VCS Methodology

VM0049

CARBON CAPTURE AND STORAGE

Version 1.0

June 27, 2024

Sectoral Scope 16

Version 1.0 of this methodology was developed by the CCS+ Initiative and Verra. The CCS+ Initiative is a collaboration of 48 member companies. Perspectives Climate Group GmbH, and South Pole Carbon Asset Management Ltd. served as the secretariat and consultants to the initiative throughout this methodology.

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1 SOURCES

This methodology uses the most recent versions of the following VCS Program modules and tools[1]:

Capture Modules

- *VMD0056 Removals from CO_2 Capture from Air (Direct Air Capture)*
- *VMD00XX Emission Reductions or Removals from CO_2 Capture from Bioenergy Combustion*
- *VMD00XX Emission Reductions or Removals from CO_2 Capture from Bioproduction Processes*
- *VMD00XX Emission Reductions from CO_2 Capture from Post-combustion Flue Gases in Fossil Fuel Power and Heat Generation*
- *VMD00XX Emission Reductions from CO_2 Capture from Industrial Processes*
- *VMD00XX Emission Reductions from CO_2 Capture from Oil and Gas Production and Processing*
- *VMD00XX Emission Reductions from CO_2 Capture from Precombustion Processes in Fossil Fuel Power and Heat Generation*
- *VMD00XX Emission Reductions from CO_2 Capture from Oxyfuel Combustion in Fossil Fuel Power and Heat Generation*

Transport Module

- *VMD0057 Project Emissions from CO_2 Transport for CCS Projects*

Storage Module

- *VMD0058 Project Emissions from CO_2 Storage in Saline Aquifers and Depleted Hydrocarbon Reservoirs*
- *VMD00XX Project Emissions from CO_2 Storage via Geological Mineralization*

Other Modules/Tools/Requirements

- *VT00XX Differentiating Reductions and Removals in CCS Projects*
- *VT00XX Accounting non-VCS CO_2 in CCS Projects*
- *Geologic Carbon Storage (GCS) Non-Permanence Risk Tool*
- *GCS Requirements*

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[1] Modules labelled as "*VMD00XX*" and Tools labelled as "*VT00XX*" are under development

This methodology uses the most recent versions of the following Clean Development Mechanism (CDM) tools:

- *CDM TOOL01 Tool for Demonstration and Assessment of Additionality*
- *CDM TOOL06 Methodological Tool: Project Emissions from Flaring*
- *CDM TOOL27 Investment Analysis*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project method
Crediting Baseline	Project method

This methodology establishes criteria and procedures to quantify the greenhouse gas (GHG) emission reductions and carbon dioxide removals (reductions and removals) from carbon capture and storage (CCS) projects.

This methodology uses a modular framework (hereinafter referred to as the methodology framework) comprising a methodology and several modules. The methodology provides overarching requirements for projects applying the framework. Separate modules establish criteria and procedures for quantifying emissions from corresponding capture, transport, and storage activities. The methodology framework allows for quantifying any combination of eligible capture, transport, and storage activities using this modular approach.

3 DEFINITIONS

In addition to the definitions set out in the *VCS Program Definitions*, the following definitions apply to this methodology.

Bioenergy
Energy derived from any form of biomass such as recently living organisms or their metabolic byproducts

Biogenic sources
Carbon/carbon dioxide sources that originate from organic materials (i.e., recently living organisms, such as plants). Carbon dioxide may be released from these sources by combustion, decomposition, or biomass processing. The biomass can be solid (e.g., wood), liquid (e.g., bioethanol), or gaseous (e.g., biogas).

Biomass sources

Carbon/carbon dioxide sources that originate from organic material excluding material that is fossilized or embedded in geological formations (i.e., includes municipal solid waste from biogenic sources, landfill gas, sludge waste, agricultural crop byproducts, straw, and other biomass solids, liquids, and gases; but excludes wood and wood-derived fuels (including black liquor), biofuels feedstock, biodiesel, and fuel ethanol)

Capture facility

A facility engineered to capture carbon dioxide through various processes such as absorption, adsorption, membrane, electro-chemical, and cryogenic methods from diverse sources.

Carbon dioxide

A naturally occurring gas and a by-product of burning fossil fuels and biomass, as well as of land-use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance.

Direct air capture (DAC)

A process to capture and concentrate carbon dioxide from the atmosphere using various separation methods

Flue gas

Gas produced by combustion of a fuel and normally emitted to the atmosphere

Geological reservoir

Subsurface body of rock with sufficient porosity and permeability to receive, transmit, and contain gases and fluids, particularly supercritical or dense phase carbon dioxide. It includes areas or zones for expansion and migration of the carbon dioxide plume defined by reservoir modelling.

Geological storage complex

Consists of the geological reservoir and either an overlying impermeable seal (or caprock) that prevents the escape of the fluids or other reliable trapping mechanisms

Intermediate storage

The processes and equipment on a site that enables temporary storage of carbon dioxide in transit during the transfer of carbon dioxide from one mode of transport to another (e.g., transfer of carbon dioxide from a pipeline to transport by ship)

Native carbon dioxide emissions

Carbon dioxide emissions that originate directly from natural sources or processes such as volcanic eruptions, respiration by plants and animals, and decomposition of organic matter

Non-VCS carbon dioxide (non-VCS CO_2)

Carbon dioxide captured outside the project boundary of a carbon capture and storage (CCS) project activity registered under the Verified Carbon Standard (VCS) Program that is conditioned, transported, or stored using (some of) the registered CCS project activity facilities

Oxy-fuel combustion
Combustion of fossil fuels with pure oxygen or a mixture of oxygen, water, and carbon dioxide

Post-combustion capture
Capture of carbon dioxide from flue gas streams after the combustion of fuels containing carbon

Pre-combustion capture
Removing or absorbing carbon dioxide from fuels before combustion

Source facility
Facility generating CO_2 and emitting it to the atmosphere

Supercritical carbon dioxide
A state where carbon dioxide is at a temperature and pressure above its critical point, where the gas cannot be liquefied under any pressure. Typically, this occurs at temperatures above 31.11 °C and pressures exceeding 7.39 MPa.

Transport facility
Any facility used to transport carbon dioxide

Transport segment
A portion of a carbon dioxide transportation system that connects a capture facility to intermediate storage facilities, other transport segments, or storage sites. A transport segment has one mode of transport.

VCS carbon dioxide (VCS CO_2)
Carbon dioxide captured, transported (as applicable), and stored inside the project boundary of a CCS project under the VCS Program

Waste heat
Heat that is discarded by an existing thermal process and would have been wasted in the absence of the project activity

4 APPLICABILITY CONDITIONS

This methodology is globally applicable to project activities that capture carbon dioxide (CO_2) from the atmosphere or from point sources at a source facility and store it permanently in geological storage complexes.

This methodology is applicable under the following conditions:

1) Project activities include at least one eligible capture activity and at least one eligible storage activity.

2) CO_2 capture activities include any one or multiple of the following:

  - a) Direct air capture (DAC) that meet the eligibility conditions in *VMD0056 Removals from CO_2 Capture from Air (Direct Air Capture)*;
  - b) Post-combustion capture from power plants, heat generation operations, and combined heat and power (CHP) units based on fossil fuel combustion or geothermal energy that meet the eligibility conditions in *VMD00XX Emission Reductions from CO_2 Capture from Post-combustion Flue Gases in Fossil Fuel Power and Heat Generation*;
  - c) Flue gas capture from industrial processes, including chemical industry, mineral production, steel production, cement plants, and hydrogen (H_2) production, that meet the eligibility conditions in *VMD00XX Emission Reductions from CO_2 Capture from Industrial Processes*;
  - d) Flue gas capture from oil and gas production and processing, including the capture of native CO_2, acid gas removal, and liquefied natural gas (LNG) production that meet the eligibility conditions in *VMD00XX Emission Reductions from CO_2 Capture from Oil and Gas Production and Processing*;
  - e) Capture of CO_2 from biomass combustion as defined in *VMD00XX Emission Reductions or Removals from CO_2 Capture from Bioenergy Combustion* and from biofuel production processes (e.g., biogas or ethanol production) that meet the eligibility conditions in *VMD00XX Emission Reductions or Removals from CO_2 Capture from Bioproduction Processes*;
  - f) Capture of CO_2 from the pre-combustion process in power and heat generation that meet the eligibility conditions in *VMD00XX Emission Reductions from CO_2 Capture from Precombustion Processes in Fossil Fuel Power and Heat Generation*; and
  - g) Capture of CO_2 from oxyfuel combustion in power and heat generation that meet the eligibility conditions in *VMD00XX Emission Reductions from CO_2 Capture from Oxyfuel Combustion in Fossil Fuel Power and Heat Generation*.

3) Where a project transports CO_2 from a capture facility to a storage site, the transport activities meet the eligibility conditions in *VMD0057 Project Emissions from CO_2 Transport for CCS Projects.*
4) Storage activities that meet the eligibility conditions of one or multiple of the following:
  - a) *VMD0058 Project Emissions from CO_2 Storage in Saline Aquifers and Depleted Hydrocarbon Reservoirs; and*
  - b) *VMD00XX Project Emissions from CO_2 Storage via Geological Mineralization*
5) The capture facility is designed to handle a CO_2 stream that is delivered to the storage site and the stream meets the following requirements:
  - a) Minimum concentration of 95% purity; and
  - b) Compliance with applicable national/regional/local regulations related to CO_2 purity and concentration of co-injected substances.

6) Where project facilities include refrigeration systems that use industrial refrigerants, these systems:
   a) Do not use refrigerants that are controlled substances under the Montreal Protocol (e.g., HCFCs) or the Kigali Amendment (e.g., HFCs); and
   b) Comply with the most conservative (i.e., stringent) applicable regulations of the country/region where the equipment is installed.

This methodology is not applicable under the following conditions:

7) Project activities utilize captured CO_2 as a feedstock for products or services (i.e., carbon capture and utilization).
8) Project activities capture and store CO_2 through enhanced weathering, biochar production, or ocean alkalinity enhancement.
9) Project activities divert CO_2 streams from other storage or utilization activities.
10) Project activities produce CO_2 for the purpose of capturing it.
11) Project activities extract CO_2 from a geologic formation to generate credits.
12) Project activities reduce energy-related emissions from an existing CCS activity through technology improvement, operational improvement, a shift in the mode of transportation, or a switch to less carbon-intensive energy sources.

5 PROJECT BOUNDARY

The project boundary encompasses all the module boundaries. Each module in this framework describes the activities and associated GHG sources, sinks and reservoirs that must be included or excluded in the module boundary. The project proponent must define each module boundary in the project description. Figure 1 illustrates the project boundary.

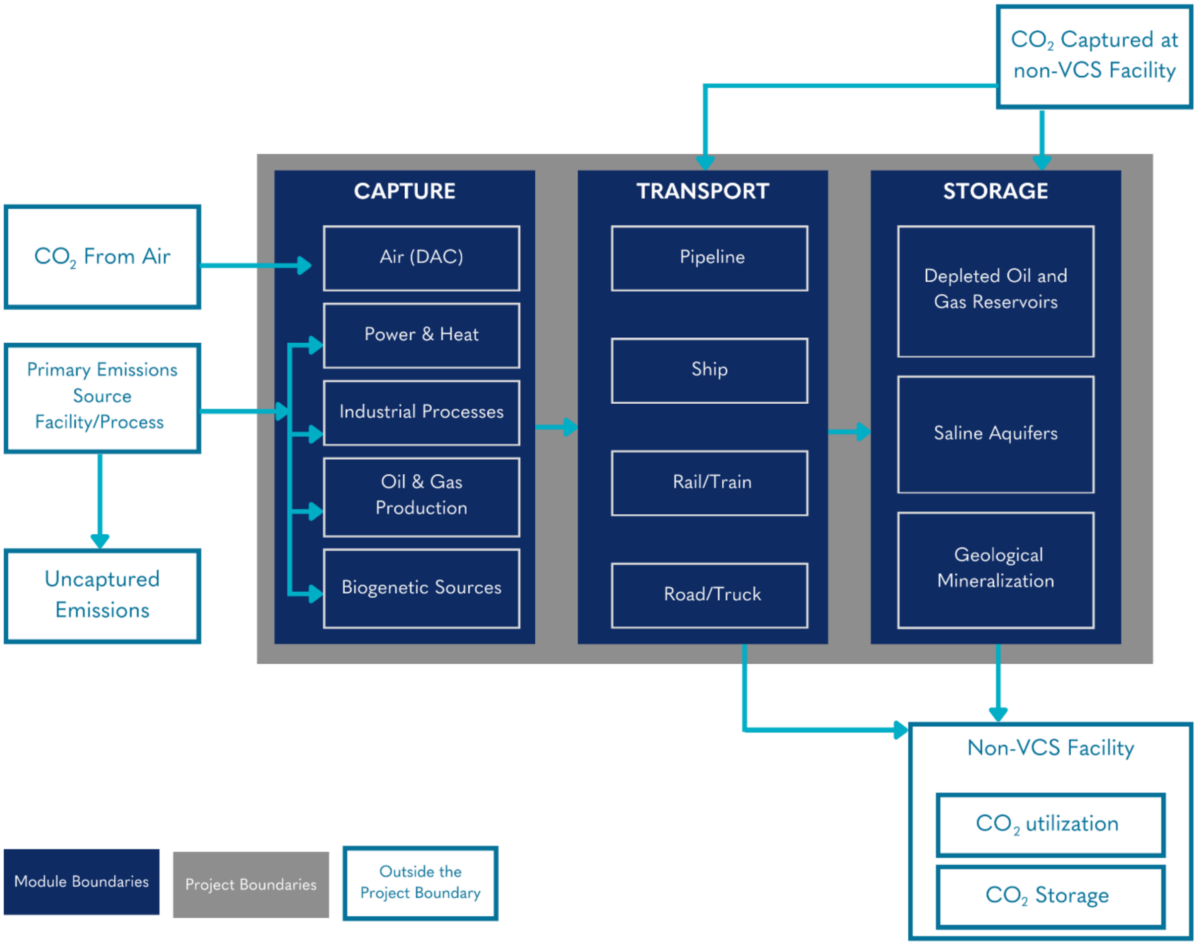
Where an emissions source is used in more than one module boundary (e.g., grid electricity consumption in capture, transport, storage activities), the proponent must:

- Describe in the project description the instances of the project activity occurring in each module boundary (e.g., grid electricity consumption occurring in the capture boundary),
- Measure or estimate each instance of that project activity separately according to the respective module requirements, and
- Quantify the impacts of the GHG source, sink or reservoir for each instance of that project activity separately in monitoring reports.

For project activities that capture CO_2 from a source facility, the project boundary includes the elements of the source facility that are directly affected, modified, or added to capture CO_2

(e.g., equipment for flue gas capture). Other elements of the source facility are not included in the project boundary.

Figure 1: Project boundary



A general overview of the GHG sources included in or excluded from the project boundary are shown in Table 1.[2] The capture, transport, and storage modules provide specific details on GHG sources and sinks relevant to those project activities.

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[2] Excluded leakage emission sources are detailed in Appendix 1.

Table 1: GHG sources included in or excluded from the project boundary

Source		Gas	Included?	Justification/Explanation
Baseline	CO_2 source facilities or the atmosphere	CO_2	Yes	CO_2 captured and injected
		CH_4	No	Only CO_2 is included. This is conservative.
		N_2O	No	Only CO_2 is included. This is conservative.
		Other	No	Only CO_2 is included. This is conservative.
Project	CO_2 capture site	CO_2	Yes	Major source. Details are provided in each capture module.
		CH_4	Yes	Major source. Details are provided in each capture module.
		N_2O	Yes	Major source. Details are provided in each capture module.
		Other	No	Negligible
	CO_2 transport facility	CO_2	Yes	Major source. Details are provided in each transport module.
		CH_4	Yes	Major source. Details are provided in each transport module.
		N_2O	Yes	Major source. Details are provided in each transport module.
		Other	No	Negligible
	CO_2 storage site	CO_2	Yes	Major source. Details are provided in each storage module.
		CH_4	Yes	Major source. Details are provided in each storage module.
		N_2O	Yes	Major source. Details are provided in each storage module.
		Other	No	Negligible

6 BASELINE SCENARIO

This methodology framework uses the project method to determine the crediting baseline scenario.

The capture modules under this framework provide the procedures and requirements for defining the baseline scenario for the relevant capture activities.

7 ADDITIONALITY

This methodology uses the project method to assess additionality using the following steps. A justification for this approach is provided in Appendix 1.

7.1 Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus per the rules and requirements set out in the most recent version of the *VCS Methodology Requirements*.

Project proponents must consider the laws, statutes, regulatory frameworks, and policies applicable in the jurisdiction of the capture site(s).

7.2 Step 2: Implementation Barrier

Project proponents must demonstrate that they face an investment barrier (i.e., capital or investment return constraints) that would prevent the project from being implemented without carbon credit revenues.

To analyze the investment barrier, project proponents must conduct an investment analysis per Step 2 in the most recent version of CDM *TOOL01 Tool for the Demonstration and Assessment of Additionality* following Option III “Apply the benchmark analysis” and using CDM *TOOL27 Investment Analysis.*

The following also applies to the investment analysis:

1) The assessment must be from the perspective of the capture activity. Transport and storage activities must be treated as costs to the capture activity. This applies to both:
    a) Projects with diverse operatorships where costs may be incurred as real fees from transport and storage site operators; and
    b) Vertically integrated projects, where the project proponent must internally account for capital and operating costs of the transport and storage site(s).
2) Revenues (e.g., from subsidies paid by governments) from capture, transport (where applicable), and storage activities must be incorporated into the investment analysis (e.g., a fee per tonne of CO_2 transported and/or stored), regardless of the owner/operator of the transport facilities and storage site(s). This does not apply to revenues arising from payments between capture, transport, and storage services as part of the project activities.
3) Where shared infrastructure is relevant to the economics of a project, costs or revenues must reflect the estimated (or contracted, where available) usage rate of transport and storage by each capture activity (e.g., where a capture activity uses 10% of the transport and storage capacity, the costs must be prorated and not reflect the cost of the entire transport and storage capacity).

4) Where multiple capture activities exist, the investment analysis must consider all capture activities in the project when demonstrating the existence of an investment barrier.

5) Where a project has undersubscribed transportation and/or storage usage at the time of the investment analysis, the expected usage rate, fee structure, and return on investment must be used as inputs.

6) Revenue and indirect financial benefits (e.g., savings) for the CO_2 source facilities must be accounted for, regardless of whether the operators of source facilities and capture facilities are the same entity. Examples include:

    a) Savings from avoiding or reducing the payment of carbon tax or other fines/levies;

    b) Revenue generation based on the forecasted value of emissions allowances granted to the project activity for periods when Verified Carbon Units (VCUs) are not issued (VCUs are not issued for the reductions and removals benefit where emissions allowances are also granted); and

    c) Savings from avoiding or reducing costs for (flue) gas cleaning.

7) Payments from the capture facilities to the source facilities for the CO_2 captured are not considered costs in the investment analysis.

8) Funding from governments or other institutions in the form of grants, tax credits, concessional loans, guarantees, contracts for difference, negative emission payments, or other subsidies (all herein referred to as public support mechanisms) must be reflected as revenues, savings, or in the determination of the benchmark as applicable, regardless of whether the project is vertically integrated or has diverse ownership.

    However, public support mechanisms should not be considered in the financial additionality analysis where:

    a) The funder requires the project proponent to try to generate and sell carbon credits as a condition for the public support mechanism; and

    b) The carbon credit revenue (in whole or part) displaces funds from the public support mechanism that would have otherwise been provided to the project.

9) In addition to the requirements of paragraph 20 (Tool01), the alternatives to the project activity used for comparison must also be mutually exclusive.

10) Option *c* in paragraph 38 (Tool01) (i.e. – a company internal benchmark) cannot be used

11) The assumptions, data, and conclusions of the investment analysis referred to paragraphs 40 – 42 (Tool01), must be consistent with information presented to the company's decision-making management and investors/lenders.

12) In addition to the requirements of paragraph 42 (Tool01), the investment analysis must also demonstrate that carbon revenues are the deciding factor in increasing the overall economic performance of the proposed activity to a level at or above the benchmark.

7.2.1 Contingencies for Operating and Maintenance Costs

Contingency costs account for costs that cannot be anticipated/forecasted when applying the investment analysis tool. Estimated contingency costs are expressed as a percentage of the operating and maintenance costs used in the investment analysis completed for a comparable prior activity. One of the following options must be used to determine contingency costs in the context of operating and maintenance costs of the project activity:

Option 1: Reference previously estimated contingency costs from other activities undertaken by the project proponent, with a comparable level of technological maturity and risk to the project activity at the time of the final investment decision.

Option 2: Reference actual historical contingency costs incurred when the project proponent implemented other activities using technologies with similar levels of maturity and risk to the project activity. The contingency costs are calculated by subtracting the actual operating and maintenance costs incurred over a given period from the estimated operating and maintenance costs for the same period. The estimated operating and maintenance costs must be obtained from background work such as feasibility studies to inform investment decisions.

Option 3: Use other approaches that have been applied in a relevant industrial sector (i.e., related to the applicable source facilities) to determine contingency costs, with a maximum value of 15% for this option.

7.3 Step 3: Common Practice

The project activity must not be common practice, determined for each capture activity included or added to the project as follows:

1) The project type must not be common practice in the respective sector and country.

- Common practice is defined as the project activity implemented in more than 20% of comparable source facilities in the sector and country.
- Similar project activities under validation, submitted for registration, or registered under any GHG crediting program may be excluded from the common practice analysis.
- The “sector” refers to the source facility sector (e.g., fossil fuel or geothermal-based power and heat generation, industrial processes, oil and gas production and processing, bioethanol production, biomass power and heat).
- Where a project includes multiple source facilities representing different sectors, each source facility requires a separate common practice assessment.

- Where different types of capture facilities are included in the project, a common practice assessment is required for each.
- DAC is not considered common practice by default, as there is no source facility.

2) Where similar activities exist, the project proponent must identify barriers faced compared with existing projects to underpin the risks, costs, and/or limitations to regular advancement of the project activity, to demonstrate that this is not common practice for the project activity.

Projects that demonstrate regulatory surplus, an investment barrier, and are not common practice are deemed additional.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND CO_2 REMOVALS

This section establishes overarching quantification approaches for reductions and removals. The approaches and equations in the modules and tools listed in Section 1 relevant to the project activity also apply.

8.1 Baseline Emissions

Baseline emissions are calculated using Equation (1):

$$BE_y = \sum_i Q_{CO2,injected,i,y} - \sum_i Q_{CO2,nonVCS,injected,i,y} \tag{1}$$

Where:

BE_y = Baseline emissions in year *y* (t CO_2e)

$Q_{CO2,injected,i,y}$ = Mass of CO_2 injected and monitored at injection point *i* in year *y* at the storage site(s), calculated using the equations for $Q_{CO2,x}$ in Section 8.1.1 (t CO_2e)

$Q_{CO2,nonVCS,injected,i,y}$ = Mass of non-VCS CO_2 injected at injection point *i* in year *y* at the storage site(s), calculated using the equations for $Q_{CO2,x}$ in Section 8.1.1 and the most recent version of *VT00XX Accounting Non-VCS CO_2 in CCS Projects*;[3] equal to zero where no non-VCS CO_2 enters the project boundary (t CO_2e)

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[3] Includes any CO_2 streams originating at capture facilities for which a valid baseline scenario is not demonstrated.

8.1.1 Methods for CO_2 Measurement

This subsection provides methods and guidance[4] for measuring the amount of CO_2 injected for safe and permanent storage. The same methods apply for measuring the amount of CO_2 captured, transported, received, and leaving the project boundary as applicable.

Flow measurements must be performed using either volumetric flow meters or mass flow meters. For supercritical phase CO_2, the total volumetric flow measurement can be inaccurate due to impurities. To determine the amount of supercritical CO_2, the project proponent must either use a mass flow meter while measuring the concentration of all impurities in the stream that are greater than 0.25% (2500 ppm) by mole fraction, or use a volumetric flow meter while measuring the density and concentration of CO_2 in the stream. The cumulative mole fraction of all neglected impurities must not exceed a 2% threshold.

Option 1: Measurement Based on Total Mass Flow

To determine the quantity of CO_2 using total mass flow measurements, the project proponent must multiply the total mass flow by the concentration of CO_2 in that flow as per Equation (2).

$$Q_{CO2,x} = FR_{mass,x} \times \%CO2_{mass,x} \tag{2}$$

Where:

$Q_{CO2,x}$ = Mass of CO_2 injected, captured, transported, received, or leaving the project boundary measured at flow meter *x* (t CO_2)

$FR_{mass,x}$ = Total mass flow measured by mass flow meter *x* during the monitoring period (tonnes)

$\%CO2_{mass,x}$ = Mass fraction of CO_2 in flow at flow meter *x* (% mass)

The mass fraction used in Equation (2) must be derived from the mole fraction (X_{CO2}) measured by sampling as per Equation (3).

$$\%CO2_{mass,x} = \frac{M_{CO2} \times X_{CO2}}{\sum_{k=1}^{n} M_k \times X_k} \tag{3}$$

Where:

M_{CO2} = Molar mass of CO_2 (g/mol)

X_{CO2} = Mole fraction of CO_2 in flow at flow meter *x* (% mole)

M_k = Molar mass of component *k* (g/mol)

X_k = Mole fraction of component *k* in flow at flow meter *x* (% mole)

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[4] Based on Section 3 of US EPA (2010). *General Technical Support Document for Injection and Geologic Storage of CO_2 under Subpart RR and UU of the GHGRP*

n = Number of components in the mixture with a mole fraction greater than 0.5% (5000 ppm), or for supercritical conditions greater than 0.25% (2500 ppm) (unitless)

Option 2: Measurement Based on Total Volumetric Flow

Alternatively, a measured total volumetric flow and corresponding density may be used to determine the CO_2 mass for a project activity. This is achieved by multiplying the total volumetric flow at standard temperature and pressure (STP)[5] by the concentration of CO_2 in the flow and by the density of CO_2 at STP as per Equation (4).

$$Q_{CO2,x} = FR_{vol,x(STP)} \times \%CO2_{vol,x(STP)} \times \rho CO2_{x(STP)} \tag{4}$$

Where:

$Q_{CO2,x}$ = Mass of CO_2 injected, captured, transported, received, or leaving the project boundary measured at flow meter *x* (t CO_2)

$FR_{vol,x(STP)}$ = Total volume measured by flow meter *x* at actual conditions during the monitoring period and converted to STP conditions (m^3)

$\%CO2_{vol,x(STP)}$ = Volumetric fraction of CO_2 in flow at flow meter *x* at STP conditions (% volume)

$\rho CO2_{x(STP)}$ = Density of CO_2 at flow meter *x* at STP conditions (t CO_2/m^3)

The volumetric CO_2 fraction must be derived from the mole fraction (X_{CO2}) measured by sampling and evaluated at STP, as shown in Equation (5).

$$\%CO2_{vol,x(STP)} = \frac{X_{CO2}}{\sum_{k=1}^{n} X_k} \tag{5}$$

Where:

X_{CO2} = Mole fraction of CO_2 in flow at flow meter *x* (% mole)

X_k = Mole fraction of component *k* in flow at flow meter *x* (% mole)

n = Number of components in the mixture with a mole fraction greater than 0.5% (5000 ppm), or for supercritical conditions greater than 0.25% (2500 ppm)

Using the operating temperature and pressure, the actual volume of CO_2 is converted into STP conditions as per Equation (6).

$$FR_{vol,x(STP)} = \frac{FR_{vol,x(P,T)} \times \rho CO2_{x(P,T)}}{\rho CO2_{x(STP)}} \tag{6}$$

Where:

$FR_{vol,x(P,T)}$ = Total volume measured by flow meter *x* at actual conditions (m^3)

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[5] STP must be selected and defined by the project proponent as per industry practice in their geographic location.

$\rho CO2_{x(P,T)}$ = Density of CO_2 at actual conditions at flow meter x (t CO_2/m^3)

$\rho CO2_{x(STP)}$ = Density of CO_2 at STP conditions at flow meter x (t CO_2/m^3)

8.2 Project Emissions

The overarching equation for project emissions is Equation (7):

$$PE_y = \sum_c PE_{Cap,c,y} + \sum_t PE_{Tra,t,y} + \sum_s PE_{Sto,s,y} \tag{7}$$

Where:

PE_y = Project emissions in year y (t CO_2e)

$PE_{Cap,c,y}$ = Project emissions from CO_2 capture activity c in year y (t CO_2e)

$PE_{Tra,t,y}$ = Project emissions from CO_2 transport activity t in year y (t CO_2e)

$PE_{Sto,s,y}$ = Project emissions from CO_2 storage activity s in year y (t CO_2e)

Quantification procedures for project emissions from capture, transport, and storage are established under the respective modules listed in Section 1.

8.3 Leakage Emissions

The overarching equation for leakage emissions is Equation (8):

$$LE_y = \sum_c LE_{Cap,c,y} + \sum_t LE_{Tra,t,y} + \sum_s LE_{Sto,s,y} \tag{8}$$

Where:

LE_y = Leakage emissions in year y (t CO_2e)

$LE_{Cap,c,y}$ = Leakage emissions from CO_2 capture activity c in year y (t CO_2e)

$LE_{Tra,t,y}$ = Leakage emissions from CO_2 transport activity t in year y (t CO_2e)

$LE_{Sto,s,y}$ = Leakage emissions from CO_2 storage activity s in year y (t CO_2e)

Quantification procedures for leakage emissions from capture, transport, and storage are established under the respective modules listed in Section 1.

8.4 Estimated GHG Emission Reductions and Carbon Dioxide Removals

Reductions or removals are generally calculated as per Equation (9):

$$ER_y = \left(BE_y - PE_y - LE_y\right) \times (1 - DF) \tag{9}$$

Where:

ER_y = Total net reductions or removals in year y (t CO_2e)

BEy = Baseline emissions in year y as calculated in Equation (1) (t CO2e)

PE_y = Project emissions in year y as calculated in Equation (7) (t CO_2e)
LE_y = Leakage emissions in year y as calculated in Equation (8) (t CO_2e)
DF = Discount factor for conservativeness calculated in Equation (13) (%)

Projects that achieve both reductions and removals must use the most recent version of *VT00XX Differentiating Reductions and Removals in CCS Projects*. In such cases, Equation (9) is replaced by Equations (10), (11), and (12).

$$ER_y = ER_{CAPR,y} + ER_{CAPE,y} \tag{10}$$

$$ER_{CAPR,y} = \left(BE_{CAPR,y} - \sum_g PE_{CAPR,g,y} - \sum_g LE_{CAPR,g,y}\right) \times (1 - DF) \tag{11}$$

$$ER_{CAPE,y} = (BE_{CAPE,y} - \sum_g PE_{CAPE,g,y} - \sum_g LE_{CAPE,g,y}) \times (1 - DF) \tag{12}$$

Where:

$ER_{CAPR,y}$ = Removals in year y (t CO_2e)
$ER_{CAPE,y}$ = Reductions in year y (t CO_2e)
$BE_{CAPR,y}$ = Baseline emissions associated with removals in year y as calculated in Section 5 of *VT00XX Differentiating Reductions and Removals in CCS Projects* (t CO_2e)
$PE_{CAPR,g,y}$ = Project emissions from segment g in year y associated with removals as calculated in Section 5 of *VT00XX Differentiating Reductions and Removals in CCS Projects* (t CO_2e)
$LE_{CAPR,g,y}$ = Leakage emissions from segment g in year y associated with removals as calculated in Section 5 of *VT00XX Differentiating Reductions and Removals in CCS Projects* (t CO_2e)
$BE_{CAPE,y}$ = Baseline emissions associated with reductions in year y as calculated in Section 5 of *VT00XX Differentiating Reductions and Removals in CCS Projects* (t CO_2e)
$PE_{CAPE,g,y}$ = Project emissions from segment g in year y associated with reductions as calculated in Section 5 of *VT00XX Differentiating Reductions and Removals in CCS Projects* (t CO_2e)
$LE_{CAPE,g,y}$ = Leakage emissions from segment g in year y associated with reductions as calculated in Section 5 of *VT00XX Differentiating Reductions and Removals in CCS Projects* (t CO_2e)
DF = Discount factor for conservativeness calculated in Equation (13) (%)

8.5 Uncertainty

This methodology allows project proponents to develop projects using a combination of capture, transportation and storage activities and each may have a different level of inherent uncertainty. As such, the process for determining the uncertainty associated with each project activity is defined in the relevant module under the methodology.

8.5.1 Identification and Assessment of Uncertainties

For modules that require the project proponent to assess uncertainty, that assessment must follow the steps below.

Step 1: Identify Potential Sources of Uncertainty

Examine all steps in the GHG calculation process to identify potential sources of uncertainty, including measurement errors, model assumptions, and data quality issues.

Step 2: Calculation of Overall Uncertainty ($U_{overall}$)

The project proponent must calculate the overall uncertainty in the volume of net reductions and removals using one of the following approaches.

- **Error Propagation:** Use error propagation equations to combine uncertainties from various data sources and measurement errors. Project proponents may follow Volume 1, Chapter 3, Section 3.2.3.1 in IPCC (2006) to estimate overall uncertainty.
- **Monte Carlo Simulations:** Employ Monte Carlo simulations for more complex or interdependent data sources to model the probability distributions of inputs and calculate the resulting distribution of the emission estimates. This technique is beneficial when dealing with non-linear relationships or when input variables are not independent.

Step 3: Calculation of Discount Factor (DF)

The project proponent must apply a discount factor to the calculated net reductions and removals. The discount factor is identified as follows:

1) Where the overall uncertainty calculated in Step 2 is unlikely to exceed 10%, the discount factor may be estimated to be zero.
2) Where the overall uncertainty calculated in Step 2 is likely to exceed 10%, the discount factor must be calculated with the following equation.

$$DF = \frac{U_{Overall}}{t_{\alpha=10\%}} \times x\ t_{\alpha=66.6\%} \qquad (13)$$

Where:

DF = Discount factor for conservativeness (%)
$U_{overall}$ = Overall uncertainty (%)
$t_{\alpha=10\%}$ = t-value for a two-sided 90% confidence interval, equal to (1.6449)
$t_{\alpha=66.690\%}$ = t-value for a one-sided 66.67% confidence interval, equal to (0.4307)

9 MONITORING

9.1 Data and Parameters Available at Validation

Data/Parameter	M_{CO2}
Data unit	g/mol
Description	Molar mass of CO_2
Equations	(3)
Source of data	The most recent version of the CDM *TOOL06 Methodological Tool: Project Emissions From Flaring*
Value applied	44.0095
Justification of choice of data or description of measurement methods and procedures applied	A physical constant
Purpose of data	Calculation of baseline and project emissions
Comments	N/A

Data/Parameter	*STP*
Data unit	K and Pa
Description	Standard temperature and pressure
Equations	(4), (5), (6)
Source of data	Industry practice
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Standard temperature and pressure must be defined to allow the conversion of volumetric flow from operating to standard conditions.
Purpose of data	To determine CO_2 density
Comments	The project description must clearly identify the standard temperature and pressure used as a reference.

Data/Parameter	$\rho CO2_{x(STP)}$
Data unit	t CO_2/m^3
Description	Density of CO_2 at flow meter *x* at standard temperature and pressure
Equations	(4), (6)
Source of data	Internationally accepted datasets following equation of states as applicable (e.g., Span and Wagner, 1996)[6]
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Density depends on temperature and pressure as defined under standard temperature and pressure conditions.
Purpose of data	Calculation of baseline and project emissions
Comments	The project description must clearly identify the standard temperature and pressure used as a reference.

9.2 Data and Parameters Monitored

Data/Parameter	$FR_{mass,x}$
Data unit	tonnes
Description	Mass flow measured by mass flow meter *x*
Equations	(2)
Source of data	Mass flow meters
Description of measurement methods and procedures to be applied	Mass flow rates must be determined by commercially available devices that measure the mass flow rate of a fluid flowing through a measurement channel (e.g., Coriolis meters, thermal meters, impeller meters, twin turbine meters).
Frequency of monitoring/recording	Monitored continuously (i.e., one measurement at least every 15 minutes)

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[6] For further information, see National Institute of Standards and Technology (NIST) available at https://webbook.nist.gov/chemistry/fluid/ or similar.

QA/QC procedures to be applied	The metering equipment must be installed and calibrated in accordance with the specifications of either local/national standards or the manufacturer. Where local/national standards and manufacturer specifications are unavailable, international standards (e.g., IEC, ISO) must be followed.
Purpose of data	Calculation of baseline and project emissions
Calculation method	Direct measurement (preferred) or the accumulated mass for each sampling interval of mole fractions (composition analysis)
Comments	For further guidance see US EPA (2010). *General Technical Support Document for Injection and Geologic Sequestration of Carbon Dioxide: Subparts RR and UU GHG Reporting Program*.

Data/Parameter	M_k
Data unit	g/mol
Description	Molar mass of component *k*
Equations	(3)
Source of data	Physical property tables
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	To be updated based on components *k* found in the CO_2 stream
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of baseline and project emissions
Calculation method	N/A
Comments	N/A

Data/Parameter	X_{CO2}
Data unit	% mole

Description	Mole fraction of CO_2 in flow at flow meter *x*
Equations	(3), (5)
Source of data	Composition analysis
Description of measurement methods and procedures to be applied	Mole fractions must be determined by commercially available devices. **Option A:** gas chromatography **Option B:** gas chromatography with IR spectroscopy
Frequency of monitoring/recording	**Option A:** Monitored every 15 minutes and aggregated weekly **Option B:** Monitored every 15 minutes and aggregated monthly
QA/QC procedures to be applied	The metering equipment must be installed and calibrated in accordance with the specifications of either local/national standards or the manufacturer. Where local/national standards and manufacturer specifications are unavailable, international standards (e.g., IEC, ISO) must be followed.
Purpose of data	Calculation of baseline and project emissions
Calculation method	Direct measurement **Option A:** Use the lower value of two consecutive composition analyses to calculate continuous (i.e., at least every 15 minutes) values between the two composition measurements. **Option B:** Use values from IR spectroscopy measurements
Comments	For further guidance see US EPA (2010).

Data/Parameter	X_k
Data unit	% mole
Description	Mole fraction of component *k* in flow at flow meter *x*
Equations	(3), (5)
Source of data	Composition analysis
Description of measurement methods and procedures to be applied	Mole fractions must be determined by commercially available devices. **Option A:** gas chromatography **Option B:** gas chromatography with IR spectroscopy

Frequency of monitoring/recording	**Option A:** Monitored every 15 minutes and aggregated weekly **Option B:** Monitored every 15 minutes and aggregated monthly
QA/QC procedures to be applied	The metering equipment must be installed and calibrated in accordance with the specifications of either local/national standards or the manufacturer. Where local/national standards and manufacturer specifications are not available, international standards (e.g., IEC, ISO) must be followed.
Purpose of data	Calculation of baseline and project emissions
Calculation method	Direct measurement **Option A:** Use the lower value of two consecutive composition analyses to calculate continuous (i.e., at least every 15 minutes) values between the two composition measurements. **Option B:** Use values from IR spectroscopy measurements.
Comments	For further guidance see US EPA (2010).

Data/Parameter	$x(P,T)$
Data unit	Pa and K
Description	Pressure and temperature at operating conditions in flow at flow meter x
Equations	(6)
Source of data	Pressure and temperature meters
Description of measurement methods and procedures to be applied	Instruments with recordable electronic signals (analog or digital) are required (e.g., pressure transducers, thermocouples, thermistors).
Frequency of monitoring/recording	Monitored continuously (i.e., same time interval as flow rate measurement)
QA/QC procedures to be applied	The metering equipment must be installed and calibrated in accordance with the specifications of either local/national standards or the manufacturer. Where local/national standards and manufacturer specifications are unavailable, international standards (e.g., IEC, ISO) must be followed.
Purpose of data	Calculation of baseline and project emissions
Calculation method	Average value over the same time interval as the flow rate measurement

Comments	N/A

Data/Parameter	$FR_{vol,x(P,T)}$
Data unit	m^3
Description	Total volume measured by flow meter *x* at actual conditions during the monitoring period
Equations	(6)
Source of data	Volumetric flow meters
Description of measurement methods and procedures to be applied	Volumetric flow must be determined by commercially available devices that measure the flow of a fluid through a measurement channel (e.g., rotameters, turbine meters, orifice meters, wedge meters, ultra-sonic flow meters, vortex flow meters).
Frequency of monitoring/recording	Monitored continuously (i.e., one measurement at least every 15 minutes)
QA/QC procedures to be applied	The metering equipment must be installed and calibrated in accordance with the specifications of either local/national standards or the manufacturer. Where local/national standards and manufacturer specifications are not available, international standards (e.g., IEC, ISO) must be followed.
Purpose of data	Calculation of baseline and project emissions
Calculation method	Flow is measured directly and aggregated for reporting period to calculate total volume.
Comments	For further guidance see US EPA (2010).

Data/Parameter	$\rho CO2_{x(P,T)}$
Data unit	t CO_2/m^3
Description	Density of CO_2 at actual conditions at flow meter *x*
Equations	(6)

Source of data	Internationally accepted datasets following equation of states as applicable (e.g., Span and Wagner, 1996)[7]
Description of measurement methods and procedures to be applied	Density is derived from the measurement of temperature and pressure at actual conditions.
Frequency of monitoring/recording	Aligned to the measurement of $FR_{vol,x(P,T)}$
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of baseline and project emissions
Calculation method	Density of CO_2 at actual conditions
Comments	For further guidance see US EPA (2010).

9.3 Description of the Monitoring Plan

The project proponent must establish, maintain, and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling, and analyzing data, parameters, and other information important for quantifying and reporting GHG emissions relevant to the project and baseline scenarios. Monitoring procedures must address the following:

1) Types of data and information to be reported;
2) Units of measurement;
3) Origin of the data;
4) Monitoring methodologies (e.g., estimation, modeling, measurement, and calculation);
5) Type of equipment used;
6) Monitoring times and frequencies;
7) QA/QC procedures;
8) Monitoring roles and responsibilities, including experience and training requirements; and
9) GHG information management systems, including the location, backup, and retention of stored data.

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[7] For further information, see National Institute of Standards and Technology (NIST) or similar.

Where measurement and monitoring equipment is used, the project proponent must ensure the equipment is calibrated according to current good practice (e.g., relevant industry standards).

Quality assurance/quality control (QA/QC) procedures must include, but are not limited to:

a) Data gathering, input, and handling measures;

b) Checking input data for typical errors, including inconsistent physical units and unit conversion errors;

c) Checking for typographical errors caused by data transcription from one document to another and missing data for specific time periods or physical units;

d) Checking input time series data for unexpected variations (e.g., orders of magnitude) that may indicate input errors;

e) Use of version control for all electronic files to ensure consistency;

f) Physical protection of monitoring equipment;

g) Physical protection of records of monitored data (e.g., hard copy and electronic records);

h) Checking and documenting input data units; and

i) Documenting all sources of data, assumptions, and emission factors.

Additional criteria and procedures for monitoring are established in respective capture, transport, and storage modules and related VCS and CDM tools.

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APPENDIX 1: BACKGROUND INFORMATION

A1.1 Justification for the Use of the Project Method to Demonstrate Additionality

The selection of the project method for assessing additionality is based on the following considerations pertinent to CCS projects:

- **Complex regulatory and operational environments:** CCS projects are subject to a diverse array of legal, technological, and market conditions that vary significantly across jurisdictions. The project method allows for an in-depth and conservative examination of these factors on a project-by-project basis, ensuring that assessments of regulatory surplus and specific implementation barriers are accurately discussed.

- **Investment barriers:** Given the high capital requirements, technological uncertainties, and potential for variable financial returns associated with CCS projects, demonstrating investment barriers is a central component of establishing additionality. The project method effectively addresses this by incorporating detailed investment analysis tools, enabling a nuanced evaluation of the financial viability and specific economic challenges faced by CCS projects.

- **Technology-specific considerations:** The range of technologies involved in CCS, each with a different level of maturity and implementation challenges, necessitates a method that can accommodate such variability. The project method allows for the consideration of technology-specific factors, including performance, integration complexity, and scalability, which are vital for assessing the additionality of CCS projects.

- **Sectoral and geographic variability:** CCS encompasses a broad spectrum of activities across various sectors and regions, each with distinct attributes and challenges. The flexibility of the project method in evaluating additionality for different capture activities, sectors, and geographic contexts ensures that the unique aspects of various CCS applications are adequately considered.

- **Dynamic market conditions:** The evolving nature of policies, technologies, and market dynamics impacting the CCS sector requires an additionality assessment approach that can adapt to changing conditions. The project method provides a structured, flexible framework that facilitates incorporation of the most recent and relevant data, reflecting the dynamic environment in which CCS projects operate.

A1.2 Materiality Threshold

The materiality threshold determines which leakage emissions are material and are either included in the GHG quantification or excluded. A leakage source has been included in the quantification where it is estimated to equal more than 2% of the net project reductions and removals over the anticipated typical project lifetime. Total excluded leakage emissions must not exceed this 2% threshold in total. The following leakage sources are excluded.

1) Production and transport of equipment and materials used for construction of project facilities;
2) Research and development activities;
3) Staff commuting; and
4) Direct and indirect land use change due to construction and operation of project facilities and equipment.

DOCUMENT HISTORY

Version	Date	Comment
v1.0	27 June 2024	Initial version