP = the total quantity of liquid aluminium production in month "m" (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 average pitch content or other binding agent in paste in month "m" (kg pitch or other binding agent / kg paste).

S_p = the sulphur content or other binding agent in pitch in month "m" (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 H_2 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 Søderberg electrolysis cells (kg C / kg liquid aluminium, or a value of 0).

3.664 = ratio of molecular weights, CO_2 to C.

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

Calculate the total annual CO_2 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 CO_2 emissions from anode and cathode baking (tonnes).

$E_{CO2\,PM}$ = the total annual quantity of CO_2 emissions from packing material, as specified in Equation 5-4.

$E_{CO2\,P}$ = the total annual quantity of CO_2 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 CO_2 emissions from packing material using Equation 5-4.

Equation 5-4

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

Where:

$E_{CO2\,PM}$ = the total annual quantity of CO_2 emissions from packing material consumption (tonnes).

CPM = the quantity of packing material consumption in month “m” (tonnes packing material / tonnes baked anodes or cathodes).

BAC = the quantity of baked anodes or cathodes removed from furnace in month “m” (tonnes).

$Ash_{p\,m}$ = the ash content of packing material in month “m” (kg ash / kg packing material).

$S_{p\,m}$ = the sulphur content of packing material in month “m” (kg S / kg packing material).

3.664 = ratio of molecular weights, CO_2 to C.

5.A.5 **CO_2 Emissions from Coking of Pitch or Other Binding Agent**

Calculate the total annual CO_2 emissions from coking of pitch or other binding using Equation 5-5.

Equation 5-5

$$E_{CO_2\,P} = \sum_{m=1}^{12} \left(GAC - BAC - \left(H_p \times PC \times GAC\right) - RT\right)_m \times 3.664$$

Where:

$E_{CO2\,P}$ = the total annual quantity of CO_2 emissions from coking of pitch or other binding agent (tonnes).

GAC = the total quantity of green anodes or cathodes put into furnace in month “m” (tonnes).

BAC = the total quantity of baked anodes or cathodes removed from furnace in month “m” (tonnes).

H_p = the hydrogen content in pitch or other binding agent or the International Aluminium Institute factor used in month “m”, listed in Table 5-1 (kg H_2 / kg pitch or other binding agent).

PC = the pitch or other binding agent content in green anodes or cathodes in month “m” (kg pitch or other binding agent / kg anodes or cathodes).

RT = the total quantity of recovered tar in month “m” (tonnes).

3.664 = ratio of molecular weights, CO_2 to carbon.

5.A.6 **CO_2 Emissions from Green Coke Calcination**

Calculate the total annual CO_2 emissions from green coke calcination using Equation 5-6.

Equation 5-6

$$E_{CO_2\,GC} = \sum_{m=1}^{12} \Big[\left(GC \times (1 - H_2O_{GC} - V_{GC} - S_{GC}) - (CC + UCC + ED) \times (1 - S_{cc})\right) \times 3.664 + (GC \times 0.035 \times 2.75)\Big]_m$$

Where:

$E_{CO2\,GC}$ = the total annual quantity of CO_2 emissions from green coke calcination (tonnes).

GC = the total quantity of green coke consumption in month “m” (tonnes).

H_2O_{GC} = the water content in green coke in month “m” (kg H_2O / kg green coke).

V_{GC} = the volatiles content in green coke in month “m” (kg volatiles / kg green coke).

S_{GC} = the sulphur content in green coke in month “m” (kg S / kg green coke).

$\mathbf{CC}$ = the total quantity of calcinated coke production in month “m” (tonnes).

$\mathbf{UCC}$ = the total quantity of under-calcinated coke production in month “m” (tonnes).

$\mathbf{ED}$ = the total quantity of emissions from coke dust in month “m” (tonnes).

$\mathbf{S}_{\mathbf{cc}}$ = the sulphur content in calcinated coke in month “m” (kg S / kg calcinated coke).

$\mathbf{3.664}$ = ratio of molecular weights, CO_2 to carbon.

$\mathbf{0.035}$ = CH_4 and tar content in coke volatiles contributing to CO_2 emissions.

$\mathbf{2.75}$ = Conversion factor, CH_4 to CO_2.

5.A.7 **CF_4 and C_2F_6 Emissions from Anode Effects**

Calculate the total annual CF_4 and C_2F_6 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 CF_4 and C_2F_6 emissions as specified in Section 5.B.1.

5.A.7.a The Slope Method for CF_4 Emissions from Anode Effects

Calculate the total annual CF_4 emissions from anode effects using Equation 5-7.

Equation 5-7

$$\boldsymbol{E_{CF_4} = \sum_{m=1}^{12} \left[Slope_{CF_4} \times AED \times MP\right]_m}$$

Where:

$\mathbf{E}_{\mathbf{CF4}}$ = the total annual quantity of CF_4 emissions from anode effects (tonnes).

$\mathbf{Slope}_{\mathbf{CF4}}$ = the slope for series of pots *j* in month “m” (tonnes CF_4 / tonnes liquid aluminium / anode effect minute / pot-day).

$\mathbf{AED}$ = the anode effect duration in month “m” (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).

$\mathbf{MP}$ = the production of liquid aluminium in month “m” (tonnes).

5.A.7.b The Overvoltage Coefficient Method for CF_4 Emissions from Anode Effects

Calculate the total annual CF_4 emissions from anode effects using Equation 5-8.

Equation 5-8

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

Where:

E_{CF4} = the total annual quantity of CF_4 emissions from anode effects (tonnes).

n = number of series of pots.

OVC_{CF4} = the overvoltage coefficient (tonnes of CF_4 / tonnes liquid aluminium/millivolt).

AEO = the anode effect overvoltages in month “m” for series of pots “j” (millivolts / pot).

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

MP = the production of liquid aluminium in month “m” (tonnes).

5.A.7.c Calculation Method for C_2F_6 Emissions from Anode Effects

Calculate the total annual C_2F_6 emissions from anode effects using Equation 5-9.

Equation 5-9

$$E_{C_2F_6} = \sum_{m=1}^{12}\left[E_{CF_4} \times F\right]_m$$

Where:

E_{C2F6} = the total annual quantity of C_2F_6 emissions (tonnes).

E_{CF4} = the total quantity of CF_4 emissions in month “m” (tonnes).

F = the weight fraction of C_2F_6 / CF_4 determined by the emitter or selected from Table 5-2 (kg C_2F_6 / kg CF_4).

5.A.8 **Emissions from SF_6 Used as a Cover Gas**

Calculate the total annual emissions from SF_6 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 SF_6 emissions used as a cover gas (tonnes).

$S_{Inv\text{-}Begin}$ = the total annual quantity of SF_6 in storage at the beginning of the year (tonnes).

$S_{Inv\text{-}End}$ = the total annual quantity of SF_6 in storage at the end of the year (tonnes).

$S_{Purchased}$ = the total annual quantity of SF_6 purchases for the year (tonnes).

$S_{Shipped}$ = the total annual quantity of SF_6 shipped out of the facility during the year (tonnes).

Equation 5-11

$$E_{SF_6} = \sum_{m=1}^{12} \left[(Q_{Input} \times C_{Input}) - (Q_{Output} \times C_{Output}) \right]_m$$

Where:

E_{SF6} = the total annual quantity of SF_6 emissions used as a cover gas (tonnes).

Q_{Input} = the total quantity of cover gas entering the electrolysis cells in month “m” (tonnes).

C_{Input} = the concentration of SF_6 in the cover gas entering the electrolysis cells in month “m” (tonnes SF_6 / tonnes input gas).

Q_{Output} = the quantity of gas containing SF_6 collected and shipped out of the facility in month “m” (tonnes).

C_{Output} = the concentration of SF_6 in the gas collected and shipped out of the facility in month “m” (tonnes SF_6 /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 SF_6 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

$$\boldsymbol{CCP_M = RF \times CGC}$$

Where:

$\mathbf{CCP_M}$ = the calcinated coke produced and measured during the measurement period (tonnes).

$\mathbf{RF}$ = the recovery factor determined annually during a measurement period (tonnes calcinated coke / tonnes green coke).

$\mathbf{CGC}$ = the consumption of green coke measured during the measurement period (tonnes).

5.B.1. Persons using CEMS for CF_4 and C_2F_6 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 SF_6 emissions from the consumption of a cover gas shall, measure monthly the quantity of SF_6 entering the electrolysis cells and the quantity and SF_6 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, SF_6 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:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

$\mathbf{QS}_{\mathbf{ACT}}$ = Quantity of actual samples or measurements obtained by the person.

$\mathbf{QS}_{\mathbf{REQUIRED}}$ = 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 SF_6 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 CO_2 concentration, stack gas flow rate, fuel flow rate, HHV, 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:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

$\mathbf{HS}_{\mathbf{ACT}}$ = Quantity of actual samples or measurements obtained by the person.

$\mathbf{HS}_{\mathbf{REQUIRED}}$ = Quantity of samples or measurements required for Section 5.

Table 5-1: Default Factors for Parameters Used to Quantify CO_2 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: C_2F_6 / CF_4 Weight Fractions Based on the Technology Used

Technology used	Weight fraction (kg C_2F_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 Production

6.A CO_2 Emissions from Iron and Steel Production

The total annual CO_2 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 CO_2 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 Induration Furnace

Equation 6-1

Calculate the total annual CO_2 emissions from the induration 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 induration furnace (tonnes).

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

C_T = the annual weighted average carbon content of green pellets fed to the furnace (tonnes C / tonnes green 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 fired 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 CO_2.

Equation 6-2

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

Where:

$E_{CO2\ IP}$ = the total annual quantity of emissions from induration furnace (tonnes).

n = number of additives.

AD_j = the total annual quantity of additive material “j” (e.g. limestone, dolomite, bentonite) consumed by the furnace (tonnes).

$C_{AD\ j}$ = the annual weighted average carbon content of additive material “j” consumed by the furnace (tonnes C / tonnes additive material).

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

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

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 fired 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 CO_2.

6.A.2 **Basic Oxygen Furnace**

Calculate the total annual CO_2 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.

$\mathbf{m}$ = number of carbonaceous materials.

$\mathbf{I}$ = the total annual quantity of molten iron charged to furnace (tonnes).

$\mathbf{C}_{\mathbf{I}}$ = the annual weighted average carbon content of molten iron charged to furnace (tonnes of C / tonnes of molten iron).

$\mathbf{SC}$ = the total annual quantity of ferrous scrap charged to furnace (tonnes).

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

$\mathbf{FL}_{\mathbf{t}}$ = the total annual quantity of non-biomass flux material "t" (e.g. limestone, dolomite, bentonite) charged to the furnace (tonnes).

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

$\mathbf{CAR}_{\mathbf{i}}$ = the total annual quantity of non-biomass carbonaceous material "i" (e.g. coal, coke) consumed by the furnace (tonnes).

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

$\mathbf{ST}$ = the total annual quantity of molten raw steel produced by the furnace (tonnes).

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

$\mathbf{SL}$ = the total annual quantity of slag produced by the furnace (tonnes).

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

$\mathbf{BOG}$ = the total annual quantity of furnace gas transferred off site (tonnes).

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

$\mathbf{R}$ = the annual quantity of air pollution control residue collected (tonnes).

$\mathbf{C}_{\mathbf{R}}$ = the annual weighted average carbon content of air pollution control residue collected (tonnes C / tonnes residue).

$\mathbf{3.664}$ = conversion factor from tonnes of C to tonnes of CO_2.

6.A.3 **Coke Oven Battery**

Calculate the total annual CO_2 emissions from the coke oven battery using Equation 6-4.

Equation 6-4

$$\boldsymbol{E_{CO_2\,COKE}} = \left[(\boldsymbol{C_C} \times \boldsymbol{C_{CC}}) + \sum_{i=1}^{n} (\boldsymbol{OM_i} \times \boldsymbol{C_{OMi}}) - (\boldsymbol{CO} \times \boldsymbol{C_{CO}}) - (\boldsymbol{BY} \times \boldsymbol{C_{BY}}) - (\boldsymbol{COG} \times \boldsymbol{C_{COG}}) - (\boldsymbol{R} \times \boldsymbol{C_R}) \right] \times \mathbf{3.664}$$

Where:

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

$\mathbf{C_C}$ = the total annual quantity of non-biomass coking coal charged to battery (tonnes).

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

$\mathbf{OM_i}$ = the total annual quantity of non-biomass carbonaceous material “i”, other than coking coal, such as natural gas and fuel oil, charged to battery (tonnes).

$\mathbf{C_{OMi}}$ = the annual weighted average carbon content of non-biomass carbonaceous material “i”, other than coking coal, charged to battery (tonnes of C / tonnes of process material).

$\mathbf{n}$ = number of non-biomass carbonaceous materials, other than coking coal, charged to battery.

$\mathbf{CO}$ = the total annual quantity of coke produced (tonnes).

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

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

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

$\mathbf{COG}$ = the total annual quantity of coke oven gas transferred off-site (tonnes).

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

$\mathbf{R}$ = the annual quantity of air pollution control residue collected (tonnes).

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

$\mathbf{3.664}$ = conversion factor from tonnes of C to tonnes of CO_2.

6.A.4 **Sinter**

Calculate the total annual CO_2 emissions from sinter production using Equation 6-5.

Equation 6-5

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

Where:

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

n = number of carbonaceous materials.

CAR_i = the total annual quantity of non-biomass carbonaceous material "i" (e.g. coal, coke) consumed by the furnace (tonnes).

$C_{CAR\,i}$ = the annual weighted average carbon content of non-biomass carbonaceous material "i" 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 CO_2.

6.A.5 **Electric Arc Furnace**

Calculate the total annual CO_2 emissions from electric arc furnace using Equation 6-6.

Equation 6-6

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

Where:

$E_{CO2\,EAF}$ = the total annual quantity of emissions from electric arc furnace (tonnes).

n = number of flux materials.

$\mathbf{m}$ = number of carbonaceous materials.

$\mathbf{I}$ = the total annual quantity of direct reduced iron charged to furnace (tonnes).

$\mathbf{C_I}$ = the annual weighted average carbon content of direct reduced iron charged to the furnace (tonnes C / tonnes direct reduced iron).

$\mathbf{SC}$ = the total annual quantity of ferrous scrap consumed by the furnace (tonnes).

$\mathbf{C_{SC}}$ = the annual weighted average carbon content of ferrous scrap consumed by the furnace (tonnes C / tonnes ferrous scrap).

$\mathbf{FL_t}$ = the total annual quantity of non-biomass flux material "t" (e.g. limestone, dolomite, bentonite) charged to the furnace (tonnes).

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

$\mathbf{EL}$ = the total annual quantity of non-biomass carbon electrodes consumed by the furnace (tonnes).

$\mathbf{C_{EL}}$ = the annual weighted average carbon content of non-biomass carbon electrodes consumed by the furnace (tonnes C / tonnes carbon electrode).

$\mathbf{CAR_i}$ = the total annual quantity of non-biomass carbonaceous material "i" (e.g. coal, coke) consumed by the furnace (tonnes).

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

$\mathbf{ST}$ = the total annual quantity of molten raw steel produced by the furnace (tonnes).

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

$\mathbf{SL}$ = the total annual quantity of slag produced by the furnace (tonnes).

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

$\mathbf{R}$ = the annual quantity of air pollution control residue collected (tonnes).

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

$\mathbf{3.664}$ = conversion factor from tonnes of C to tonnes of CO_2.

6.A.6 **Argon-oxygen Decarburization Vessels**

Calculate the total annual CO_2 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 CO_2.

6.A.7 **Iron Production from Direct Reduction Furnace**

Calculate the total annual CO_2 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.

m = number of carbonaceous materials.

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

$\mathbf{C_{Ore}}$ = 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).

$\mathbf{RM_{k}}$ = the total annual consumed raw material “k” other than carbonaceous material and ore (tonnes).

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

$\mathbf{CAR_{i}}$ = the total annual quantity of non-biomass carbonaceous material “i” (e.g. coal, coke) consumed by the furnace (tonnes).

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

$\mathbf{I}$ = the total annual quantity of iron produced by the furnace (tonnes).

$\mathbf{C_{I}}$ = the annual weighted average carbon content of iron produced by the furnace
(tonnes C / tonnes iron).

$\mathbf{NM}$ = the total annual quantity of non-metallic material produced by the furnace (tonnes).

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

$\mathbf{R}$ = the total annual quantity of air pollution control residue collected (tonnes).

$\mathbf{C_{R}}$ = the annual weighted average annual carbon content of air pollution control residue collected or a default value of 0 (tonnes C / tonnes residue).

$\mathbf{3.664}$ = conversion factor from tonnes of C to tonnes of CO_2.

6.A.8 **Iron Production from Blast Furnace**

Calculate the total annual CO_2 emissions from the blast furnace using Equation 6-9.

Equation 6-9

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

Where:

$\mathbf{E_{CO2\,BF}}$ = the total annual quantity of emissions from blast furnace (tonnes).

$\mathbf{n}$ = number of raw materials, other than carbonaceous materials and ore.

$\mathbf{m}$ = number of carbonaceous materials.

$\mathbf{p}$ = number of flux materials.

$\mathbf{Ore}$ = the total annual quantity of iron ore or iron ore pellets fed to the furnace (tonnes).

$\mathbf{C}_{\mathbf{Ore}}$ = 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).

$\mathbf{RM}_{\mathbf{k}}$ = the total annual quantity of consumed raw material “k” other than carbonaceous material and ore (tonnes).

$\mathbf{C}_{\mathbf{RM\,k}}$ = the annual average carbon content of raw material “k”, other than carbonaceous material and ore (tonnes C / tonnes raw material).

$\mathbf{CAR}_{\mathbf{i}}$ = the total annual quantity of non-biomass carbonaceous material “i” (e.g. coal, coke) consumed by the furnace (tonnes).

$\mathbf{C}_{\mathbf{CAR\,i}}$ = the annual weighted average carbon content of non-biomass carbonaceous material “i” consumed by the furnace (tonnes C / tonnes carbonaceous material).

$\mathbf{FL}_{\mathbf{t}}$ = the total annual quantity of non-biomass flux material “t” (e.g. limestone, dolomite, bentonite) charged to the furnace (tonnes).

$\mathbf{C}_{\mathbf{FL\,t}}$ = the annual weighted average carbon content of non-biomass flux material “t” charged to the furnace (tonnes C / flux material).

$\mathbf{I}$ = the total annual quantity of iron produced by the furnace (tonnes).

$\mathbf{C}_{\mathbf{I}}$ = the annual weighted average carbon content of iron produced by the furnace (tonnes C / tonnes iron).

$\mathbf{NM}$ = the total annual quantity of non-metallic material produced by the furnace (tonnes).

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

$\mathbf{BG}$ = the total annual quantity of blast furnace gas transferred off-site (tonnes).

$\mathbf{C}_{\mathbf{BG}}$ = the annual weighted average carbon content of blast furnace gas transferred off-site (tonnes C / tonnes blast furnace gas).

$\mathbf{R}$ = the total annual quantity of air pollution control residue collected (tonnes).

$\mathbf{C}_{\mathbf{R}}$ = the annual weighted average annual carbon content of air pollution control residue collected or a default value of 0 (tonnes C / tonnes residue).

$\mathbf{3.664}$ = conversion factor from tonnes of C to tonnes of CO_2.

6.A.9 **Molten Steel Production from Ladle Furnace**

Calculate the total annual CO_2 emissions from the ladle furnace using Equation 6-10.

Equation 6-10

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

Where:

$E_{CO2\ LF}$ = the total annual quantity of emissions from ladle furnace (tonnes).

m = number of additives.

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 "j" (e.g. limestone, dolomite, bentonite) consumed by the furnace (tonnes).

$C_{AD\ j}$ = the annual weighted average carbon content of additive material "j" 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).

Rp = 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 CO_2.

6.A.10 **CO_2 Emissions from Iron and Steel Production Using CEMS**

Persons operating a facility with installed CEMS shall calculate CO_2 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_{CO2} = the total annual quantity of CO_2 emissions from iron and steel production (tonnes) calculated by subtracting fuel combustion emissions for CO_2 as specified in Section 2 from the total annual CO_2 quantity measured using CEMS.

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

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

6.B **CO_2 Emissions from Iron and Steel Powder Production**

Calculate the total annual CO_2 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 Equation 6-12 to Equation 6-16 by mass balance. Persons operating a facility with CEMS, shall calculate the annual CO_2 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 CO_2 emissions from iron and steel powder production (tonnes).

$E_{CO2\,A}$ = the total annual quantity of CO_2 emissions from the atomization of molten cast iron (tonnes).

$E_{CO2\,D}$ = the total annual quantity of CO_2 emissions from the decarburization of iron powder (tonnes).

$E_{CO2\,SG}$ = the total annual quantity of CO_2 emissions from molten steel grading (tonnes).

$E_{CO2\,SA}$ = the total annual quantity of CO_2 emissions from steel powder annealing.

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

Calculate the total annual CO_2 emissions from the atomization of molten cast iron using Equation 6-13.

Equation 6-13

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

Where:

$E_{CO2\,A}$ = the total annual quantity of CO_2 emissions from the atomization of molten cast iron (tonnes).

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

m = number of byproducts.

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 "k" used in the process (tonnes).

$C_{M\,k}$ = the annual weighted average carbon content of other material "k" 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 "j" (tonnes).

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

3.664 = Ratio of molecular weights, CO_2 to carbon.

6.B.2 CO_2 Emissions from the Decarburization of Iron Powder

Calculate the total annual CO_2 emissions from the decarburization of iron powder using Equation 6-14.

Equation 6-14

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

Where:

$E_{CO2\,D}$ = the total annual quantity of CO_2 emissions from the decarburization of iron powder (tonnes).

m = number of byproducts.

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 "j" (tonnes).

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

3.664 = ratio of molecular weights, CO_2 to carbon.

6.B.3 **CO_2 Emissions from Steel Grading**

Calculate the total annual CO_2 emissions from steel grading using Equation 6-15.

Equation 6-15

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

Where:

$E_{CO2\,SG}$ = the total annual quantity of CO_2 emissions from steel grading (tonnes).

m = number of additives.

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 “j” used in the process (tonnes).

$C_{AD\,j}$ = the annual weighted average carbon content of additive “j” 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, CO_2 to carbon.

6.B.4 **CO_2 Emissions from Steel Powder Annealing**

Calculate the total annual CO_2 emissions from steel powder annealing using Equation 6-16.

Equation 6-16

$$E_{CO_2\,SA} = \left[(P_a \times C_{P\,a}) - (SP_p \times C_{SP\,p}) - \sum_{j=1}^{m}(BP_j \times C_{BP\,j})\right] \times 3.664$$

Where:

$E_{CO2\,SA}$ = the total annual quantity of CO_2 emissions from steel powder annealing (tonnes).

m = number of byproducts.

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

$C_{P\,a}$ = 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).

$C_{SP\,p}$ = the annual weighted average carbon content of steel powder production (tonnes C / tonnes steel powder).

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

$C_{BP\,j}$ = the annual weighted average carbon content of byproduct “j”, or a default value of 0 (tonnes C / tonnes byproduct).

3.664 = ratio of molecular weights, CO_2 to carbon.

6.B.5 **CO_2 Emissions from Iron and Steel Powder Production Using CEMS**

Persons operating a facility with installed CEMS shall calculate CO_2 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 CO_2 emissions from iron and steel powder production (tonnes) calculated by subtracting fuel combustion emissions for CO_2 as specified in Section 2, from the total annual CO_2 quantity measured using CEMS.

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

$E_{CO2\,FC}$ = the total annual CO_2 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 in 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, 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 ±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:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

$\mathbf{QS}_{\mathbf{ACT}}$ = Quantity of actual samples or measurements obtained by the person.

$\mathbf{QS}_{\mathbf{REQUIRED}}$ = 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 CO_2 concentration, stack gas flow rate, fuel flow rate, HHV, 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

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

Where:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

$\mathbf{HS}_{\mathbf{ACT}}$ = Quantity of actual samples or measurements obtained by the person.

$\mathbf{HS}_{\mathbf{REQUIRED}}$ = Quantity of samples or measurements required for Section 6.

7 QUANTIFICATION METHODS FOR ELECTRICITY AND HEAT GENERATION

An electricity and/or heat generating unit is any device that combusts solid, liquid, or gaseous fuel for the purpose of producing electricity and/or useful heat or steam either for sale or for use onsite. This does not include portable or emergency generators with a nameplate capacity less than 50 kW or that generate less than 2 MWh in the reporting year.

Quantify emissions of CO_2, CH_4, and N_2O for each generating unit of electric power, steam, heated air and water.

For generating units without individual meters (or no dedicated tank in the case of diesel and heavy oil) and no CEMS in place, the facility may use a common meter or tank to disaggregate emissions for each unit using an engineering estimation approach that accounts for total emissions, and operating hours and combustion efficiency of each individual unit.

For diesel generating facilities in non-integrated remote areas (those facilities not connected to the North American power grid), allocate diesel fuel to each generating unit from a common tank based on the proportion of MWh energy delivered by each unit.

7.A CO_2 Emissions from Electricity and Heat Generation

Estimate CO_2 emissions from fuel combustion using methods outlined in Section 2: Quantification Methods for Fuel Combustion and Flaring for electricity and/or heat generation (or in the case of fossil fuel electric power generation facilities - NAICS 221112, for each electricity generating unit), with some specific references presented in section 7.A(1) to 7.A(5).

(1) Non-variable fuels. For generating units combusting non-variable fuels (Table 2-1 and Table 2-2) use quantification methods outlined in Section 2.A.1.

(2) Variable fuels. For generating units combusting variable fuels, use quantification methods outlined in Section 2.A.2.

(3) Biomass fuels. For generating units combusting biomass fuels, use quantification methods outlined in Section 2.A.1 or 2.A.2.d, as applicable.

(4) CEMS. Determine CO_2 emissions using quantification methods outlined in Section 2.A.3.

(5) For generating units that combust more than one type of fuel, calculate CO_2 emissions as follows.

  (A) For units burning only fossil fuels, determine CO_2 emissions using one of the following methods:

    (i) A CEMS in accordance with Section 2.A.3. Operators using this method need not report emissions separately for each fossil fuel.

    (ii) For units not equipped with a CEMS, calculate the CO_2 emissions separately for each fuel type (refer to Key Notes box in Section 0) using the methods specified in paragraphs (1), (2) and (3) of this section.

(B) For generating units burning biomass-derived fuel with a fossil fuel, determine CO_2 emissions using one of the following methods:

(i) A CEMS in accordance with Section 2.A.3. Determine the portion of the total CO_2 emissions attributable to the biomass-derived fuel and portion of the total CO_2 emissions attributable to the fossil fuel using the methods specified in 2.A.4.

(ii) For units not equipped with a CEMS, calculate the CO_2 emissions separately for each fuel type, as specified in Section 2, using the methods specified in paragraphs (1), (2) and (3) of this section.

7.B CH_4 and N_2O Emissions from Electricity and Heat Generation

Calculate the annual CH_4 and N_2O emissions of electricity and/or heat generating units using the methods specified in Section 2.B.

7.C CO_2 Emissions from Acid Gas Scrubbing

Calculate the annual CO_2 emissions from electricity generating units that use acid gas scrubbers, or add an acid gas reagent to the combustion unit, using Equation 7-1, if these CO_2 emissions are not already determined using a CEMS.

Equation 7-1: Acid Gas Scrubbing

$$\boldsymbol{CO_2} = \boldsymbol{S} \times \boldsymbol{R} \times \left(\frac{\boldsymbol{44}}{\boldsymbol{Sorbent_{MW}}}\right)$$

Where:

CO_2 = CO_2 emitted from sorbent for the report year (tonnes).

S = Limestone or other sorbent used in the report year (tonnes).

R = Ratio of moles of CO_2 released upon capture of one mole of acid gas.

44 = Molecular weight of carbon dioxide.

$Sorbent_{MW}$ = Molecular weight of sorbent (if calcium carbonate, 100).

7.D **Sampling, Analysis, and Measurement Requirements**

(1) CO_2, CH_4 and N_2O Emissions from Fuel Combustion. Operators using CEMS to estimate CO_2 emissions from fuel combustion shall comply with the requirements in section 2.A.3. Operators using methods other than CEMS shall comply with the applicable fuel sampling, fuel consumption monitoring, heat content monitoring, carbon content monitoring, and calculation methods specified in section 2.D.

(2) CO_2 Emissions from Acid Gas Scrubbing. Measure the amount of limestone or other sorbent used during the reporting year in electricity generating units that use acid gas scrubbers or add an acid gas reagent to the combustion unit.

7.E **Procedures for Estimating Missing Data**

Whenever a quality-assured value of a required parameter is unavailable (e.g., a CEM system malfunction during unit operations or no required fuel sample taken), a substitute data value for the missing parameter shall be used in the emission calculations.

When data related to sampling is unavailable, use the prescribed methods in Section 7.D to re-analyze the original sample, a backup sample or the replacement sample for the same measurement and sampling period; if this is not possible, the missing data should be substituted using the following approach.

(1) For missing sampled or analyzed data (e.g. carbon content, temperature, pressure), determine the sampling or measurement rate using Equation 7-2 and, replace the missing data as described in paragraphs (A) through (C) follows:

Equation 7-2: Sampling Rate

$$\boldsymbol{R} = \frac{\boldsymbol{Q_{SACT}}}{\boldsymbol{Q_{SREQUIRED}}}$$

Where:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

$\mathbf{Q_{S\ ACT}}$ = Quantity of actual samples or measurements obtained by the facility operator.

$\mathbf{Q_{S\ REQUIRED}}$ = Quantity of samples or measurements required.

(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.

(2) For missing data concerning a quantity of raw materials (e.g. sorbent), substitute the data based on the best available estimate of that parameter using all available process data. Document and retain records of the procedures used for all such estimates.

(3) For missing parameters regarding CEM systems, determine the replacement data using 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) or use the procedure described in paragraph (1) above.

8 Quantification Methods for Ammonia Production

Ammonia production comprises the following process units:

(a) Ammonia manufacturing processes in which ammonia is manufactured from a fossil-based feedstock produced via steam reforming of a hydrocarbon.

(b) Ammonia manufacturing processes in which ammonia is manufactured through the gasification of solid and liquid raw material.

8.A CO_2 Emissions from Ammonia Production

Calculate and report the annual process CO_2 emissions from ammonia manufacturing process units using the procedures in either paragraph (1) or (2) of this section.

(1) Calculate and report under this subpart the process CO_2 emissions using Equation 8-1 if operating and maintaining a CEMS.

Equation 8-1: Ammonia Production—CEMS

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

Where:

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

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

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

(2) Calculate and report process CO_2 emissions using the procedures in paragraphs (2)(A) through (2)(F) of this section for gaseous feedstock, liquid feedstock, or solid feedstock, as applicable.

(A) **Gaseous feedstock**. Calculate the CO_2 process emissions from gaseous feedstock according to Equation 8-2 of this section:

Equation 8-2: Gaseous Feedstock

$$CO_{2,G,k} = \left(\sum_{m=1}^{12} 3.664 \times Fdstk_{m,k} \times CC_m \times \frac{MW}{MVC}\right) \times 10^{-3}$$

Where:

$CO_{2,G,k}$ = Annual CO_2 emissions arising from gaseous feedstock consumption in processing unit "k" (tonnes).

$Fdstk_{m,k}$ = Volume of the gaseous feedstock used in month "m" (m^3 of feedstock) in processing unit "k" at reference temperature and pressure conditions as used by the facility. If a mass flow meter is used, measure the feedstock used in the month "m" as kg feedstock and replace the term "MW/MVC" with "1".

CC_m = Carbon content of the gaseous feedstock, for month *"m"*, in processing unit "k"(kg C per kg of feedstock), determined according to section 8.B(3).

MW = Molecular weight of the gaseous feedstock (kg/kg-mole).

MVC = Molar volume conversion factor at the same reference conditions as the above $Fdstk_{n,k}$ (m^3/kg-mole).
= 8.3145 * [273.16 + reference temperature in °C] / [reference pressure in kilopascal].

3.664 = Ratio of molecular weights, CO_2 to carbon.

10^{-3} = Conversion factor from kg to tonnes.

(B) **Liquid feedstock**. You must calculate, from each ammonia manufacturing unit, the CO_2 process emissions from liquid feedstock according to Equation 8-3 of this section:

Equation 8-3: Liquid Feedstock

$$CO_{2,L,k} = \left(\sum_{m=1}^{12} 3.664 \times Fdstk_{m,k} \times CC_m\right) \times 10^{-3}$$

Where:

$CO_{2,L,k}$ = Annual CO_2 emissions arising from liquid feedstock consumption in processing unit "k" (tonnes).

$Fdstk_{m,k}$ = Volume of the liquid feedstock used in month "m" in processing unit "k" (kilolitres of feedstock). If a mass flow meter is used, measure the feedstock used in month "m", processing unit "k", as kg of feedstock and measure the carbon content of feedstock in kg C per kg of feedstock.

CC_m = Carbon content of the liquid feedstock, for month "m" as determined according to section 8.B(3) (kg of C per kilolitre of feedstock when feedstock consumption is measured in kilolitres or kg of C per kg of feedstock when feedstock consumption is measured in kg).

3.664 = Ratio of molecular weights, CO_2 to carbon.

10^{-3} = Conversion factor from kg to tonnes.

(C) **Solid feedstock**. You must calculate, from each ammonia manufacturing unit "k", the CO_2 process emissions from solid feedstock according to Equation 8-4 of this section:

Equation 8-4: Solid Feedstock

$$CO_{2,S,k} = \left(\sum_{m=1}^{12} 3.664 \times Fdstk_{m,k} \times CC_m\right) \times 10^{-3}$$

Where:

$CO_{2,S,k}$ = Annual CO_2 emissions arising from solid feedstock consumption in processing unit “k” (tonnes).

$Fdstk_{m,k}$ = Mass of the solid feedstock used in month “m” in processing unit “k” (kg of feedstock).

CC_m = Carbon content of the solid feedstock, for month “m”, processing unit “k” (kg C per kg of feedstock), determined according to section 8.B(3).

3.664 = Ratio of molecular weights, CO_2 to carbon.

10^{-3} = Conversion factor from kg to tonnes.

(D) You must calculate the annual process CO_2 emissions from each ammonia processing unit “*k*” at your facility summing emissions, as applicable from Equation 8-2, Equation 8-3, and Equation 8-4 of this section using Equation 8-5.

Equation 8-5: Total Emissions per Unit

$$E_{CO2k} = CO_{2,G} + CO_{2,S} + CO_{2,L}$$

Where:

E_{CO2k} = Annual CO_2 emissions from each ammonia processing unit “*k*” (tonnes).

$E_{CO2,G}$ = Annual CO_2 emissions arising from solid feedstock consumption (tonnes).

$E_{CO2,S}$ = Annual CO_2 emissions arising from gaseous feedstock consumption (tonnes).

$E_{CO2,L}$ = Annual CO_2 emissions arising from liquid feedstock consumption (tonnes).

(E) You must determine the combined CO_2 emissions from all ammonia processing units at your facility using Equation 8-6 of this section.

Equation 8-6: Facility Emissions

$$CO_2 = \sum_{k=1}^{n} E_{CO2k} - CO_{2urea}$$

Where:

CO_2 = Annual combined CO_2 emissions from all ammonia processing units (tonnes).

E_{CO2k} = Annual CO_2 emissions from each ammonia processing unit "*k*" (tonnes).

n = Total number of ammonia processing units.

CO_{2urea} = Annual CO_2 consumed in urea production (tonnes) using Equation 8-7.

(F) If applicable, determine the CO_2 consumed in the production of urea using Equation 8-7.

Equation 8-7: Urea

$$CO_{2urea} = M_{urea} \times \frac{MW_{CO2}}{MW_{urea}}$$

Where:

CO_{2urea} = Annual CO_2 consumed in urea production (tonnes)

M_{urea} = Mass of urea produced (tonnes)

MW_{CO2} = Molecular weight of CO_2 (tonnes/mol)

MW_{urea} = Molecular weight of urea (tonnes/mol)

8.B **Monitoring and QA/QC Requirements**

(1) Continuously measure the quantity of gaseous or liquid feedstock consumed using a flow meter. The quantity of solid feedstock consumed can be obtained from company records and aggregated on a monthly basis.

(2) Document the procedures used to ensure the accuracy of the estimates of feedstock consumption.

(3) Determine monthly carbon contents and the average molecular weight of each feedstock consumed from reports from your supplier(s). As an alternative to using supplier information on carbon contents, you can also collect a sample of each feedstock on a monthly basis and analyze the carbon content and molecular weight of the fuel using any of the following methods, as appropriate, listed in paragraphs (3)(A) through (3)(H) of this section, as applicable.

(A) ASTM D1945-03 Standard Test Method for Analysis of Natural Gas by Gas Chromatography.

(B) ASTM D1946-90 (Reapproved 2006) Standard Practice for Analysis of Reformed Gas by Gas Chromatography.

(C) ASTM D2502-04 (Reapproved 2002) Standard Test Method for Estimation of Mean Relative Molecular Mass of Petroleum Oils from Viscosity Measurements.

(D) ASTM D2503-92 (Reapproved 2007) Standard Test Method for Relative Molecular Mass (Molecular Weight) of Hydrocarbons by Thermoelectric Measurement of Vapor Pressure

(E) ASTM D3238-95 (Reapproved 2005) Standard Test Method for Calculation of Carbon Distribution and Structural Group Analysis of Petroleum Oils by the n-d-M Method.

(F) ASTM D5291-02 (Reapproved 2007) Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants.

(G) ASTM D3176-89 (Reapproved 2002) Standard Practice for Ultimate Analysis of Coal and Coke.

(H) ASTM D5373-08 Standard Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Laboratory Samples of Coal.

(4) If CO_2 from ammonia production is used to produce urea at the same facility, you must determine the quantity of urea produced using methods or plant instruments used for accounting purposes (such as sales records). Document the procedures used to ensure the accuracy of the estimates of urea produced.

8.C **Procedures for Estimating Missing Data**

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

When data related to sampling is unavailable, use the prescribed methods in Section 8.B to re-analyze the original sample, a backup sample or the replacement sample for the same measurement and sampling period; if this is not possible, the missing data should be substituted using the following approach.

(1) For missing sampled or analyzed data (e.g. carbon content, temperature, pressure), determine the sampling or measurement rate using Equation 8-8 and, replace the missing data as described in paragraphs (A) through (C) follows:

Equation 8-8: Sampling Rate

$$R = \frac{Q_{SACT}}{Q_{SREQUIRED}}$$

Where:

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

$Q_{S\ ACT}$ = Quantity of actual samples or measurements obtained by the facility operator.

$Q_{S\ REQUIRED}$ = Quantity of samples or measurements required.

(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.

(2) For missing data concerning a quantity of raw materials (e.g. feedstock consumption), substitute the data based on the best available estimate of that parameter using all available process data. Document and retain records of the procedures used for all such estimates.

(3) For missing parameters regarding CEM systems, determine the replacement data using 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) or use the procedure described in paragraph (1) above.

9 Quantification Methods for Nitric Acid Production

A nitric acid production facility uses one or more trains to produce weak nitric acid (30 to 70 percent in strength), through the catalytic oxidation of ammonia followed by the absorption of nitrogen oxides by water. The absorber tail gas contains unabsorbed nitrogen oxides, including nitrous oxide, emissions of which may be reduced via abatement systems.

9.A N_2O Emissions from Nitric Acid Production

Determine annual N_2O process emissions from each nitric acid train according to paragraphs (1), (2) or (3) of this section.

(1) Calculate and report the process N_2O emissions by operating and maintaining CEMS according to the European Commission *Guidance Document – The Monitoring and Reporting Regulation – Continuous Emissions Monitoring Systems (CEMS),* 2017. The CEMS method is a continuous direct measurement of stack flow and N_2O concentrations, which is used to determine the mass flow of N_2O emissions in the stack.

   (A) For each nitric acid production train, calculate N_2O emissions from a CEMS in the reporting period using Equation 9-1. Add N_2O emissions calculated from each train to calculate the total N_2O emissions.

Equation 9-1: N_2O CEMS Calculation

$$N_2O_p = \sum_{t=1}^{T}\left[vel_{s,t} \times Area_s \times C_{N2O,t} \times \left(\frac{P_{act,t} \times 288.15}{101.325 \times T_{act,t}}\right)\right] \times \frac{MW_{N2O}}{23.645} \times 0.001$$

Where:

N_2O_p = N_2O mass emissions from nitric acid production in reporting period, *p* (tonnes N_2O).

t = CEMS data reporting interval (hour).

T = Number of CEMS data reporting intervals in reporting period (T= 8,760 hours for a non-leap year annual reporting period).

Vel_s = Stack gas velocity (m/h), measured by continuous ultrasonic flow meter.

$Area_s$ = Stack cross-sectional area (m^2).

$C_{N2O,t}$ = N_2O concentration (wet basis) of stack gas ($kmol_{N2O}/kmol_{GAS}$), measured by in-situ gas analyzer; (If analyzer provides N_2O concentration in ppmv, then $C_{N2O,t}$ = ppmv · 10^6).

MW_{N2O} = Molecular weight of N_2O = 44.01 kg/kmol.

P_{act} = Measured actual pressure of stack gas volume (kPa).

T_{act} = Measured actual temperature of stack gas volume (K).

288.15 = Standard temperature (K).

101.325 = Standard pressure (kPa).

23.645 = Standard molar volume at standard conditions.

0.001 = Mass conversion factor: tonnes per kg.

(2) For systems with abatement downtime: The N_2O Emission Factor Method is used for acid trains that do not measure N_2O emissions directly using a CEMS and had abatement downtime when the NO_x abatement system was bypassed for a certain period of time during the reporting period. This method requires an annual measurement of N_2O concentration in the NO_x Absorber tail gas stream (before the NO_x abatement system) and N_2O concentration in the final stack gas stream (after the NO_x abatement system). Use a site-specific emission factor and production data according to paragraphs (A) through (H) of this section.

(A) For each nitric acid train, calculate N_2O emissions using Equation 9-2. Add N2O emissions calculated from each train to calculate the total N2O emissions.

Equation 9-2: Nitric Acid Emissions

$$N_2O_p = m_{pNA} \times EF_{N2O,NAO} \times \left(1 - (DF_{N2O} \times AF_{N2O})\right) \times 0.001$$

Where:

N_2O_p = N_2O mass emissions from nitric acid production in reporting period, p (tonnes N_2O).

m_{PNA} = Production mass of nitric acid (100% basis), (tonnes nitric acid product) in reporting period.

DF_{N2O} = Average destruction efficiency of NO_x abatement system (%), determined by either:

1) Manufacturer’s specifications;
2) Documented engineering estimates based on process knowledge; or
3) Calculated using the direct measurement as shown in Equation 9-3 if the test personel can safely access the upstream of the NO_x abatement system.

$EF_{N2O,NAO}$ = Average N_2O emission factor for NO_x Absorber Outlet (NAO) (kg N_2O per tonne nitric acid), as defined in Equation 9-4.

AF_{N2O} = NO_x abatement system operating fraction (%) in the reporting period, as defined in Equation 9-5.

0.001 = Mass conversion factor (tonnes/kg).

(B) The destruction efficiency can be calculated using Equation 9-3:

Equation 9-3: Destruction Efficiency

$$DF_{N2O} = \frac{(N_2O_{NAO} \times Q_{NAO}) - (N_2O_{NAS} \times Q_{NAS})}{N_2O_{NAO} \times Q_{NAO}} \times 100\%$$

Where:

DF_{N2O} = Average abatement system destruction efficiency (%) in reporting period.

N_2O_{NAO} = N_2O concentration (ppmv) from the NO_x Absorber Outlet (NAO).

Q_{NAO} = Flow rates (m^3/h) from the NO_x Absorber Outlet (NAO).

N_2O_{NAS} = N_2O concentration (ppmv) from the nitric acid stack (NAS).

Q_{NAS} = Flow rates (m^3/h) from the nitric acid stack (NAS).

(C) The train-specific average N_2O emissions factor is calculated based on direct measurement of N_2O concentration in the NO_x Absorber Outlet (NAO) and using Equation 9-4:

Equation 9-4: Site-specific Emission Factor

$$EF_{N2O,NAO} = \frac{\sum_{i=1}^{N} \frac{Q_{NAO,i} \times C_{N2O,NAO,i}}{PR_{NA,i}} \times 1.861 \times 10^{-6}}{N}$$

Where:

$EF_{N2O,NAO}$ = Average N_2O emission factor for NO_x Absorber Outlet (kg N_2O per tonne nitric acid).

N = Number of N_2O measurement test runs during stack test.

$Q_{NAO,i}$ = Volumetric flow rate of effluent gas at NO_x Absorber Outlet during test run “i” (m^3/h) at 15°C & 1 atm.

$C_{N2O,NAO,i}$ = Measured N_2O concentration at NO_x Absorber Outlet in test run “i” (ppmv N_2O);

$PR_{NA,i}$ = Measured nitric acid production rate during test run “i” (tonnes nitric acid per hour).

1.861×10^{-6} = N_2O Density conversion factor (kg/m^3·ppmv-1; at 15°C & 1 atm).

(D) Determine the abatement factor for each N_2O abatement technology. This factor corrects the N_2O equation for any periods during the year when the N_2O destruction by the NO_x abatement system is not applied. For operations having 100% NO_x abatement uptime, the default AF_{N2O} = 1.0. The abatement factor is calculated for each nitric acid train according to Equation 9-5 of this section.

Equation 9-5: Abatement Factor

$$AF_{N2O} = \frac{PR_{NA,Abate}}{PR_{NA,Total}}$$

Where:

AF_{N2O} = NO_x abatement system operating fraction (%) in the reporting period.

$PR_{NA,Abate}$ = Nitric acid production when NO_x abatement system is operating (tonnes nitric acid) in the reporting period.

$PR_{NA,Total}$ = Total nitric acid production (tonnes nitric acid) in the reporting period.

(E) The nitric acid production for the reporting period and the monthly nitric acid production when the N_2O abatement system is operating must be determined from measurement systems used for accounting purposes.

(F) Stack tests to determine $EF_{N2O,NAO}$ must be conducted at least once per year. A minimum of three test runs for each stack test and hourly measurement of nitric acid production are required during the stack test and the results averaged. Conduct the performance tests for determining $EF_{N2O,NAO}$ when nitric acid production process has changed or abatement equipment is installed.

(G) If the NO_x abatement system destruction efficiency is determined by direct measurement, tests must occur at least once every three years, using the same N_2O concentration methods outlined above.

(H) For the calculation of AF_{N2O}, the operating time of the NO_x abatement system during the reporting period must be determined hourly.

(3) N_2O Emission Factor Method for direct stack test: The N_2O Emission Factor Method is used for nitric acid production where NO_x abatement systems are integrated within the operating process and cannot be bypassed. A site-specific emission factor is developed based on N_2O emissions by stack testing on the final Nitric Acid Stack (NAS) and production data according to paragraphs (A) through (E) of this section.

(A) For each nitric acid train, calculate N_2O emissions using Equation 9-6. Add N_2O emissions calculated from each train to calculate the total N_2O emissions.

Equation 9-6: Nitric Acid Train Emissions

$$N_2O_p = m_{pNA} \times EF_{N2O,NAS} \times 0.001$$

Where:

N_2O_p = N_2O mass emissions from nitric acid production in the reporting period, *p* (tonnes N_2O).

m_{PNA} = Production mass of nitric acid (100% basis) (tonnes nitric acid product) in reporting period.

$EF_{N2O,NAS}$ = Average N_2O emission factor (kg N_2O per tonne nitric acid) for the final Nitric Acid Stack (NAS) based on the direct stack testing of the final N_2O emission stack and calculated in Equation 9-7.

0.001 = Mass conversion factor: tonnes per kg.

(B) Determine an N_2O emissions factor to use in Equation 9-6 of this section. Using the results of the performance test, calculate an average site-specific emission factor for each nitric acid train "t" according to Equation 9-7:

Equation 9-7: Site-specific Emission Factor

$$EF_{N2O,NAS} = \frac{\sum_{i=1}^{N} \frac{Q_{NAS,i} \times C_{N2O,NAS,i}}{PR_{NA,i}} \times 1.861 \times 10^{-6}}{N}$$

Where:

$EF_{N2O,NAS}$ = Average N_2O emission factor based on final Nitric Acid Stack (NAS) (kg N_2O per tonne nitric acid) in the reporting period.

N = Number of N_2O measurement test runs during stack test;

$Q_{NAS,i}$ = Volumetric flow rate of effluent gas at final NAS during test run "i" (m^3/h) at 15°C & 1 atm.

$C_{N2O,NAS,i}$ = Measured N_2O concentration at NAS in test run "i" (ppmv N_2O);

$PR_{NA,i}$ = Measured nitric acid production rate during test run "i" (tonnes nitric acid per hour).

$1.861x10^{-6}$ = N_2O Density conversion factor (kg/m^3·ppmv-1; at 15°C & 1 atm).

(C) The nitric acid production for reporting period and the monthly nitric acid production when the N_2O abatement system is operating must be determined from measurement systems used for accounting purposes.

(D) Stack tests to determine $EF_{N2O,NAS}$ must be conducted at least once per year. A minimum of three test runs for each stack test and hourly measurement of nitric acid production are required during the stack test and the results averaged.

(E) The performance test for determining the $EF_{N2O,NAS}$ must be conducted when nitric acid production process has changed including abatement equipment installation.

9.B **Sampling, Analysis, and Measurement Requirements**

(1) Conduct a new performance test and calculate a new site-specific emissions factor according to a test plan annually and when your nitric acid production process is changed, specifically when abatement equipment is installed.

(2) The NO_x CEMS must comply with all relevant requirements of the European Commission *Guidance Document – The Monitoring and Reporting Regulation – Continuous Emissions Monitoring Systems (CEMS)*, 2017.

(3) Measure the N_2O concentration during the performance test using one of the methods in paragraphs (3)(A) or (3)(B) of this section.

  (A) EPA Method 320 at 40 CFR part 63, appendix A, Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive Fourier Transform Infrared (FTIR) Spectroscopy.

  (B) ASTM D6348-03 Standard Test Method for Determination of Gaseous Compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy.

(4) Measure stack gas temperature and pressure continuously using stack instruments.

(5) Determine the production rate(s) (100 percent basis) from each nitric acid train during the performance test according to paragraphs (5)(A) or (5)(B) of this section.

  (A) Direct measurement of production and concentration (such as using flow meters or weigh scales, for production and concentration measurements).

  (B) Existing plant procedures used for accounting purposes (i.e. dedicated tank-level and acid concentration measurements).

(6) Conduct all performance tests in conjunction with the applicable methods. For each test, the facility must prepare an emission factor determination report that must include the items in paragraphs (6)(A) through (6)(C) of this section.

  (A) Analysis of samples, determination of emissions, and raw data.

  (B) All information and data used to derive the emissions factor(s).

  (C) The production rate during each test and how it was determined.

(7) Determine the annual nitric acid production and the annual nitric acid production during which N_2O abatement technology is operating for each train by summing the respective monthly nitric acid production quantities.

9.C **Procedures for Estimating Missing Data**

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

When data related to sampling is unavailable, use the prescribed methods in Section 9.B to re-analyze the original sample, a backup sample or the replacement sample for the same measurement and sampling period; if this is not possible, the missing data should be substituted using the following approach.

(1) For missing sampled or analyzed data (e.g. carbon content, temperature, pressure), determine the sampling or measurement rate using Equation 9-8 and, replace the missing data as described in paragraphs (A) through (C) follows:

Equation 9-8: Sampling Rate

$$\boldsymbol{R} = \frac{\boldsymbol{Q_{SACT}}}{\boldsymbol{Q_{SREQUIRED}}}$$

Where:

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

$\mathbf{Q_{S\,ACT}}$ = Quantity of actual samples or measurements obtained by the facility operator.

$\mathbf{Q_{S\,REQUIRED}}$ = Quantity of samples or measurements required.

(A) If R ≥ 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 ≤ 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.

(2) For missing data concerning a quantity of raw materials (e.g. nitric acid production), substitute the data based on the best available estimate of that parameter using all available process data. Document and retain records of the procedures used for all such estimates.

(3) For missing parameters regarding CEM systems, determine the replacement data using 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) or the European Commission *Guidance Document – The Monitoring and Reporting Regulation – Continuous Emissions Monitoring Systems (CEMS),* 2017. Alternatively, use the procedure described in paragraph (1) above.

10 Quantification Methods for Hydrogen Production

Hydrogen production occurs at bitumen upgraders, petroleum refineries, chemical plants and fertilizer plants, where needed for purification or synthesis of substances. In addition, stand-alone industrial gas producers also manufacture hydrogen. The produced hydrogen can be both, used on-site and transferred off-site.

For ammonia production, the quantification methods in Section 8 incorporate emissions associated with hydrogen production.

10.A CO_2 Emissions from Hydrogen Production

Two main processes can transform hydrocarbons into hydrogen gas, both of which result in CO_2 emissions as a by-product:

(i) steam reforming of methane, followed by shift reactions; or

(ii) partial oxidation of hydrocarbons into synthesis gas ("syngas")

As per IPCC guidelines[6], if the hydrogen production is associated with production or processing of fossil fuels (e.g. at a petroleum refinery, upgrading operation), then the CO_2 emissions are attributed to the energy sector and categorised as fugitive - venting emissions source category. Otherwise, CO_2 emissions from hydrogen production are attributed to the appropriate key category in the Industrial Process and Product Use sector, example Ammonia. Note that this is solely related to allocation by source category; emissions are not quantified or treated in any different manner otherwise.

If the syngas produced from partial oxidation is combusted to generate useful heat or work, attribute the GHG emissions from that combustion to the fuel combustion emissions source category. Otherwise, attribute emissions from syngas combustion to the fugitive - flaring emissions source category.

Calculate annual CO_2 emissions from hydrogen production as specified in paragraph (1) or (2) of this section:

(1) Determine hydrogen production CO_2 emissions using Equation 10-1, if operating and maintaining a CEMS.

Equation 10-1: Hydrogen Production—CEMS

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

Where:

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

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[6] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Chapter 4: Fugitive Emissions, p. 4.33 (https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf)

$\mathbf{E}_{\mathbf{CO2\ CEMS}}$ = the total annual quantity of CO_2 emissions from CEMS including fuel combustion and hydrogen production emissions (tonnes).

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

(2) Determine CO_2 emissions from hydrogen production using the feedstock methodology specified by Equation 10-2. This methodology uses the mass or volume and the carbon content of the feedstock.

Equation 10-2: Feedstock Methodology

$$CO_2 = \sum_{m=1}^{12} Feed_m \times CC_m \times \frac{MW}{MVC} \times \frac{44}{12} \times 10^{-3} - R_{CO_2}$$

Where:

$\mathbf{CO_2}$ = annual CO_2 emissions from hydrogen production (tonnes)

$\mathbf{Feed}_{\mathrm{m}}$ = consumption of feedstock in month "**m**" (solids in kilograms, liquids in litres, and gases in cubic metres, at 15°C and 101.325 kPa, measured as specified in 10.B., or specific to petroleum refineries at dry reference conditions (25°C, 101.325 kPa and 0% moisture (dRm^3/period), if applicable). If a mass flow meter is used, then the units for liquids and gases are kilograms and set "MW/MVC" = 1.

$\mathbf{CC}_{\mathrm{m}}$ = weighted average carbon content in month "**m**" (kilograms of carbon per unit of fuel and feedstock), measured as specified in 2.D.4.

MW = Molecular weight of the gaseous fuel and feedstock (kg/kg-mole)

MVC = Molar volume conversion factor at the same reference conditions as the above Feed$_m$ (m^3/kg-mole). MVC = 8.3145 * [273.16 + reference temperature in °C] / [reference pressure in kilopascal].

44 / 12 = ratio of molecular weights, CO_2 to carbon.

$\mathbf{R}_{\mathbf{CO2}}$ = CO_2 recovered (tonnes) for downstream use in other manufacturing industries, for on-site use or for sending to permanent storage.

$\mathbf{10^{-3}}$ = conversion factor from kilograms to tonnes.

10.B **Sampling, Analysis and Measurement Requirements**

Measure consumption of feedstock and hydrogen production daily. Conduct sampling and analysis of feedstock, or use results received from fuel suppliers, at the following frequencies:

(1) Monthly for natural gas feedstock not mixed with another feedstock prior to consumption.

(2) Daily for all other feedstock, with a weighted average calculated for each month.

Collect samples at a location in the feedstock handling system that is representative of the feedstock consumed in the hydrogen production process.

Quantify the carbon content of the feedstock, as applicable, as specified in Section 2.D.4—"Fuel carbon content monitoring requirements".

10.C **Procedures for Estimating Missing Data**

Whenever a quality-assured value of a required parameter is unavailable (e.g., a CEM system malfunction during unit operations or no required fuel sample taken), a substitute data value for the missing parameter shall be used in the emission calculations.

When data related to sampling is unavailable, use the prescribed methods in Section 10.B to re-analyze the original sample, a backup sample or the replacement sample for the same measurement and sampling period; if this is not possible, the missing data should be substituted using the following approach.

(1) For missing sampled or analyzed data (e.g. carbon content, temperature, pressure), determine the sampling or measurement rate using Equation 10-3 and, replace the missing data as described in paragraphs (A) through (C) follows:

Equation 10-3: Sampling Rate

$$R = \frac{Q_{SACT}}{Q_{SREQUIRED}}$$

Where:

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

$Q_{S\ ACT}$ = Quantity of actual samples or measurements obtained by the facility operator.

$Q_{S\ REQUIRED}$ = Quantity of samples or measurements required.

- (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.

(2) For missing data concerning a quantity of raw materials (e.g. gas flow rate, volume of hydrogen), substitute the data based on the best available estimate of that parameter using all available process data. Document and retain records of the procedures used for all such estimates.

(3) For missing parameters regarding CEM systems, determine the replacement data using 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) or use the procedure described in paragraph (1) above.

11 QUANTIFICATION METHODS FOR PETROLEUM REFINERIES

This section provides quantification methods for the following sources at petroleum refineries: catalytic cracking units; fluid coking units; delayed coking units; catalytic reforming units; coke calcining units; asphalt blowing operations; blowdown systems; storage tanks; process equipment components (compressors, pumps, valves, pressure relief devices, flanges, and connectors) in gas service; marine vessel, barge, tanker truck, and similar loading operations; and sulphur recovery plants.

For crude oil charged to refineries, use sampling, analysis and measurement methods for liquid fuels in Section 2.D to report volumes and weighted average annual, HHV and carbon content.

Methodologies for estimating emissions from fuel combustion and flares, and hydrogen plants (i.e., hydrogen plants that are owned or under the direct control of the refinery owner and operator), are covered in Section 2, and Section 10, of this document, respectively.

Calculate GHG emissions using the methods in Sections 11.A through 11.M. If a CEMS measures CO_2 emissions from process vents, asphalt production, sulphur recovery, or other control devices then the operator may calculate the CO_2 emissions from these processes using the CEMS as specified in Section 2.A.3.

When the flue gas from two or more processes or stationary combustion sources are discharged through a common stack or duct before exiting to the atmosphere and if CEMS as specified in 2.A.3 are used to continuously monitor the CO_2 emissions, report the combined emissions from the processes or stationary combustion sources sharing the common stack or duct. This is in lieu of separately reporting the GHG emission from individual processes or stationary combustion sources.

11.A Emissions from Catalyst Regeneration

Calculate the CO_2, CH_4, and N_2O process emissions resulting from catalyst regeneration using the methods in paragraph (1), (2) and (3), respectively.

CO_2 Emissions

(1) Use the methods in paragraphs (A) through (C). For units equipped with CEMS, calculate fugitive CO_2 emissions resulting from catalyst regeneration using CEMS in accordance with 2.A.3.

(A) Calculate fugitive CO_2 emissions from the continuous regeneration of catalyst material in fluid catalytic cracking units (FCCU) and fluid cokers using paragraphs (i) to (iii) or alternatively using paragraph (iv) of this section.

(i) Calculate fugitive CO_2 emissions:

Equation 11-1: Continuous Regeneration Emissions

$$CO_2 = \sum_{i=1}^{n} CR_i \times CF \times 3.664 \times 10^{-3}$$

Where:

CO_2 = Annual mass of CO_2 emissions (tonnes).

n = Number of hours of operation in the reporting year.

CR_i = Hourly mass of coke burn, for period i (kg).

CF = Carbon fraction in coke burned, measured as specified in Section 11.N.1 and 2.D.4 or by engineering estimation, refer to Appendix A for detail.

3.664 = Ratio of molecular weights, CO_2 to carbon.

10^{-3} = Conversion factor from kilograms to tonnes.

(ii) Calculate the hourly mass of coke burn using Equation 11-2 or from facility measurement or engineering estimate:

Equation 11-2: Hourly Coke Burn

$$CR_i = K_1 Q_r \times (\%CO_2 + \%CO) + K_2 Q_a - K_3 Q_r \times \left[\frac{\%CO}{2} + \%CO_2 + \%O_2\right] + K_3 Q_{oxy} \times (\%O_{oxy})$$

Where:

CR_i = Hourly mass of coke burn for period i (kg).

K_1, K_2, K_3 = Material balance and conversion factors (K_1, K_2, and K_3 from Table 11-1 or from facility measurement or engineering estimate).

Q_r = Volumetric flow rate of exhaust gas before entering the emission control system from Equation 11-3 (dRm^3/min) at dry reference condition (101.325 kPa, 25°C and 0% moisture).

Q_a = Volumetric flow rate of air to regenerator as determined from control room instrumentation, at reference temperature and pressure conditions used in variable Q_r (dRm^3/min).

$\%CO_2$ = CO_2 concentration in regenerator exhaust, percent by volume—dry basis, 0% moisture.

$\%CO$ = CO concentration in regenerator exhaust, percent by volume—dry basis. When no auxiliary fuel is burned and a continuous CO monitor is not required, assume %CO to be zero.

$\% O_2$ = O_2 concentration in regenerator exhaust, percent by volume—dry basis, 0% moisture.

Q_{oxy} = Volumetric flow rate of O_2 enriched air to regenerator as determined from control room instrumentation at reference temperature and pressure conditions used in variable Q_r (dRm^3/min).

$\%O_{oxy}$ = O_2 concentration in O_2 enriched air stream inlet to regenerator, percent by volume—dry basis, 0% moisture.

(iii) Either continuously monitor the volumetric flow rate of exhaust gas from the FCCU regenerator or fluid coking unit burner prior to the combustion of other fossil fuels or calculate the volumetric flow rate of this exhaust gas stream using Equation 11-3 of this section.

Equation 11-3: Volumetric Flow Rate

$$\boldsymbol{Q_r} = \frac{(\mathbf{79} \times \boldsymbol{Q_a} + (\mathbf{100} - \%\boldsymbol{O_{oxy}}) \times \boldsymbol{Q_{oxy}})}{\mathbf{100} - \%\boldsymbol{CO_2} - \%\boldsymbol{CO} - \%\boldsymbol{O_2}}$$

Where:

Q_r = Volumetric flow rate of exhaust gas from regenerator before entering the emission control system, dRm^3/min (101.325 kPa , 25°C and 0% moisture).

Q_a = Volumetric flow rate of air to regenerator, as determined from control room instrumentation at dry reference conditions used for Q_r (dRm^3/min).

O_{oxy} = Oxygen concentration in oxygen enriched air stream, percent by volume—dry basis, 0% moisture.

Q_{oxy} = Volumetric flow rate of O2 enriched air to regenerator as determined from catalytic cracking unit control room instrumentation at dry reference conditions used for Q_r (dRm^3/min).

$\%CO_2$ = Carbon dioxide concentration in regenerator exhaust, percent by volume—dry basis, 0% moisture.

$\%CO$ = CO concentration in regenerator exhaust, percent by volume—dry basis. When no auxiliary fuel is burned and a continuous CO monitor is not required, assume %CO to be zero.

$\%O_2$ = O_2 concentration in regenerator exhaust, percent by volume—dry basis, 0% moisture.

(iv) Alternatively, calculate process CO_2 emissions from the continuous regeneration of catalyst material in fluid catalytic cracking units (FCCU) and fluid cokers using Equation 11-4 and Equation 11-3.

Equation 11-4: Alternative Catalyst Regeneration

$$CO_2 = \sum_{p=1}^{n} [(Q_r)_p \times \frac{(\%CO_2 + \%CO)_p}{100\%} \times \frac{44}{MVC} \times 10^{-3}]$$

Where:

CO_2 = Annual mass of CO_2 emissions (tonnes).

Q_r = Volumetric flow of exhaust gas before entering the emission control system using Equation 11-3, dRm^3/hr (101.325 kPa , 25°C and 0% moisture).

$\%CO_2$ = Average hourly CO_2 concentration in regenerator exhaust, per cent by volume—dry basis, 0% moisture.

%CO = Average hourly CO concentration in regenerator exhaust, per cent by volume—dry basis. When there is no post-combustion device, assume %CO to be zero.

44 = Molecular weight of CO_2 (kg/kg-mole).

MVC = Molar volume conversion factor at the same reference conditions as the above Q_r (dRm^3/kg-mole) = 8.3145 * [273.16 + reference temperature in °C]/[reference pressure in kilopascal].

10^{-3} = Conversion factor from kilograms to tonnes.

n = Number of hours of operation in the report year.

$\%O_2$ = O_2 concentration in regenerator exhaust, percent by volume—dry basis, 0% moisture.

Q_{oxy} = Volumetric flow rate of O_2 enriched air to regenerator as determined from control room instrumentation used for Q_r, dRm^3/min.

$\%O_{oxy}$ = O_2 concentration in O_2 enriched air stream inlet to regenerator, percent by volume—dry basis, 0% moisture.

Table 11-1. Coke Burn Rate Material Balance and Conversion Factors, Dry Reference Condition

	(kg min)/(hr dRm^3%)	(lb min)/(hr dscf %)
K_1	0.2982	0.0186
K_2	2.0880	0.1303
K_3	0.0994	0.0062

(B) Calculate process CO_2 emissions resulting from continuous catalyst regeneration in operations other than FCCUs and fluid cokers (e.g. catalytic reforming) using Equation 11-5.

Equation 11-5: Continuous Regeneration (Other) Emissions

$$CO_2 = CC_{irc} \times (CF_{spent} - CF_{regen}) \times H \times 3.664$$

Where:

CO_2 = Annual mass of CO_2 emissions (tonnes)

CC_{irc} = Average catalyst regeneration rate (tonnes/hr)

CF_{spent} = Weight carbon fraction of spent catalyst

CF_{regen} = Weight carbon fraction of regenerated catalyst (default = 0)

H = Annual hours regenerator was operational (hr)

3.664 = Ratio of molecular weights, CO_2 to carbon.

(C) Calculate process CO_2 emissions resulting from periodic catalyst regeneration using Equation 11-6.

Equation 11-6: Periodic Regeneration Emissions

$$CO_2 = \sum_{1}^{n}[(CB_Q)_n \times CC \times 3.664 \times 10^{-3}]$$

Where:

CO_2 = Annual mass of CO_2 emissions (tonnes).

CB_Q = Coke burn-off quantity per regeneration cycle from engineering estimates (kg).

n = Number of regeneration cycles in the calendar year.

CC = Carbon content of coke (kg C/kg coke) based on measurement as specified in Section 2.D.4.

3.664 = Ratio of molecular weights, CO_2 to carbon.

10^{-3} = Conversion factor from kilograms to tonnes.

CH_4 Emissions

(2) Calculate CH_4 emissions using either unit specific measurement data, a unit specific emission factor based on a source test of the unit, or Equation 11-7 of this section.

Equation 11-7: Catalyst Regeneration—CH_4

$$CH_4 = (CO_2 \times \frac{EmF_2}{EmF_1})$$

Where:

CH_4 = Annual mass of CH_4 emissions from coke burn-off (tonnes).

CO_2 = Annual emissions of CO_2 from coke burn-off calculated in paragraph (1) of this section, as applicable (tonnes).

EmF_1 = Default CO_2 emission factor for petroleum coke (97 kg CO_2/GJ).

EmF_2 = Default CH_4 emission factor for petroleum coke (2.8×10^{-3} kg CH_4/GJ).

N_2O Emissions

(3) Calculate N_2O emissions using either unit specific measurement data, a unit-specific emission factor based on a source test of the unit, or Equation 11-8 of this section.

Equation 11-8: Catalyst Regeneration—N_2O

$$N_2O = (CO_2 \times \frac{EmF_3}{EmF_1})$$

Where:

N_2O = Annual mass of N_2O emissions from coke burn-off (tonnes).

CO_2 = Annual emissions of CO_2 from coke burn-off calculated in paragraph (1) of this section, as applicable (tonnes).

EmF_1 = Default CO_2 emission factor for petroleum coke (97 kg CO_2/GJ).

EmF_3 = Default N_2O emission factor for petroleum coke (5.7×10^{-4} kg N_2O/GJ).

11.B **Emissions from Process Vents**

Guidance for calculating vented emissions associated with hydrogen production can be found in Section 10.A - Hydrogen Production of this document. Calculate other fugitive emissions of CO_2, CH_4, and N_2O from process vents using Equation 11-9. Report for each process vent that contains greater than 2 percent by volume CO_2 or greater than 0.5 percent by volume of CH_4 or greater than 0.01 percent by volume (100 parts per million) of N_2O.

Equation 11-9: Process Vent Emissions

$$\boldsymbol{E_x = \sum_{i=1}^{n} VR_i \times F_{xi} \times (\frac{MW_x}{MVC}) \times VT_i \times 10^{-3}}$$

Where:

E_x = Annual mass of emissions of gas "x" (tonnes), where x = CO_2, N_2O, or CH_4.

VR_i = Average volumetric flow rate for venting event "*i*" from measurement data, process knowledge or engineering estimates (dRm^3/unit time). If a mass flow meter is used, measure the flow rate in kg/unit time and replace the term "MW_x/MVC" with "1".

F_{xi} = Molar fraction by type of gas "x" in vent stream during event "i", from measurement data, process knowledge or engineering estimates.

MW_x = Molecular weight of gas "x" (kg/kg-mole).

MVC = Molar volume conversion factor at dry reference conditions as used for VR_i (dRm^3/kg-mole).
= 8.3145 * [273.16 + reference temperature in °C]/[reference pressure in kilopascal]

VT_i = Time duration of venting event "i", in same units of time as VR_i.

n = Number of venting events in report year.

10^{-3} = Conversion factor from kilograms to tonnes.

11.C **Emissions from Asphalt Production**

Calculate CO_2 and CH_4 fugitive emissions from asphalt blowing activities using either process vent method specified in paragraph 11.B or applicable provisions in paragraphs (1) and (2) of this section.

(1) For uncontrolled asphalt blowing operations or asphalt blowing operations controlled by vapor scrubbing, calculate CO_2 and CH_4 emissions using Equation 11-10 and Equation 11-11 of this section, respectively.

Equation 11-10: Uncontrolled Asphalt Emissions—CO_2

$$CO_2 = (Q_{AB} \times EF_{AB,CO_2})$$

Where:

CO_2 = Annual mass of CO_2 emissions from uncontrolled asphalt blowing (tonnes).

Q_{AB} = Annual quantity of asphalt blown (million barrels, million bbl).

$EF_{AB,CO2}$ = Emission factor for CO_2 from uncontrolled asphalt blowing from facility-specific test data (tonnes CO_2/million bbl asphalt blown); default = 1,100.

Equation 11-11: Uncontrolled Asphalt Emissions—CH_4

$$CH_4 = (Q_{AB} \times EF_{AB,CH_4})$$

Where:

CH_4 = Annual mass of CH_4 emissions from uncontrolled asphalt blowing (tonnes).

Q_{AB} = Annual quantity of asphalt blown (million bbl).

$EF_{AB,CH4}$ = Emission factor for CH_4 from uncontrolled asphalt blowing from facility-specific test data (tonnes CH_4/million bbl asphalt blown); default = 580.

(2) For asphalt blowing operations controlled by thermal oxidizer or flare, calculate CO_2 and CH_4 emissions using Equation 11-12 and Equation 11-13 of this section, provided these emissions are not already included in the flaring emissions specified in paragraph 11.E of this section (and quantified by methods outlined in Section 2.C).

Equation 11-12: Controlled Asphalt Emissions—CO_2

$$CO_2 = 0.98 \times (Q_{AB} \times CEF_{AB} \times 3.664)$$

Where:

CO_2 = Annual mass of CO_2 emissions from controlled asphalt blowing (tonnes).

0.98 = Assumed combustion efficiency of thermal oxidizer or flare, if facility factor is unavailable.

Q_{AB} = Annual quantity of asphalt blown (million bbl).

CEF_{AB} = Carbon emission factor from asphalt blowing from facility-specific test data (tonnes C/million bbl asphalt blown), default = 2,750.

3.664 = Ratio of molecular weights, CO_2 to carbon.

Equation 11-13: Controlled Asphalt Emissions—CH_4

$$CH_4 = 0.02 \times (Q_{AB} \times EF_{AB,CH_4})$$

Where:

CH_4 = Annual mass of CH_4 emissions from controlled asphalt blowing (tonnes).

0.02 = Fraction of methane not combusted in thermal oxidizer or flare based on assumed 98% combustion efficiency.

Q_{AB} = Annual quantity of asphalt blown (million bbl).

$EF_{AB,CH4}$ = Emission factor for CH_4 from uncontrolled asphalt blowing from facility-specific test data (tonnes CH_4/million bbl asphalt blown), default = 580.

11.D **Emissions from Sulphur Recovery**

Calculate CO_2 process emissions from Sulphur recovery units (SRUs) using Equation 11-14. For the molar fraction (MF) of CO_2 in the sour gas, use either a default factor of 0.20 or a source specific molar fraction value. If a source specific value is used, document and provide the methodology.

Equation 11-14: Sulphur Recovery Emissions

$$\boldsymbol{CO_2 = FR \times \frac{44}{MVC} \times MF \times 10^{-3}}$$

Where:

CO_2 = Annual mass of CO_2 emissions (tonnes).

FR = Volumetric flow rate of acid gas to SRU, dRm^3/year. If a mass flow meter is used, measure the acid gas flow in kg per year and replace the term "MW_{CO2}/MVC" with "1".

44 = Molecular weight of CO_2 (kg/kg-mole).

MVC = Molar volume conversion factor at the same reference conditions as the FR variable (dRm^3/kg-mole).
= 8.3145 * [273.16 + reference temperature in °C]/[reference pressure in kilopascal].

MF = Molar fraction (%) of CO_2 in sour gas based on measurement or engineering estimate (default MF = 20% expressed as 0.20).

10^{-3}= Conversion factor from kilograms to tonnes.

11.E **Emissions from Flares and Other Control Devices**

Calculate CO_2, CH_4 and N_2O emissions resulting from the combustion of flare pilot and hydrocarbons routed to the flare using the appropriate method(s) specified in section 2.C.

11.F **Emissions from Storage Tanks**

For storage tanks other than those that meet the descriptions in paragraph (3) of this section, calculate CH_4 emissions using the applicable methods in paragraphs (1) and (2).

(1) For storage tanks, not processing unstabilized crude oil. Calculate CH_4 emissions from storage tanks having a vapor-phase methane concentration of 0.5 volume percent or more using, tank-specific methane composition data (from measurement data or product knowledge) and estimation methods provided in Section 7.1 of the *AP-42 - Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*, including TANKS Model (Version 4.09D), or Equation 11-15 of this section.

Equation 11-15: Storage Tanks Emissions

$$CH_4 = (0.1 \times Q_{Ref})$$

Where:

CH_4 = Annual mass of CH_4 emissions from storage tanks (tonnes).

0.1 = Default emission factor for storage tanks (tonnes CH_4/millionbbl).

Q_{Ref} = Annual quantity of crude oil plus the quantity of intermediate products received from off site that are processed at the facility (millionbbl).

(2) For storage tanks that process unstabilized crude oil, calculate CH_4 emissions using either, tank-specific methane composition data (from measurement data or product knowledge) and direct measurement of the gas generation rate, or Equation 11-16 of this section.

Equation 11-16: Storage Tanks—Unstabilized Crude Oil

$$CH_4 = (995{,}000 \times Q_{un} \times \Delta P) \times MF_{CH4} \times \frac{16}{MVCi} \times 10^{-3}$$

Where:

CH_4 = Annual mass of CH_4 emissions from storage tanks (tonnes).

Q_{un} = Annual quantity of unstabilized crude oil received at the facility (million bbl).

ΔP = Pressure differential from the previous storage pressure to atmospheric pressure (pounds per square inch, psi).

MF_{CH4} = Mole fraction of CH_4 in vent gas from the unstabilized crude oil storage tank from facility measurements (kg-mole CH_4/kg-mole gas); use 0.27 as a default if measurement data are not available.

995,000 = Correlation equation factor (scf gas per million bbl per psi).

16 = Molecular weight of CH_4 (kg/kg-mole).

MVCi = Molar volume conversion (849.5 scf/kg-mole, 101.325 kPa, 20°C).

10^{-3} = Conversion factor from kilograms to tonnes.

(3) You do not need to calculate annual CH_4 emissions from storage tanks that meet any of the following descriptions:

  (A) Units permanently attached to conveyances such as trucks, trailers, rail cars, barges, or ships;

  (B) Pressure vessels designed to operate in excess of 204.9 kilopascals and without emissions to the atmosphere;

  (C) Bottoms receivers or sumps;

  (D) Vessels storing wastewater; or

  (E) Reactor vessels associated with a manufacturing process unit.

11.G **Emissions from Industrial Wastewater Processing**

(1) Calculate CH_4 emissions from wastewater treatment (such as anaerobic reactor, digester, or lagoon) using Equation 11-17 or Equation 11-18.

Equation 11-17: Industrial Wastewater CH_4 Emissions—COD

$$\boldsymbol{CH_4 = Q \times COD_{qave} \times B \times MCF \times 10^{-3}}$$

Equation 11-18: Industrial Wastewater CH_4 Emissions—BOD

$$\boldsymbol{CH_4 = Q \times BOD_{5qave} \times B \times MCF \times 10^{-3}}$$

Where:

$\mathbf{CH_4}$ = Annual mass of CH_4 emissions (tonnes).

$\mathbf{Q}$ = Annual volume of wastewater treated (m^3).

$\mathbf{COD_{qave}}$ = Average of quarterly determinations of chemical oxygen demand of the wastewater (kg/m^3) as specified in section 11.N.7.

$\mathbf{BOD_{5qave}}$ = Average of quarterly determinations of five-day biochemical oxygen demand of the wastewater (kg/m^3) as specified in section 11.N.7.

$\mathbf{B}$ = Methane generation capacity (B = 0.25 kg CH_4/kg COD and 0.6 kg CH_4/kg BOD_5).

$\mathbf{MCF}$ = Methane correction factor (fraction of methane generation capacity, B, that is realized with a given treatment technology or discharge pathway) from Table 11-2 or facility-specific. If using a facility-specific MCF, document how it was derived.

$\mathbf{10^{-3}}$ = Conversion factor from kilograms to tonnes.

Table 11-2. Default MCF Values for Industrial Wastewater

Type of Treatment and Discharge Pathway or System	Comments	MCF	Range
Untreated			
Sea, river and lake discharge	Rivers with high organic loading may turn anaerobic, however this is not considered here	0.1	0 – 0.2
Treated			
Aerobic treatment plant	Well maintained, some CH_4 may be emitted from settling basins	0	0 – 0.1
Aerobic treatment plant	Not well maintained, overloaded	0.3	0.2 – 0.4
Anaerobic digester for sludge	CH_4 recovery not considered here	0.8	0.8 – 1.0
Anaerobic reactor	CH_4 recovery not considered here	0.8	0.8 – 1.0
Anaerobic shallow lagoon	Depth less than 2 Meters	0.2	0 – 0.3
Anaerobic deep lagoon	Depth more than 2 Meters	0.8	0.8 – 1.0
For CH_4 generation capacity (B) in kg CH_4/kg COD, use default factor of 0.25 kg CH_4/kg COD. The emission factor for N_2O from discharged wastewater (EF_{N2O}) is 0.005 kg N_2O -N/kg-N. MCF = methane correction factor (fraction of methane generation capacity, B, that is realized with a given treatment technology or discharge pathway). COD = chemical oxygen demand (kg COD/m^3).			

(2) For anaerobic processes from which biogas is recovered and not emitted, adjust the CH_4 emissions calculated in paragraph (1) by the amount of CH_4 collected.

(3) Calculate N_2O emissions from wastewater treatment using Equation 11-19.

Equation 11-19: Industrial Wastewater N_2O Emissions

$$\boldsymbol{N_2O = Q \times N_{qave} \times EF_{N2O} \times 1.571 \times 10^{-3}}$$

Where:

$\mathbf{N_2O}$ = Annual mass of N_2O emissions (tonnes).

$\mathbf{Q}$ = Annual volume of wastewater treated (m^3).

$\mathbf{N_{qave}}$ = Average of quarterly determinations of N in wastewater stream (kg N/m^3).

EF_{N2O} = Emission factor for N_2O from discharged wastewater (0.005 kg N_2O -N/kg N or facility-specific). If using a facility-specific emission factor, document how it was derived.

1.571 = Conversion factor (kg N_2O -N to kg N_2O).

10^{-3} = Conversion factor from kilograms to tonnes.

11.H **Emissions from Oil-water Separators**

Calculate CH_4 emissions from oil-water separators using Equation 11-20. For the CF_{NMHC} conversion factor, use either a default factor of 0.6 or species specific conversion factors determined by analysis. Document and provide sampling and analysis methodology.

Equation 11-20: Oil-water Separators Emissions

$$CH_4 = EF_{sep} \times V_{water} \times CF_{NMHC} \times 10^{-3}$$

Where:

CH_4 = Annual mass of CH_4 emissions (tonnes).

EF_{sep} = NMHC (non-methane hydrocarbon) emission factor (kg/m^3) from Table 11-3.

V_{water} = Annual volume of wastewater treated by the separator (m^3).

CF_{NMHC} = NMHC to CH_4 conversion factor.

10^{-3} = Conversion factor from kilograms to tonnes.

Table 11-3. Emission Factors for Oil/Water Separators

Separator Type	**Emission factor (EF_{sep})[a] kg NMHC/m^3 wastewater treated**
Gravity type—uncovered	1.11×10^{-1}
Gravity type—covered	3.30×10^{-3}
Gravity type—covered and connected to destruction device	0
DAF[b] or IAF[c]—uncovered	4.00×10^{-3}[d]
DAF or IAF—covered	1.20×10^{-4}[d]
DAF or IAF—covered and connected to a destruction device	0
a EFs do not include ethane b DAF = dissolved air flotation type c IAF = induced air flotation device d EFs for these types of separators apply where they are installed as secondary treatment systems	

11.I **Emissions from Equipment Leaks**

Calculate CH_4 emissions using the method specified in either paragraph (1) or (2) of this section.

(1) When possible, use process-specific methane composition data (from measurement data or process knowledge) and any of the emission estimation procedures provided in the Protocol for Equipment Leak Emissions Estimates (EPA-453/R-95-017, NTIS PB96-175401).

(2) Else, use Equation 11-21 of this section.

Equation 11-21: Equipment Leaks CH_4

$$CH_4 = (0.4 \times N_{CD} + 0.2 \times N_{PU1} + 0.1 \times N_{PU2} + 4.3 \times N_{H2} + 6 \times N_{FGS})$$

Where:

CH_4 = Annual mass of CH_4 emissions from equipment leaks (tonnes)

N_{CD} = Number of atmospheric crude oil distillation columns at the facility.

N_{PU1} = Cumulative number of catalytic cracking units, coking units (delayed or fluid), hydrocracking, and full-range distillation columns (including depropanizer and debutanizer distillation columns) at the facility.

N_{PU2} = Cumulative number of, hydrotreating/hydrorefining, catalytic reforming, and visbreaking, units at the facility.

N_{H2} = Total number of hydrogen plants at the facility.

N_{FGS} = Total number of fuel gas systems at the facility.

11.J **Emissions from Coke Calcining**

Calculate GHG emissions according to the applicable provisions in paragraphs (1) through (3) of this section.

(1) If a CEMS measures CO_2 emissions according to Section 2.A.3, calculate and report CO_2 emissions for coke calcining using the CEMS Calculation Methodology specified in that section. If the coke calcining unit is not equipped with CEMS follow the requirements of paragraph (2) of this section.

(2) Calculate the CO_2 emissions from the coke calcining unit using Equation 11-22 of this section.

Equation 11-22: Coke Calcining CO_2 Emissions

$$CO_2 = 3.664 \times (M_{in} \times CC_{GC} - (M_{out} + M_{dust}) \times CC_{MPC})$$

Where:

CO_2 = Annual mass of CO_2 emissions (tonnes).

M_{in} = Annual mass of green coke fed to the coke calcining unit from facility records (tonnes).

CC_{GC} = Average mass fraction carbon content of green coke from facility measurement data (tonnes carbon/tonnes green coke).

M_{out} = Annual mass of marketable petroleum coke produced by the coke calcining unit from facility records (tonnes).

M_{dust} = Annual mass of petroleum coke dust collected in the dust collection system of the coke calcining unit from facility records (tonnes)

CC_{MPC} = Average mass fraction carbon content of marketable petroleum coke produced by the coke calcining unit from facility measurement data (tonnes carbon/tonnes petroleum coke).

3.664 = Ratio of molecular weights, carbon dioxide to carbon

(3) For all coke calcining units, use the CO_2 emissions from the coke calcining unit calculated in paragraphs (1) or (2), as applicable, and calculate CH_4 and N_2O using the following methods:

(A) Calculate CH_4 emissions using either unit specific measurement data, a unit specific emission factor based on a source test of the unit, or Equation 11-23 of this section.

Equation 11-23: Coke Calcining CH_4 Emissions

$$CH_4 = (CO_2 \times \frac{EmF_2}{EmF_1})$$

Where:

CH_4 = Annual mass of CH_4 emissions (tonnes).

CO_2 = Annual mass of CO_2 calculated in paragraphs (1) and (2) of this section, as applicable (tonnes).

EmF_1 = Default CO_2 emission factor for petroleum coke (97 kg CO_2/GJ).

EmF_2 = Default CH_4 emission factor for petroleum coke (2.8 x 10^{-3} kg CH_4/GJ).

(B) Calculate N_2O emissions using either unit specific measurement data, a unit-specific emission factor based on a source test of the unit, or Equation 11-24 of this section.

Equation 11-24: Coke Calcining N_2O Emissions

$$\boldsymbol{N_2O = (CO_2 \times \frac{EmF_3}{EmF_1})}$$

Where:

N_2O = Annual mass of N_2O emissions (tonnes).

CO_2 = Annual mass of CO_2 from paragraphs (1) and (2) of this section, as applicable (tonnes).

EmF_1 = Default CO_2 emission factor for petroleum coke (97 kg CO_2/GJ)

EmF_3 = Default N_2O emission factor for petroleum coke (5.7×10^{-4} kg N_2O /GJ).

11.K **Emissions from Uncontrolled Blowdown Systems**

For uncontrolled blowdown systems, use the methods for process vents in section 11.B.

11.L **Crude Oil, Intermediate or Product Loading Operations**

Calculate CH_4 emissions from loading operations using product-specific, vapor-phase methane composition data (from measurement data or process knowledge) and the emission estimation procedures provided in Section 5.2 of the *AP-42 - Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*, if the equilibrium vapor-phase concentration of methane is 0.5 volume percent or more.

For loading operations where the equilibrium vapor-phase concentration of methane is less than 0.5 volume percent, assume zero methane emissions.

11.M **Emissions from Delayed Coking Units**

Calculate the CH_4 emissions from the depressurization of the coking unit vessel (i.e., the “coke drum”) to the atmosphere, using either of the methods provided in paragraphs (1) or (2) and provided no water or steam is added to the vessel after venting to atmosphere. Use the method in paragraph (1) of this section if you add water or steam to the vessel after venting to atmosphere.

(1) In addition to the process vent calculations from section 11.B, also calculate the CH_4 emissions from the subsequent opening of the vessel for coke cutting operations using Equation 11-25 of this

section. For coke drums or vessels of different dimensions, use Equation 11-25 for each set of coke drums or vessels of the same size and sum the resultant emissions across each set of coke drums or vessels to calculate the CH_4 emissions for all delayed coking units.

Equation 11-25: Delayed Coking Unit Emissions

$$CH_4 = (N \times H \times \frac{(P_{CV} + 101.325)}{101.325} \times f_{void} \times \frac{\pi \times D^2}{4} \times \frac{16}{MVC} \times MF_{CH4} \times 10^{-3})$$

Where:

CH_4 = Annual mass of CH_4 emissions from the delayed coking unit vessel opening

(tonnes).

N = Cumulative number of vessel openings for all delayed coking unit vessels of the same dimensions during the year.

H = Height of coking unit vessel (metres).

P_{CV} = Gauge pressure of the coking vessel when opened to the atmosphere prior to coke cutting or, if the alternative method provided in paragraph (2) of this section is used, gauge pressure of the coking vessel when depressurization gases are first routed to the atmosphere (kilopascals).

101.325 = Assumed atmospheric pressure (kilopascals).

f_{void} = Volumetric void fraction of coking vessel prior to steaming based on engineering judgement, at dry reference temperature and pressure (dRm^3 gas/m^3 of vessel).

D = Diameter of coking unit vessel (metres).

16 = Molecular weight of CH_4 (kg/kg-mole).

MVC = Molar volume factor at the same reference conditions as the coking vessel (dRm^3/kg-mole).
= 8.3145 * [273.16 + reference temperature in °C]/[reference pressure in kilopascal].

MF_{CH4} = Average mole fraction of methane in coking vessel gas based on the analysis of at least two samples per year, collected at least four months apart (kg-mole CH_4/kg-mole gas, wet basis).

10^{-3} = Conversion factor from kilograms to tonnes.

(2) Calculate the CH_4 emissions from the depressurization vent and subsequent opening of the vessel for coke cutting operations using Equation 11-25 of this section and the pressure of the coking vessel when the depressurization gases are first routed to the atmosphere. For coke drums or vessels of different dimensions, use Equation 11-25 for each set of coke drums or vessels of the same size and sum the resultant emissions across each set of coke drums or vessels to calculate the CH_4 emissions for all delayed coking units.

11.N **Sampling, Analysis, and Measurement Requirements**

Perform sampling, analysis, and measurement, when required according to the methodology chosen in the appropriate paragraphs above, in accordance with 11.N.1 to 11.N.9. Note that where the option to use process data and engineering estimates is provided and chosen, a description of the methodology and supporting information shall be provided.

11.N.1 **Catalyst Regeneration**

For FCCUs and fluid coking units, measure the following parameters:

- (A) The daily oxygen concentration in the oxygen enriched air stream inlet to the regenerator.
- (B) Continuous measurements of the volumetric flow rate of air and oxygen enriched air entering the regenerator.
- (C) Weekly periodic measurements of the CO_2, CO and O_2 concentrations in the regenerator exhaust gas (or continuous measurements if the equipment necessary to make continuous measurements is already in place).
- (D) Daily determinations of the carbon content of the coke burned.
- (E) The number of hours of operation.
- (F) Use the measured daily or weekly values to derive the minute or hourly parameters as required by the corresponding equations.

11.N.2 **Process Vents**

Measure the following parameters for each process vent.

(1) The vent flow rate for each venting event from measurement data, process knowledge or engineering estimates.

(2) The molar fraction of CO_2, N_2O, and CH_4 in the vent gas stream during each venting event from measurement data, process knowledge or engineering estimates.

(3) The duration of each venting event.

11.N.3 **Asphalt Production**

Measure the annual mass of asphalt blown.

11.N.4 **Sulphur Recovery**

Measure the volumetric flow rate of acid gas to the SRU. When using a source specific molar fraction value based on measurements, instead of the default factor or engineering estimates, conduct an annual test of the molar fraction value.

11.N.5 **Flares and Other Control Devices**

Refer to Section 2.D.7.

11.N.6 **Storage Tanks**

Determine the annual throughput of crude oil, naphtha, distillate oil, asphalt, and gas oil for each storage tank using company records or applicable plant instruments.

11.N.7 **Wastewater Treatment**

Measure the following parameters.

(1) Collect samples representing wastewater influent to the wastewater treatment process, following all preliminary and primary treatment steps (e.g., after grit removal, primary clarification, oil-water separation, dissolved air flotation or similar solids and oil separation processes). Collect and analyze samples for COD or BOD_5 concentration quarterly.

(2) Measure the annual flow of wastewater entering the wastewater treatment process. The flow measurement location must correspond to the location used to collect samples analyzed for COD or BOD_5 concentration.

(3) The quarterly nitrogen content of the wastewater.

11.N.8 **Oil-Water Separators**

Measure the daily volume of wastewater treated by the oil-water separators.

11.N.9 **Coke Calcining**

Determine the mass of petroleum coke as required using measurement equipment used for accounting purposes. Determine the carbon content of petroleum coke using any one of the following methods:

(1) ASTM D3176-89 (Reapproved 2002) Standard Practice for Ultimate Analysis of Coal and Coke.

(2) ASTM D5291-02 (Reapproved 2007) Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants.

(3) ASTM D5373-08 Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Laboratory Samples of Coal.

11.O **Procedures for Estimating Missing Data**

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

When data related to sampling is unavailable, use the prescribed methods in Section 11.N to re-analyze the original sample, a backup sample or the replacement sample for the same measurement and sampling period; if this is not possible, the missing data should be substituted using the following approach.

(1) For missing sampled or analyzed data (e.g. carbon content, temperature, pressure, etc), determine the sampling or measurement rate using Equation 11-26 and, replace the missing data as described in paragraphs (A) through (C) follows:

Equation 11-26: Sampling Rate

$$R = \frac{Q_{SACT}}{Q_{SREQUIRED}}$$

Where:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

$\mathbf{Q_{S\ ACT}}$ = Quantity of actual samples or measurements obtained by the facility operator.

$\mathbf{Q_{S\ REQUIRED}}$ = Quantity of samples or measurements required.

(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.

(2) For missing data concerning other parameters (e.g. coke burn, volumetric flow rate, number of hours of operation, quantity of wastewater, etc) substitute the data based on the best available estimate of that parameter using all available process data. Document and retain records of the procedures used for all such estimates.

(3) For missing parameters regarding CEM systems, determine the replacement data using 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) or use the procedure described in paragraph (1) above.

12 Quantification Methods for Pulp and Paper Production

The methodology for pulp and paper production applies to those facilities primarily engaged in manufacturing pulp, paper and paper products. The manufacture of pulp involves separating the cellulose fibres from other materials in fibre sources (e.g. wood). Paper manufacturing involves matting fibres into a sheet. Converted paper products produced from paper are also considered here.

12.A Emissions from Pulp and Paper Production

Calculate emissions from each unit (i.e., kraft or soda chemical recovery furnace, sulfite chemical recovery combustion unit, stand-alone semi-chemical recovery combustion unit, or kraft or soda pulp mill lime kiln) as specified under paragraphs 12.A.1and 12.A.2 of this section. Calculate emissions from wastewater according to section 12.A.3.

12.A.1 Fuel Combustion and Electricity/Heat Emissions

(1) If generating electricity or useful heat or steam, calculate associated emissions as specified in Section 7 (Quantification Methods for Electricity and Heat Generation).

(2) Calculate CO_2, CH_4 and N_2O emissions from fuel combustion following methodologies specified in Section 2 (Quantification Methods for Fuel Combustion)

12.A.2 Process Emissions (Make-up Chemical Use)

For make-up chemical use, CO_2 process emissions may be obtained using either of the methods in paragraphs (1) or (2).

(1) If operating and maintaining a CEMS, Equation 12-1 may be used.

Equation 12-1: Make-up Chemical Use—CEMS

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

Where:

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

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

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

(2) Use Equation 12-2 or Equation 12-3 to calculate process emissions from the use of carbonates:

Equation 12-2: Make-up Chemical Use—Carbon Content

$$CO_2 = \left[\sum_{k}^{n}(P_k \times CC_k) - \sum_{j}^{m}(P_j \times CC_j)\right] \times 3.664$$

Where:

CO_2 = annual CO_2 emissions from consumption of carbonates.

n = number of carbonate input material types

m = number of carbonate output material types

P_k = annual quantity of input carbonate type “k” used (tonnes)

P_j = annual quantity of output carbonate type “j” (tonnes) A default value of 0 may be used.

CC_k = annual weighted average carbon content for material “k” (tonnes of carbon per tonne of material k), measured as specified in 12.B.

CC_j = annual weighted average carbon content for material “j” (tonnes of carbon per tonne of material j), measured as specified in 12.B.

3.664 = stoichiometric conversion factor from C to CO_2

Equation 12-3: Make-up Chemical Use—Emission Factor

$$CO_2 = \sum_{k}^{n}(P_k \times EF_k \times F_k)$$

Where:

CO_2 = annual CO_2 emissions from consumption of carbonates.

n = number of carbonate types

P_k = annual quantity of input carbonate type “k” used (tonnes)

EF_k = emission factor for the input carbonate type “k” (Table 12-1 provides default values for certain types of carbonates).

F_k = weight fraction of calcination achieved for the carbonate type “k”. A value of 1.0 may be used if assuming 100% calcination.

Table 12-1. CO_2 Default Emissions Factors for Common Carbonates

Mineral Name—Carbonate	**CO_2 Emission Factor (tonnes CO_2/tonne carbonate)**
Calcite or aragonite—$CaCO_3$	0.43971
Magnesite—$MgCO_3$	0.52197
Dolomite—$CaMg(CO_3)_2$	0.47732
Siderite—$FeCO_3$	0.37987
Ankerite—$Ca(Fe,Mg,Mn)(CO_3)_2$	0.47572
Rhodochrosite—$MnCO_3$	0.38286
Sodium Carbonate or soda ash—Na_2CO_3	0.41492
Source: Adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change National Greenhouse Gas Inventories Programme.	

12.A.3 **Wastewater Emissions**

Calculate CH_4 and N_2O emissions from wastewater using the methodology specified in section 11.G.

12.B **Sampling, Analysis, and Measurement Requirements**

(1) The annual mass of carbonate input material (e.g., limestone and dolomite) and process output material (for Equation 12-2) or carbonate inputs (for Equation 12-3) shall be determined by summing the monthly mass for the material determined for each month of the calendar year. The monthly mass may be determined using facility instruments, procedures, or records used for accounting purposes, including either direct measurement of the quantity of the material consumed or by calculations using process operating information.

(2) For Equation 12-2, obtain carbon content from supplier information or by collecting and analyzing at least three representative samples of the material each year using ASTM C25-06 “Standard Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime”.

(3) For Equation 12-3, rather than assuming a calcination fraction of 1.0, the facility may determine, on an annual basis, the calcination fraction for each carbonate consumed using the most appropriate method published by a consensus-based standards organization, if such a method exists. If no appropriate method is published by a consensus-based standards organization, use industry standard methods, noting where such methods are used and what methods are used.

12.C **Procedures for Estimating Missing Data**

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

When data related to sampling is unavailable, use the prescribed methods in Section 12.B to re-analyze the original sample, a backup sample or the replacement sample for the same measurement and sampling period; if this is not possible, the missing data should be substituted using the following approach.

(1) For missing sampled or analyzed data (e.g. carbon content, temperature, pressure), determine the sampling or measurement rate using Equation 12-4 and, replace the missing data as described in paragraphs (A) through (C) follows:

Equation 12-4

$$R = \frac{Q_{SACT}}{Q_{SREQUIRED}}$$

Where:

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

$Q_{S\,ACT}$ = Quantity of actual samples or measurements obtained by the facility operator.

$Q_{S\,REQUIRED}$ = Quantity of samples or measurements required.

(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.

(2) For missing data concerning a quantity of raw materials (e.g. mass of carbon containing inputs), substitute the data based on the best available estimate of that parameter using 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 parameters regarding CEM systems, determine the replacement data using 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) or use the procedure described in paragraph (1) above.

13 **Quantification Methods for Base Metal Production**

Base metal production considered in this section includes lead, zinc, copper, nickel, and cobalt production. Aluminum and iron and steel production are considered in sections 5 and 6, respectively.

Several processes involved in the production (smelting and/or refining) of base metals may generate CO_2 emissions. Process-related activities may include the use of carbonates as flux reagents (e.g., limestone [$CaCO_3$] or dolomite [$CaCO_3 \cdot MgCO_3$]) to assist in the removal of impurities from the metal ore concentrate; the use of carbon feedstock (e.g. metallurgical coke) as a reducing agent to extract metals or for slag cleaning; and carbon electrode consumption in electric furnaces. The raw metal ore may also represent a source of CO_2 emissions.

It is important to distinguish between fuels used for combustion and fuels used as reducing agents; only emissions from fuels used as reducing agents should be included as industrial process emissions. Guidance for emissions from fuels used for combustion is provided in Section 2.

13.A **Calculation of CO_2 Emissions**

Calculate total CO_2 emissions as specified under paragraphs (1) or (2) of this section.

(1) Determine facility process CO_2 emissions using Equation 13-1 if operating and maintaining a CEMS.

Equation 13-1: Base Metal—CEMS

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

Where:

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

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

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

(2) If not using CEMS, calculate total CO_2 emissions using Equation 13-2. This is a general equation used to determine CO_2 emissions based on a mass balance approach considering carbon content of input and output process materials. CO_2 emissions from each material and process shall be used to determine total CO_2 emissions. **Specific materials that in aggregate contribute less than 0.5% of the total carbon into the process may be excluded from the calculation**.

Equation 13-2: Base Metal Process CO_2 Emissions

$$CO_2 = \left[\sum_{i}^{n}(M_i \times CC_i) - \sum_{j}^{m}(P_j \times CC_j)\right] \times 3.664$$

Where:

$\mathbf{CO_2}$ = annual CO_2 emissions from metal production.

$\mathbf{n}$ = number of carbon-containing process input materials.

$\mathbf{m}$ = number of process output materials.

$\mathbf{M_i}$ = annual quantity of carbon-containing process input material “i” used, including waste-based reducing agents (tonnes)

$\mathbf{P_j}$ = annual quantity of process output material “j” (tonnes)

$\mathbf{CC_i}$ = annual weighted average carbon content for material “i” (for example, reductants andcarbonates,) (kilograms of carbon per tonne of material i), measured as specified in Section 13.B.

$\mathbf{CC_j}$ = annual weighted average carbon content for material “j” (for example, reductants and carbonates) (kilograms of carbon per tonne of material j), measured as specified in Section 13.B.

$\mathbf{3.664 =}$ stoichiometric conversion factor from C to CO_2

13.B **Sampling, Analysis, and Measurement Requirements**

The annual mass of each solid carbon-containing input material consumed shall be determined by summing the monthly mass for the material determined for each month of the calendar year. The monthly mass may be determined using facility instruments, procedures, or records used for accounting purposes, including either direct measurement of the quantity of the material consumed or by calculations using process operating information.

The average carbon content of each material consumed shall be determined as specified under paragraph (1) or (2) of this section.

(1) Obtain carbon content by collecting and analyzing at least three representative samples of the material each year using one of the following methods:

(A) For carbonate flux reagents (e.g., limestone and dolomite), use ASTM C25-06 “Standard Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime”.

(B) For metal-bearing materials, use ASTM E1941-04 “Standard Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys”.

(C) For solid carbonaceous reducing agents and carbon electrodes, use ASTM D5373-08 “Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Laboratory Samples of Coal”.

(D) For liquid reducing agents, use the methods described in (i) through (iv), as appropriate:

  (i) ASTM D2502-04 (reapproved 2002) “Standard Test Method for Estimation of Molecular Weight (Relative Molecular Mass) of Petroleum Oils from Viscosity Measurements”

  (ii) ASTM D2503-92 (reapproved 2002) “Standard Test Method for Relative Molecular Mass (Relative Molecular Weight) of Hydrocarbons by Thermoelectric Measurement of Vapor Pressure”

  (iii) ASTM D3238-95 (reapproved 2005) “Standard Test Method for Calculation of Carbon Distribution and Structural Group Analysis of Petroleum Oils by the n-d-M Method”

  (iv) ASTM D5291-02 (reapproved 2007) “Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants”

(E) For gaseous reducing agents, use one of the methods described in subparagraph (i) or (ii):

  (i) ASTM D1945-03 “Standard Test Method for Analysis of Natural Gas by Gas Chromatography”

  (ii) ASTM D1946-90 “Standard Practice for Analysis of Reformed Gas by Gas Chromatography”

(F) For waste-based carbon-containing material, use one of the methods described in subparagraph (i) or (ii):

  (i) Determine carbon content by operating the smelting furnace both with and without the waste-reducing agents while keeping the composition of other material introduced constant. To ensure representativeness of waste-based carbon-containing material variability, the specific testing plan (e.g. number of test runs, other process variables to keep constant, timing of runs) for these trials must be documented.

  (ii) Use an average carbon content value from samples analyzed by a Leco instrument for percent carbon. Monthly composites of e-waste need to be riffled, ground to no less than 2 mm, split and then analyzed.

(2) Obtain carbon contents of the material, including carbon electrodes from the vendor or supplier.

13.C **Procedures for Estimating Missing Data**

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

When data related to sampling is unavailable, use the prescribed methods in Section 13.B to re-analyze the original sample, a backup sample or the replacement sample for the same measurement and sampling period; if this is not possible, the missing data should be substituted using the following approach.

(1) For missing sampled or analyzed data (e.g. carbon content, temperature, pressure), determine the sampling or measurement rate using Equation 13-3 and, replace the missing data as described in paragraphs (A) through (C) follows:

Equation 13-3: Sampling Rate

$$\boldsymbol{R} = \frac{\boldsymbol{Q_{SACT}}}{\boldsymbol{Q_{SREQUIRED}}}$$

Where:

$\mathbf{R}$ = Sampling or measurement rate that was used (%).

$\mathbf{Q_{S\,ACT}}$ = Quantity of actual samples or measurements obtained by the facility operator.

$\mathbf{Q_{S\,REQUIRED}}$ = Quantity of samples or measurements required.

(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.

(2) For missing data concerning a quantity of raw materials (e.g. mass of carbon containing inputs), substitute the data based on the best available estimate of that parameter using 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 parameters regarding CEM systems, determine the replacement data using 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) or use the procedure described in paragraph (1) above.

Appendix A

Documentation—General Record Keeping

Where facility specific method(s) differ from the Quantification Requirements, supporting documentation is required for consideration and assessment. This allows a facility to account for the uniqueness of their operational conditions and circumstances.

In general, documentation of a specific method, sampling and measurement approach for an emission source, by greenhouse gases, should include but not be limited to the following:

1. Overview of the emissions by source and by greenhouse gas, where applicable.
2. Description of issue(s) with the Quantification Requirements' method (including emission factor(s), other input parameters, sampling and measurement approaches) that prevents the generation of representative emissions estimates for specific facility emission sources.
3. Description of facility specific method applied.
4. Source of the data used to derive any facility specific input variable(s) or parameter(s) used to estimate emissions and an explanation of why these provide better facility estimates.
5. Any other additional information to support the approach used, including sampling and measurement protocol(s), summary of measurement results (when available), sample calculations, and result(s) along with uncertainty estimates (when available).

14 Equations, Figures, and Tables

15 **References**

15.A **General**

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15.B **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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