Verified Carbon Standard

VCS Module

VMD0056

CO_2 CAPTURE FROM AIR (DIRECT AIR CAPTURE)

Version 1.0

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Sectoral Scope 16: Carbon Capture and Storage

This module 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.

CONTENTS

1 SUMMARY DESCRIPTION

This module provides procedures and requirements to calculate project and leakage emissions generated by direct air capture (DAC) project activities eligible under the most recent version of *VCS Methodology VM0049 Carbon Capture and Storage*.

Project emissions from DAC ($PE_{Cap,y}$) are calculated in Equation (1).

Leakage emissions from DAC ($LE_{Cap,y}$) are calculated in Equation (5).

The emissions calculated in this module, together with those calculated in the transport and storage modules, are used in *VM0049* to calculate the net CO_2 removals from DAC projects.

2 SOURCES

This module is used in combination with the most recent versions of *VM0049* and the following VCS Program modules and tools:[1]

Capture Modules

- *VMD00XX CO_2 Capture from Bioenergy Combustion*
- *VMD00XX CO_2 Capture from Bioproduction Processes*
- *VMD00XX CO_2 Capture from Post-combustion Flue Gases in Fossil Fuel Power and Heat Generation*
- *VMD00XX CO_2 Capture from Industrial Processes*
- *VMD00XX CO_2 Capture from Oil and Gas Production and Processing*
- *VMD00XX CO_2 Capture from Precombustion Processes in Fossil Fuel Power and Heat Generation*
- *VMD00XX CO_2 Capture from Oxyfuel Combustion in Fossil Fuel Power and Heat Generation*

Transport Module

- *VMD0057 CO_2 Transport for CCS Projects*

Storage Module

- *VMD0058 CO_2 Storage in Saline Aquifers and Depleted Hydrocarbon Reservoirs*

[1] Modules labeled "*VMD00XX*" and tools labeled "*VT00XX*" are under development.

- *VMD00XX CO_2 Storage via Geological Mineralization*

Other Modules, Tools, and Requirements

- *VT0010 Emissions from Electricity Consumption*
- *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*

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

- *CDM TOOL09 Determining the baseline efficiency of thermal or electric energy generation systems*
- *CDM TOOL10 Tool to determine the remaining lifetime of equipment*

3 DEFINITIONS

In addition to the definitions set out in the *VCS Program Definitions* and *VM0049*, the following definition applies to this module.

Membrane process
A method for separating carbon dioxide via semi-permeable materials that allow for the selective transport and separation of carbon dioxide

4 APPLICABILITY CONDITIONS

This module applies to project activities that capture CO_2 from ambient air using the most recent version of *VM0049*.

This module is applicable under the following conditions:

1) Project activities capture atmospheric CO_2 from ambient air using one or a combination of the following processes:

    a) Chemical or physical absorption or adsorption, with liquid solvents or solid sorbents (e.g., amines);

    b) Membrane processes;

c) Electro-chemical processes; or

d) Cryogenic processes.

2) Project activities are designed to regenerate the primary capture fluid or media, such that it is not a one-time use, and a concentrated CO_2 stream is recovered from regeneration and available for subsequent transport (where applicable) and storage.

3) Project activities lead to and include DAC at new capture facilities, an expansion of existing DAC facilities, or a refurbishment of existing DAC facilities that would have been decommissioned by the project start date in the absence of the project activity.

This module is not applicable under the following conditions:

4) Project activities capture CO_2 from a point source facility.

5 PROCEDURES

5.1 Module Boundary

The module boundary includes at least the DAC facility. Commonly used equipment or processes include:

- Equipment used to generate airflow for the capture process (e.g., fans);
- Capture of CO_2 in contactors, beds, or vessels by absorption, adsorption, or other processes;
- Regeneration processes to generate a CO_2 stream and recover capture fluid or media;
- Conditioning of CO_2 to allow further processing of CO_2 along the CCS segments (namely transport and storage); and
- Co-located utilities for the CO_2 capture process (e.g., air separation units, water treatment systems, steam systems).

Section 5 of the most recent version of *VM0049* provides further details on determining the module boundary. The DAC facility, ancillary sites, equipment, and relevant project emissions included in the module boundary and quantified using this module must be clearly identified and documented. The project proponent must ensure that equipment is not omitted or double counted.

This module calculates the total emissions from the sources listed in Table 1.

In cases where non-VCS[2] CO_2 flows through the project boundary, the most recent version of *VT00XX Accounting non-VCS CO_2 in CCS Projects* must be used to calculate the proportion of emissions from project sources associated with that non-VCS CO_2.

The boundary for this module is presented in Figure 1.

Figure 1: Module boundary of a DAC project

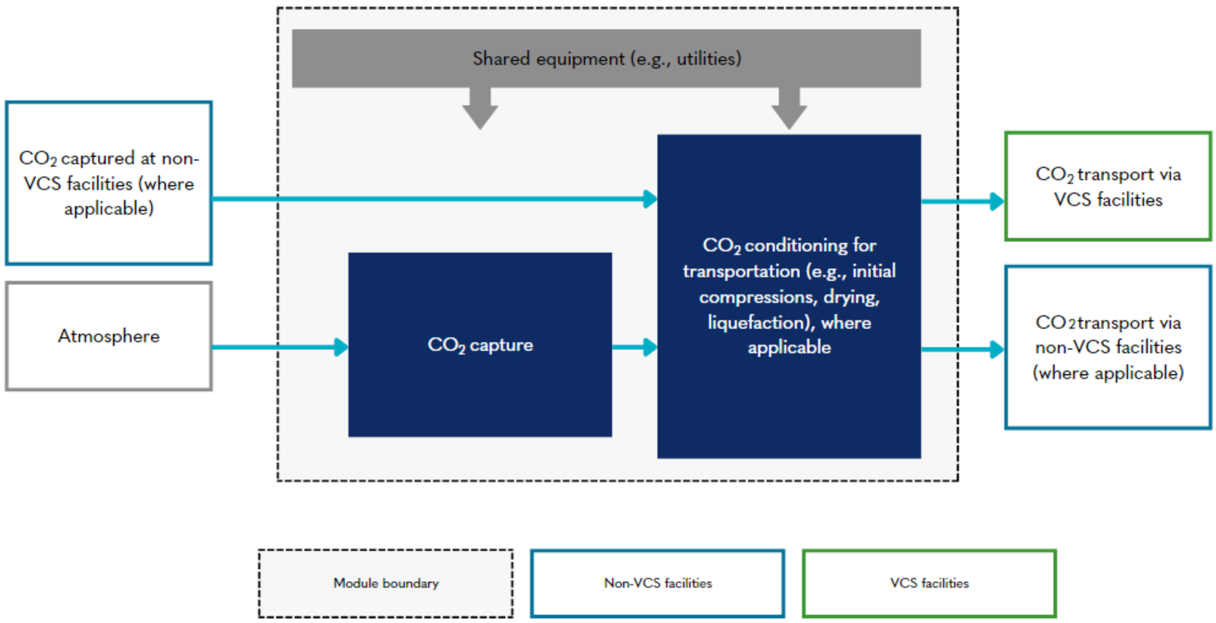
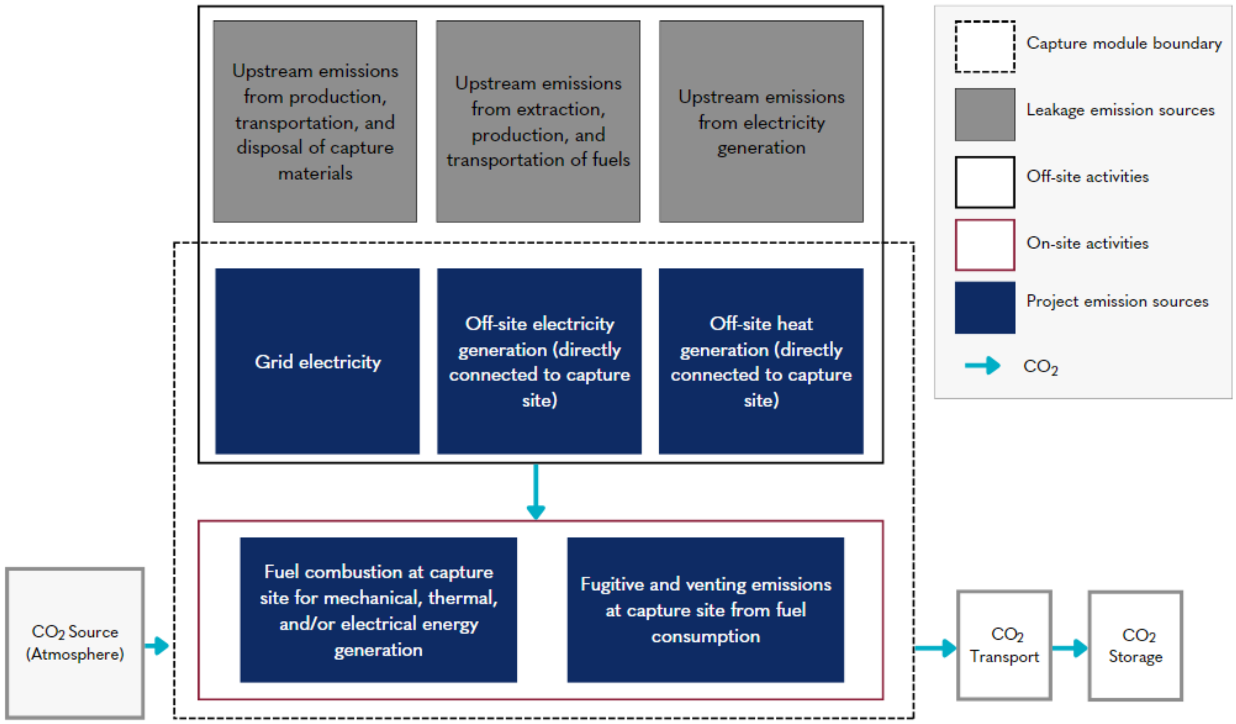


Figure 2 illustrates the project and leakage emissions covered in this module, relative to the module boundary.

[2] Non-VCS CO_2 is defined as "CO_2 that flows through a CCS project boundary that is not eligible for crediting in the VCS" in *VT00XX Accounting non-VCS CO_2 in CCS Projects.*

Figure 2: Included greenhouse gas sources



The greenhouse gases (GHGs) included in or excluded from the module boundary are detailed in Table 1.

This module assumes that no capture of CO_2 relevant to the project activities took place in the baseline scenario. As such, no emissions sources associated with the baseline scenario are included in Table 1.

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

Source		Gas	Included?	Justification/Explanation
Project	Electricity consumption	CO_2	Yes	Major emission source
		CH_4	Yes	Included for completeness
		N_2O	Yes	Included for completeness
		Other	No	Excluded for simplicity; emissions are considered negligible.
	Fuel consumption	CO_2	Yes	Major emission source
		CH_4	Yes	Included for completeness
		N_2O	Yes	Included for completeness
		Other	No	Excluded for simplicity; emissions are considered negligible.

Source		Gas	Included?	Justification/Explanation
	CO_2 fugitive and venting emissions	CO_2	Yes	Included. Any loss of CO_2 due to fugitive emissions or venting during capture is inherently deducted from the overall calculation of GHG emission removals since only injected CO_2 volumes are quantified as the baseline emissions.
	Fugitive and venting emissions from on-site fuel use	CO_2	No	Excluded for simplicity; emissions are considered negligible.
		CH_4	Yes	Significant emission source
		N_2O	No	Excluded for simplicity; emissions are considered negligible.
		Other	No	Excluded for simplicity; emissions are considered negligible.

5.2 Description of Baseline Scenario

Project proponents must accurately determine the activities and GHG emissions that would have occurred in the absence of the project activity.

Baseline B1: A direct air capture facility would not be operating at the project site.

To use baseline B1, project proponents must demonstrate:

a) No DAC facility existed before the start of the project at the location designated for the project, or

b) An existing DAC facility was at end of life before the start of the project using the most recent version of *CDM TOOL10 Tool to determine the remaining lifetime of equipment*[3]

Baseline B2: There would be no increase in the atmospheric CO_2 capture capacity at the existing facility relevant to the project.

To use baseline B2, project proponents must demonstrate the DAC capacity of the existing facility at the start of the project.

Under baseline B2 the amount of CO_2 that would have been captured before the project start date that is stored within the project boundary must be accounted for as non-VCS CO_2 in each segment according to the procedures outlined in the most recent version of *VT00XX Accounting non-VCS CO_2 in CCS Projects*.

5.3 Quantification of Project Emissions

The following sections provide guidance for determining project emissions from DAC activities (i.e., $PE_{Cap,y}$). Project emissions are calculated as per Equation (1).

$$PE_{Cap,y} = PE_{Comb_{Fuel},y} + PE_{Fuel_{FV},y} + PE_{Elec,y} - PE_{nonVCS\ CO2,y} \quad (1)$$

Where:

$PE_{Cap,y}$	=	Project emissions from capture in year *y* (t CO_2e)
$PE_{Comb\_Fuel,y}$	=	Project emissions from fuel combustion to operate on-site and/or third-party (for off-site heat/steam supply) equipment for capture and conditioning processes in year *y* (t CO_2e)
$PE_{Fuel\_FV,y}$	=	Fugitive and venting from on-site fuel use (e.g., natural gas) in the module in year *y* (t CO_2e)
$PE_{Elec,y}$	=	Project emissions from electricity consumption to operate equipment in the DAC facility in year *y* calculated using *VT0010 Emissions from Electricity Consumption* (t CO_2e)
$PE_{nonVCS\ CO2,y}$	=	Project emissions from processes and equipment related to non-VCS sources in year *y* determined using the most recent version of *VT00XX Accounting Non-VCS CO_2 in CCS Projects*; equal to zero for projects with no non-VCS CO_2 (t CO_2e)

5.3.1 Project Emissions from Fuel Combustion

Project emissions from fossil fuel combustion for mobile equipment, flaring, and power and heat generation are calculated as follows:

$$PE_{Comb_{Fuel},y} = \sum_d (Q_{Fuel,d,y} \times EF_{Fuel,CO2,d}) + \sum_d (Q_{Fuel,d,y} \times EF_{Fuel,CH4,d}) \times GWP_{CH4} + \sum_d (Q_{Fuel,d,y} \times EF_{Fuel,N2O,d}) \times GWP_{N2O} \quad (2)$$

Where:

$Q_{Fuel,d,y}$	=	Quantity of fuel type *d* used to operate on-site and/or third-party (for off-site heat/steam supply) equipment in year *y* (m^3 or kg or GJ)
$EF_{Fuel,CO2,d}$	=	CO_2 emission factor for combustion of fuel *d* (t CO_2/m^3 or t CO_2/kg or t CO_2/GJ); equal to zero for fuels derived from biomass[4]
$EF_{Fuel,CH4,d}$	=	CH_4 emission factor for combustion of fuel *d* (t CH_4/m^3 or t CH_4/kg or t CH_4/GJ)
$EF_{Fuel,N2O,d}$	=	N_2O emission factor for combustion of fuel *d* (t N_2O/m^3 or t N_2O/kg or t N_2O/GJ)
GWP_{CH4}	=	Global warming potential for CH_4 (t CO_2e/t CH_4)

[4] Sustainable biomass is defined in the most recent version of *VT00XX Differentiating Reductions and Removals in CCS Projects*.

GWP_{N2O} = Global warming potential for N_2O (t CO_2e/t N_2O)

In the absence of an emissions factor that only considers combustion emissions for a given fuel, a combined emissions factor for both combustion and upstream emissions may be used as $EF_{Fuel,d}$ in Equation (2).

Off-site Fuel Consumption

The quantity of power or heat supplied from a directly connected off-site facility, $Q_{Fuel,d,y}$, is determined using Equation (3).

$$Q_{Fuel,d,y} = Q_{Cogen,d,y} \times \frac{\left({Heat_{DAC,y}}/{\eta_{Heat,y}} + {Electricity_{DAC,y}}/{\eta_{Elec,y}} \right)}{\left({Heat_{Cogen,y}}/{\eta_{Heat,y}} + {Electricity_{Cogen,y}}/{\eta_{Elec,y}} \right)} \quad (3)$$

Where:

$Q_{Cogen,d,y}$	=	Quantity of fuel type *d* used by the cogeneration unit to generate electricity and/or heat in year *y* (m^3 or kg or GJ)
$Heat_{DAC,y}$	=	Quantity of useful thermal energy supplied to the DAC facility by the cogeneration unit in year *y* (MWh)
$Electricity_{DAC,y}$	=	Quantity of electricity supplied to the DAC facility by the cogeneration unit in year *y*; equal to zero where only heat is supplied to the DAC facility (MWh)
$Heat_{Cogen,y}$	=	Total quantity of useful thermal energy produced by the cogeneration unit in year *y* (MWh)
$Electricity_{Cogen,y}$	=	Total quantity of electricity produced by the cogeneration unit in year *y* (MWh)
$\eta_{Heat,y}$	=	Efficiency of thermal energy production from cogeneration unit determined in year *y* using the most recent version of CDM TOOL09
$\eta_{Elec,y}$	=	Efficiency of electricity production from cogeneration unit determined in year *y* using the most recent version of CDM TOOL09

Co-capture of Fossil Fuel Combustion CO_2 in the DAC Facility

A portion of the CO_2 captured from the ambient environment around a DAC facility with on-site fossil fuel combustion is derived from that combustion. However, the combustion emissions are accounted for as project emissions in Equation (2) and therefore are not accounted for as part of the captured CO_2 eligible to generate credits under this module.

Waste Heat

Project emissions from the consumption of waste heat may be assumed to be zero for heat sources that meet the definition of waste heat in *VM0049*. The emissions associated with the generation of heat that does not meet the definition of waste heat must be accounted for in Equation (2) or (3) as appropriate.

5.3.2 Fugitive and Venting Emissions from On-site Fuel Use

DAC projects using natural gas on-site must quantify fugitive and venting emissions during facility operations. Quantification is based on component counts and respective emission factors, fugitive emissions are quantified following the approach in the US Environmental Protection Agency's *Electronic Code of Federal Regulations*, Title 40, Part 98, Subpart W, § 98.233 (r).[5]

Examples of emission sources for fugitive emissions include components such as valves, pipe fittings/connectors, open-ended pipes, pressure relief valves, flanges, meters, and instruments.

$$PE_{Fuel_{FV},y} = \left(\sum_n Count_{n,y} \times EF_n \times T_{n,y} \times 0.001 + \sum_m V_m\right) \times GWP_{CH_4} \quad (4)$$

Where:

$Count_{n,y}$	=	Total number of components *n* in natural gas service at the facility during year *y* (unitless)
EF_n	=	Emission factor for fugitive emissions for component *n* (kg CH_4/hr/unit)
$T_{n,y}$	=	Pressurized time of component *n* in year *y* (hours)
V_m	=	Vented CH_4 emissions for venting event *m* (t CH_4/event)
0.001	=	Conversion from kg to t

5.4 Quantification of Leakage

The leakage emissions from the project activities are calculated as per Equation (5).

$$LE_{Cap,y} = LE_{Fuel,y} + LE_{Elec,y} + LE_{Mat,y} + LE_{Biomass,y} - LE_{nonVCS\,CO2,y} \quad (5)$$

Where:

$LE_{Cap,y}$	=	Leakage emissions from capture in year *y* (t CO_2e)
$LE_{Fuel,y}$	=	Leakage emissions from upstream sources related to the fuel consumed in in the module boundary year *y* (t CO_2e)
$LE_{Elec,y}$	=	Leakage emissions from electricity consumption to operate equipment in the DAC facility in year *y* calculated using *VT0010 Emissions from Electricity Consumption* (t CO_2e)
$LE_{Mat,y}$	=	Leakage emissions from capture materials used in the DAC process in year *y* (t CO_2e)
$LE_{Biomass,y}$	=	Leakage emissions from the supply of biomass feedstock *d* for energy production in year y determined using the most recent version of *VMD00XX CO2 Capture from Bioenergy Combustion*

[5] Available at: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-W/section-98.233

$LE_{nonVCS\ CO2,y}$	=	Leakage emissions from processes and equipment related to non-VCS sources in year *y* determined using the most recent version of *VT00XX Accounting non-VCS CO_2 in CCS Projects*; equal to zero for projects with no non-VCS CO_2 (t CO_2e)

5.4.1 Leakage Emissions from Fuel Consumption

Upstream emissions from the production and transportation of fuel to the DAC site and directly connected off-site facilities are calculated using Equation (6).

$$LE_{Fuel,y} = \sum_d (Q_{Fuel,d,y} \times EF_{Upstream\_Fuel,d}) \quad (6)$$

Where:

$EF_{Upstream\_Fuel,d}$	=	Emission factor for upstream sources related to fuel type *d* used in module boundary (t CO_2e/m^3 or t CO_2e/kg or t CO_2e/GJ)

Where power and heat are supplied from an off-site facility, $Q_{Fuel,d,y}$ must be determined as a proportion of the total fuel used to generate the total electricity and heat at the directly connected facility using Equation (3).

Where no separate information on $EF_{Fuel,d}$ and $EF_{Upstream\_Fuel,d,y}$ is available, project proponents may apply a combined emission factor in Equation (2)

5.4.2 Leakage Emissions from Consumption of Capture Materials

Capture materials are the chemicals and media used by a DAC process to capture atmospheric CO_2. Depending on the technology, this may include capture solvents, solid sorbents, membranes, and catalysts, which may have to be replaced periodically due to loss or degradation over time. Examples include aqueous potassium hydroxide (KOH) and amine supported on activated carbon. These materials degrade over time and must be replaced during the project's lifetime. Leakage emissions from regeneration and replacement and the related production of these materials during subsequent years are calculated per Equation (7).

$$LE_{Mat,y} = \sum_j (Q_{Mat,j,y} \times EF_j) \quad (7)$$

Where:

$Q_{Mat,j,y}$	=	Quantity of capture material *j* consumed by the DAC facility in year *y* (kg or m^3 or units)
EF_j	=	GHG emissions from the production of capture material *j* (t CO_2e/kg or t CO_2e/m^3 or t CO_2e/unit)

5.5 Uncertainty

The primary sources of uncertainty identified for the project activities covered in this module are measurement error for fuel combustion and measurement error related to leakage emissions from the production of capture materials. All other potential sources of uncertainty are either considered de minimis or accounted for in the conservativeness of the default factors.

Uncertainty of measurement error related to project emissions from fuel combustion for capture activities is considered de minimis where the metering equipment used for determining fuel volumes, $Q_{fuel,d,y}$, uses a custody transfer meter or fiscal metering for a transaction.

Uncertainty of measurement error from leakage emissions from the production of capture materials is considered de minimis where the magnitude of the leakage emissions from the production of capture materials is less than 2% of the net emission reduction or removal benefit of the project.

Uncertainty of measurement or estimation error from venting emissions from project fuel consumption is considered de minimis where the magnitude of the emissions from venting is less than 2% of the net emission reduction or removal benefit of the project.

Proponents whose projects do not meet the above conditions for a source of uncertainty must include that source of uncertainty in their uncertainty assessment described in section 8.5 of *VM0049*.

6 DATA AND PARAMETERS

Additional data and parameters are defined in *VM0049* and related tools (VCS and CDM) as applicable.

6.1 Data and Parameters Available at Validation

Data/Parameter	GWP_{CH4}
Data unit	t CO_2e/t CH_4
Description	Global warming potential for CH_4
Equations	(2), (4)

Source of data	Version of IPCC Assessment Report required by *VCS Standard*
Value applied	See the most recent version of the *VCS Standard*.
Justification of choice of data or description of measurement methods and procedures applied	Required by *VCS Standard*
Purpose of data	Calculation of project emissions
Comments	N/A

Data/Parameter	GWP_{N2O}
Data unit	t CO_2e/t N_2O
Description	Global warming potential for N_2O
Equations	(2)
Source of data	Version of IPCC Assessment Report required by *VCS Standard*
Value applied	See the most recent version of the *VCS Standard*.
Justification of choice of data or description of measurement methods and procedures applied	Required by *VCS Standard*
Purpose of data	Calculation of project emissions
Comments	N/A

6.2 Data and Parameters Monitored

Data/Parameter	$EF_{Fuel,CO2,d}$
Data unit	t CO_2/m^3 or t CO_2/kg or t CO_2/GJ
Description	CO_2 emission factor for combustion of fuel *d* in year *y*
Equations	(2)

Source of data	The following data sources may be used: 1) Emission factor from IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* 2) Emission factors published by US EPA https://www.epa.gov/climateleadership/ghg-emission-factors-hub or similar source 3) Data provided by the fuel supplier or manufacturer where the data used is consistent with that reported to a regulatory body.
Description of measurement methods and procedures to be applied	Use the most recent data published by the above sources at the time of reporting project emissions.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data/Parameter	$EF_{Fuel,CH4,d}$
Data unit	t CH_4/m^3 or t CH_4/kg or t CH_4/GJ
Description	CH_4 emission factor for combustion of fuel *d*
Equations	(2)
Source of data	The following data sources may be used: 1) Emission factor from IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* 2) Emission factor from US EPA https://www.epa.gov/climateleadership/ghg-emission-factors-hub or similar source

	3) Data provided by the fuel supplier or manufacturer where the data used is consistent with that reported to a regulatory body.
Description of measurement methods and procedures to be applied	Use the most recent data published by the above sources at the time of reporting project emissions.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data/Parameter	$EF_{Fuel,N2O,d}$
Data unit	t N_2O/m^3 or t N_2O/kg or t N_2O/GJ
Description	N_2O emission factor for combustion of fuel *d*
Equations	(2)
Source of data	The following data sources may be used: 1) Emission factor from IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* 2) Emission factor from US EPA https://www.epa.gov/climateleadership/ghg-emission-factors-hub or similar source 3) Data provided by the fuel supplier or manufacturer where the data used is consistent with that reported to a regulatory body.
Description of measurement methods and procedures to be applied	Use the most recent data published by the above sources at the time of reporting project emissions.

Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data/Parameter	$Q_{Fuel,d,y}$
Data unit	m^3 or kg or GJ
Description	Quantity of fuel type *d* used in capture facility and/or third party (for off-site heat/steam supply) equipment in year *y* in project activities
Equations	(2), (6)
Source of data	Fuel receipts/invoices or flow meter readings
Description of measurement methods and procedures to be applied	Measured from flow meters or calculated from fuel receipts/invoices.
Frequency of monitoring/recording	Continuous
QA/QC procedures to be applied	Measuring equipment (e.g., flow meters, weighing scale) must operate within the manufacturer's specified operating conditions and must be routinely calibrated, inspected, and maintained according to the manufacturer's specifications.
Purpose of data	Calculation of project and leakage emissions
Calculation method	Monthly fuel consumption is determined by summing the quantities from calibrated device readings or fuel receipts/invoices.
Comments	N/A

Data/Parameter	$Q_{Cogen,d,y}$
Data unit	m^3 or kg or GJ
Description	Total quantity of fuel type *d* used by the cogeneration unit to generate electricity and/or heat in year *y*

Equations	(3)
Source of data	Fuel receipts/invoices or flow meter readings, as applicable
Description of measurement methods and procedures to be applied	Measured from flow meters or calculated from fuel receipts/invoices.
Frequency of monitoring/recording	Continuous or for every invoice, aggregated annually
QA/QC procedures to be applied	Measuring equipment (e.g., flow meters, weighing scale) must operate within the manufacturer's specified operating conditions and must be routinely calibrated, inspected, and maintained according to manufacturer specifications.
Purpose of data	Calculation of project emissions
Calculation method	Monthly fuel consumption is determined by summing the quantities from calibrated device readings or fuel receipts/invoices.
Comments	Invoices and/or contracts with the third party must be in place to allow proper data collection.

Data/Parameter	$Heat_{DAC,y}$
Data unit	MWh
Description	Quantity of useful thermal energy supplied to the DAC facility by the cogeneration unit in year *y*
Equations	(3)
Source of data	Utility receipts/invoices or metered data for heat usage
Description of measurement methods and procedures to be applied	Measured from calorimeters or calculated from receipts/invoices, considering energy content in steam and condensate return as applicable based on steam properties.
Frequency of monitoring/recording	Continuous, aggregated annually
QA/QC procedures to be applied	The calorimeter must be routinely calibrated, inspected, and maintained according to manufacturer specifications.
Purpose of data	Calculation of project emissions
Calculation method	Monthly supplied heat is determined by summing the quantities from calibrated device readings or fuel receipts/invoices.

Comments	Invoices and/or contracts with the third party must be in place to allow proper data collection.

Data/Parameter	$Electricity_{DAC,y}$
Data unit	MWh
Description	Quantity of electricity supplied to the DAC facility by the cogeneration unit in year *y*
Equations	(3)
Source of data	Utility receipts/invoices or metered data for electricity use
Description of measurement methods and procedures to be applied	Measured from electricity meters or calculated from receipts/invoices.
Frequency of monitoring/recording	Continuous, aggregated annually
QA/QC procedures to be applied	Electricity meters must be routinely calibrated, inspected, and maintained according to manufacturer specifications.
Purpose of data	Calculation of project emissions
Calculation method	Monthly supplied electricity is determined by summing the quantities from calibrated device readings or fuel receipts/invoices.
Comments	Invoices and/or contracts with the third party must be in place to allow proper data collection. Value is equal to zero where only heat is supplied to the DAC facility.

Data/Parameter	$Heat_{Cogen,y}$
Data unit	MWh
Description	Total quantity of useful thermal energy produced by the cogeneration unit in year *y*
Equations	(3)
Source of data	Utility receipts/invoices or metered data for heat produced
Description of measurement methods and procedures to be applied	Direct measurement of steam flows (or other heat transfer fluid) and characteristics at the cogeneration facility, considering energy content in steam and condensate return

Frequency of monitoring/recording	Continuous, aggregated monthly
QA/QC procedures to be applied	Calorimeters must be routinely calibrated, inspected, and maintained according to manufacturer specifications.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	Invoices and/or contracts with the third party must be in place to allow proper data collection.

Data/Parameter	$Electricity_{Cogen,y}$
Data unit	MWh
Description	Total quantity of electricity produced by the cogeneration unit in year *y*
Equations	(3)
Source of data	Utility receipts/invoices or metered data
Description of measurement methods and procedures to be applied	Measured from electricity meters or calculated from receipts/invoices.
Frequency of monitoring/recording	Continuous, aggregated monthly
QA/QC procedures to be applied	Invoices and/or contracts with the third party
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	Invoices and/or contracts with the third party must be in place to allow proper data collection.

Data/Parameter	$Count_{n,y}$
Data unit	Unitless
Description	Total number of components *n* in the natural gas service at the facility during year *y*
Equations	(4)
Source of data	Records of DAC facility (e.g., pipe and instrument drawing, parts lists)

Description of measurement methods and procedures to be applied	Counting based on capture facility records as per US EPA *Electronic Code of Federal Regulations Title 40,* Chapter I, Subchapter C, Part 98, Subpart W § 98.233. Available at: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-W/section-98.233#p-98.233(a)(1)
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Use the most recent data available from the DAC facility.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data/Parameter	$T_{n,y}$
Data unit	hours
Description	Pressurized time of component *n* in year *y*
Equations	(4)
Source of data	Records of DAC facility (e.g., control systems, recorded operational data)
Description of measurement methods and procedures to be applied	Data from DAC facility records
Frequency of monitoring/recording	Continuous, aggregated monthly
QA/QC procedures to be applied	Use the most recent data available from the DAC facility.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	

Data/Parameter	V_m
Data unit	t CH_4/event
Description	Vented CH_4 emissions for venting event *m*

Equations	(4)
Source of data	Data from the DAC facility
Description of measurement methods and procedures to be applied	**Option 1:** Direct measurement of venting **Option 2:** Estimated based on isolated volumes of pipes and equipment **Option 3:** Estimated based on non-isolated volumes of pipes and equipment. The project proponent must determine the quantity of vented CH_4 by transient flow rate calculations for compressible fluids appropriate for the expected evolving conditions in the pipeline or component based on the approximate geometry of the escaping flow and pipelines/components connected to the venting.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Cross-checked based on energy balance related to metered fuel use.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data/Parameter	EF_n
Data unit	kg CH_4/hr
Description	Emission factor for fugitive emissions for component *n*
Equations	(4)
Source of data	Emission factor derived from US EPA *Electronic Code of Federal Regulations, Title 40*, Part 98, Subpart W, § 98.233(a)(1) [6] or equivalent regulations appropriate to the jurisdiction in which the project is located.
Description of measurement methods and procedures to be applied	Use the most recent data published by the above sources at the time of reporting project emissions.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	N/A

[6] For more information see US EPA: Available at: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-W/section-98.233

Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data/Parameter	$EF_{Upstream\_Fuel,d}$
Data unit	t CO_2e/m^3 or t CO_2e/kg or t CO_2e/GJ
Description	Emission factor for upstream sources related to fuel type *d* used in DAC and/or third party (for off-site heat/steam supply) facilities
Equations	(6)
Source of data	The value of this parameter may be obtained from the following sources: 1) A life cycle assessment (LCA) conducted by a qualified third party in accordance with the most recent version of ISO 14040, that uses either primary or published and peer-reviewed data[7]; 2) A compliance market-approved tool (e.g., such as CA-GREET[8], GHGenius[9]); 3) Emission factors published in peer-reviewed literature[10] representative of the fuels used in DAC plant operation both temporally and geographically; or 4) Data provided by the fuel supplier or manufacturer where the data used is consistent with that reported to a regulatory body.
Description of measurement methods and procedures to be applied	Use the most recent data published by the sources at the time of reporting project emissions.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Use the most recent data published by the above sources at the time of reporting project emissions.

[7] State or national government data on a fuel's carbon intensity are also acceptable sources of data for determining emission factors for fuels used by the transport facility.

[8] The Greenhouse Gases, Regulated Emissions and Energy use in Technologies (GREET) model. Available at: https://greet.es.anl.gov/

[9] Model for Life Cycle Assessment of Transportation Fuels. Available at: https://www.ghgenius.ca/

[10] Peer-reviewed literature must be indexed in the Web of Science: Science Citation Index (SCI; available at https://mjl.clarivate.com), as specified in Section 2.5.2 of the *VCS Methodology Requirements, v4.4*.

	Where peer-reviewed literature is used, it must have been published within a year of reporting project emissions. It must be temporally and geographically representative of the DAC facility.
Purpose of data	Calculation of leakage emissions
Calculation method	N/A
Comments	

Data/Parameter	EF_j
Data unit	t CO_2e/kg or t CO_2e/m^3 or t CO_2e/unit
Description	GHG emissions from the production of capture material *j*
Equations	(7)
Source of data	Emissions from the production of the capture material must be calculated using one of the following: 1) Compliance market-approved tool 2) A third-party audited product life cycle assessment (LCA) that complies with ISO 14044 guidelines; 3) Data published in peer-reviewed literature, such as scientific journals; or 4) Data provided by the technology supplier.
Description of measurement methods and procedures to be applied	In line with sources of data
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Use the most recent data published by the above sources at the time of reporting project emissions. Where peer-reviewed literature is used, it must have been published within a year of reporting project emissions.
Purpose of data	Calculation of leakage emissions
Calculation method	N/A
Comments	See Appendix 1 for examples of data sources.

Data/Parameter	$Q_{Mat,j,y}$

Data unit	kg or m^3 or units
Description	Quantity of capture material *j* consumed by project activities in the capture facility in year *y*
Equations	(7)
Source of data	Receipts/invoices or flow meter or weighing scale/equipment readings, depending on capture material type
Description of measurement methods and procedures to be applied	Measured from material flow meters or weighing equipment or calculated from receipts/invoices.
Frequency of monitoring/recording	Aggregated annually. As per the flow meter or weighing equipment specification by the manufacturer. Manufacturers must be compliant with ISO standards. Alternatively, the sum of all receipts/invoices for capture materials in year *y* is used.
QA/QC procedures to be applied	Flow meters must be routinely calibrated, inspected, and maintained according to manufacturer specifications.
Purpose of data	Calculation of leakage emissions
Calculation method	N/A
Comments	N/A

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APPENDIX 1: SECONDARY EMISSIONS DATA SOURCES

A1.1 Established Tools and Datasets for Lifecycle Assessments

A variety of life cycle inventory (LCI) data sources exist in both public and commercial domains (e.g., ecoinvent, GaBi). Public data sources from the United States Department of Energy (DOE) and the federal government are provided below for reference.

- National Energy Technology Laboratory (NETL)
  - Natural gas model: https://netl.doe.gov/energy-analysis/details?id=35d27478-88a0-4ef4-ab51-2e1bbcf5332e
  - Gate-to-grave saline aquifer storage model: https://netl.doe.gov/energy-analysis/details?id=94309bc8-0539-42d3-9c13-01f2f34f27e3
- US electricity baseline
  - Grid Mix Explorer Excel tool: https://netl.doe.gov/energy-analysis/details?id=f0f94954-3627-4e9b-a5c0-c29cfe419d1c
  - openLCA unit processes: https://www.lcacommons.gov/lca-collaboration/Federal_LCA_Commons/US_electricity_baseline/datasets
- Unit Process Library: https://netl.doe.gov/node/2573
- Argonne National Laboratory (ANL) The Greenhouse gases, Regulated Emissions and Energy use in Technologies (GREET) model: https://greet.es.anl.gov/
- US Federal Life Cycle Analysis Commons: https://www.lcacommons.gov/lca-collaboration
- National Renewable Energy Lab United States Life Cycle Inventory Database (USLCI): https://www.nrel.gov/lci/
- US Environmental Protection Agency Environmentally-Extended Input-Output (US EEIO) Models: https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-models

Table 2: Key data collection processes, parameters, and sources

Data Category	Parameters	DOE and Other Federal Resources
Project Operation	Inputs and outputs associated with facility operations, including any on-site emissions	Unique to each project – user input based on the engineering model
Consumables – Electricity	Consumption mix technology contributions by generation type Inclusive of generation facility emissions and fuel and material supply chains, where applicable Future grid mixes based on the proposed year of deployment using data provided in EIA's Annual Energy Outlook "Reference Case"	US Electricity Baseline (NETL) – regionalized consumption mixes with options to customize technological representation ANL GREET
Consumables – Heat	For on-site combustion: direct emissions should be included in DAC operation, but the fuel supply chain (e.g., natural gas) is accounted for separately. For off-site combustion: both fuel combustion and fuel supply chain should be accounted for.	NETL ANL GREET Federal LCA Commons
Non-Consumables – Construction/Capital Activities	Amounts (mass or dollars) of key materials (e.g., steel, concrete, aluminum, copper, plastics) for process equipment and site infrastructure	Process-based LCA may be conducted with material LCI data from NETL, GREET, or Federal LCA Commons. Alternatively, estimate data based on purchasing to leverage the US EEIO approach.
Consumables – Process Chemicals and Water	Inclusive of initial system charges as well as any required routine make-up over the life of the facility (e.g., solvents, sorbents)	Highly dependent on the chemical – some data are available from NETL, GREET, and US LCI. Alternatively, estimate data based on purchasing to leverage the US EEIO approach.
CO_2 Compression, Transport, Injection, Monitoring, Reporting, and Verification (MRV)	Initial on-site compression of captured CO_2 should be included in the DAC site electricity consumption but required boost compression and transport are included here. Storage site activities include site preparation, well construction, injection, and brine management – these are all variable by site and may be parameterized	NETL gate-to-grave assessment of saline aquifer storage of CO_2

	where desired to evaluate geographic/geologic variability.	
Waste management	Handling, transporting, and managing process wastes from DAC operations	US LCI for landfilling or incineration; GREET or NETL for transport
Land use change	Site disturbance/clearing to facilitate DAC operations and infrastructure	GREET and NETL have land use change/conversion factors
Decommissioning	Deconstruction, waste disposal, material recycling	Proxy industrial facility for these impacts (e.g., power plant decommissioning is included in some NETL LCAs)

A1.2 Established Tools and Datasets for CCS Projects in the EU

- European Commission Joint Research Centre, Definition of Input Data to Assess GHG Default Emissions from Biofuels in EU legislation, most recent edition.

A1.3 Established Tools and Datasets for CCS Projects in Canada

- Environment and Climate Change Canada, Fuel Life Cycle Assessment (LCA) Model Database and Methodology, most recent edition.

DOCUMENT HISTORY

Version	Date	Comment
v1.0	October 24, 2024	Initial version