MODULE FOR CO_2 TRANSPORT

Document Prepared by:

Perspectives Climate Group GmbH and South Pole Carbon Asset Management Ltd

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Contact information	info@ccsplus.org

CONTENTS

1 SOURCES

The following have also informed the development of the module:

- "Best Practices for Life Cycle Assessment (LCA) of Direct Air Capture with Storage", U.S. Department of Energy, Office of Fossil Energy and Carbon Management
- "Carbon dioxide capture, transportation, and geological storage — Quantification and verification", Standard ISO/TR 27915:2017:
- "Carbon Dioxide Transport, Injection and Geological Storage", Chapter 5 in Volume 2 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- "The GHG Protocol for Project Accounting", World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI)
- "A Greenhouse Gas Accounting Framework for Carbon Capture and Storage Projects", Centre for Climate and Energy Solutions
- Methodology for the quantification, monitoring, reporting and verification of greenhouse gas emissions reductions and removals from carbon capture and storage projects, Version 1.1., published by the American Carbon Registry
- "Guidelines for Carbon Capture, Transport and Storage", WRI
- "Carbon Capture and Sequestration Protocol under the Low Carbon Fuel Standard", California Air Resources Board
- "Modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities", UNFCCC
- "Commission Implementing Regulation (EU) 2018/2066" of the European Commission, Directorate-General for Climate Action
- "EU Directive on the geological storage of carbon dioxide" of the European Parliament and of the Council

This module is used in combination with the latest version of the following methodologies, modules, and tools:

- *VM00XX Methodology for Carbon Capture and Storage*

Capture Modules

- *VMD00XX: CO_2 Capture from Air (Direct Air Capture)*
- *VMD00XX: CO_2 Capture from Fossil Fuel or Geothermal Based Power and Heat Generation* (under development)
- *VMD00XX: CO_2 Capture from Industrial Processes* (under development)

- *VMD00XX: CO_2 Capture from Oil and Gas Production and Processing* (under development)
- *VMD00XX: CO_2 Capture from Biogenic Sources (BECCS)* (under development)

Transport Module(s)

- *VMD00XX: Module for CO_2 Transport*

Storage Modules

- *VMD00XX: CO_2 Storage in Saline Aquifers*
- *VMD00XX: CO_2 Storage in Depleted Oil and Gas Reservoirs* (under development)

Other Modules/Tools

- *VMT00XX: Tool for Differentiation between Emission Reductions and Removals in Carbon Capture and Storage Projects* (under development)
- *VMT00XX: Tool for Baseline Quantification and Allocation of Project Emissions in Projects with VCS and non-VCS-CO_2 flows in Carbon Capture and Storage Projects* (under development)

This module uses the latest versions of the following CDM Tools:

- CDM *Tool 12: Project and leakage emissions from transportation of freight*

2 SUMMARY DESCRIPTION OF THE MODULE

The module provides procedures and requirements for project activities that transport carbon dioxide (CO_2) via pipelines, ships/barges, rail, and trucks for eligible carbon capture and storage (CCS) activities under *VM00XX Methodology for Carbon Capture and Storage*.

3 DEFINITIONS

In addition to the definitions set out in the *Program Definitions* of the VCS Program, the following definitions apply to this module:

CO_2 Conditioning

The process of treatment of an incoming CO_2 stream to achieve the required conditions for transport and/or injection and storage of the CO_2 in a CCS project activity. It may include various processes including but not limited to refrigeration, dehydration, desulphurization, deoxygenation, and compression

Geological Reservoir
Subsurface body of rock with sufficient porosity and permeability to receive, transmit and contain fluids, particularly super-critical or dense phase CO_2, including areas or zones for expansion and migration of the CO_2 plume defined by the reservoir modelling.

Intermediate Storage
Intermediate storage includes the processes and equipment on a site that enables temporary storage of CO_2 in transit, during the transfer of CO_2 from one mode of transport to another (e.g., transfer of CO_2 from a pipeline to transport by ship)

Mode of Transport
Refers to how CO_2 can be moved from an entry point (e.g., a capture site) to a point of delivery (e.g., other modes of transport or storage). This typically includes CO_2 transport by pipelines, ships, rail, and/or trucks

Non-condensable Gas
Non-condensable gases are gases that do not condensate into the liquid phase within the operating temperature of a system. They are relevant for geothermal power/heat plants

Non-VCS-CO_2
The CO_2 captured outside the project boundary of a CCS project activity registered under VCS that is conditioned, transported, or stored using (some of) the facilities of the registered CCS project activity

Solvent
Solvent-based CO_2 capture involves the chemical or physical absorption of CO_2 from flue gas into a liquid carrier

Storage Facility
Any facility used for geological storage of CO_2

Transport Facility
Any facilities used to transport CO_2

Transport of CO_2
A network, single pipeline, or any other mode of transport that has been purpose-built to transport CO_2, or which is existing but dedicated to and authorized for the transport of CO_2

Transport Segment
A portion of a CO_2 transportation system that connects a capture facility to intermediate storage, other transport segments, intermediate storage facilities and storage facilities. Transport segments have one mode of transport.

4 APPLICABILITY CONDITIONS

This module applies to the transport of CO_2 in a carbon capture and storage (CCS) project activity using the latest version of *VM00XX Methodology for Carbon Capture and Storage*.

This module is applicable under the following conditions:

1. The project activity transports a concentrated CO_2 stream from a capture site(s) to a noncontiguous storage site(s) as a free-flowing fluid.
2. The project CO_2 stream is transported through one or a combination of the following transport modes:
    a. Pipelines;
    b. Ships/barges (hereinafter referred to as ships, unless specified);
    c. Railway; or
    d. Trucks.
3. The project must include one or multiple transport segments that connects capture site(s), intermediate storage site(s), and storage site(s).
4. The project may include intermediate storage sites that enable temporary storage of the project CO_2 stream while in transit, during the transfer of CO_2 to or from a transport segment, if the storage is in above-ground vessels[1].

This module is not applicable under the following conditions:

1. Transportation or intermediate storage of CO_2 that is dissolved in solvents, diluted in diluents (beyond remnants of the capture process or feedstock contaminants), mineralized in materials, or infused in products[2].
2. Intermediate storage that is in a geological reservoir.
3. Upgrades to existing transport facilities or changes in operational practices leading to improved transport efficiency cannot be registered as a new project activity by itself. For transport projects already registered under the VCS, such improvements may occur and would be considered in the calculation of the baseline and the project emissions over the crediting period.

[1] Including ship transport.

[2] Additional modules allowing transport for example transport in dissolved in water are under development.

5 MODULE BOUNDARY

The module boundary for this module encompasses CO_2 transport and all the associated processes along the CO_2 transport value chain. Commonly used equipment or processes may include:

- CO_2 Conditioning (e.g., dehydration, cooling);
- Compression of CO_2;
- Loading and unloading of CO_2 to/from ships, trains, and trucks;
- Propulsion of ships, trains, and trucks for transport of CO_2;
- Holding CO_2 conditions (e.g., temperature) in pressure vessels;
- Reconditioning of CO_2 to alter the mode of transport or change the delivery condition (e.g., regasification);

The point of custody transfer is appropriate to define module and segment boundaries in the case of projects with diverse ownership.

Within the transport module boundary, the project activities are further sub-divided into intermediate storage sites or transport segments, where:

- Intermediate storage sites include the processes and equipment on a site that enables temporary storage of CO_2 in transit, during the transfer of CO_2 from one transport segment to another.
- Transport segments include equipment and processes for moving a CO_2 stream through a portion of the transportation system that uses a common quantification approach as described in section 6. Transport segments must meet the following criteria:
    - Transport segments do not include intermediate storage facilities or equipment outside the module boundary (as defined above).
    - All equipment and processes in a transport segment are connected such that they do not straddle other transport segments or intermediate storage facilities.
    - Each transport segment moves CO_2 through one mode of transport (i.e., each different mode of transport in a project must be a separate transport segment).
    - Pipelines and electric rail networks that cross international boundaries must use separate transport segments for each country to properly determine project emissions from grid electricity consumption in each jurisdiction. Truck, ship, and diesel rail networks that cross international boundaries do not need a separate transport segment for portions of the transport in each country.

The boundary for this module is presented in Figure 1.

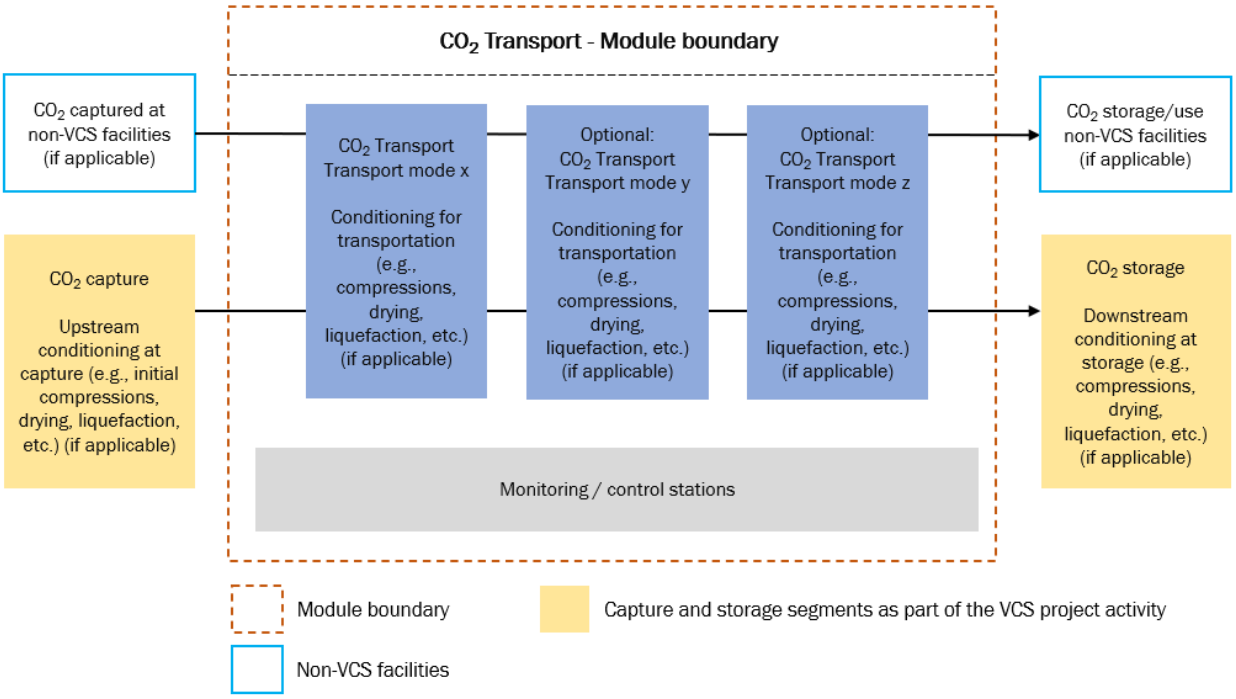

Figure 1: Module boundary for CO_2 transport.

Emission sources, including both primary and secondary effects, that are considered in this module are illustrated relative to the module boundary in Figure 2.

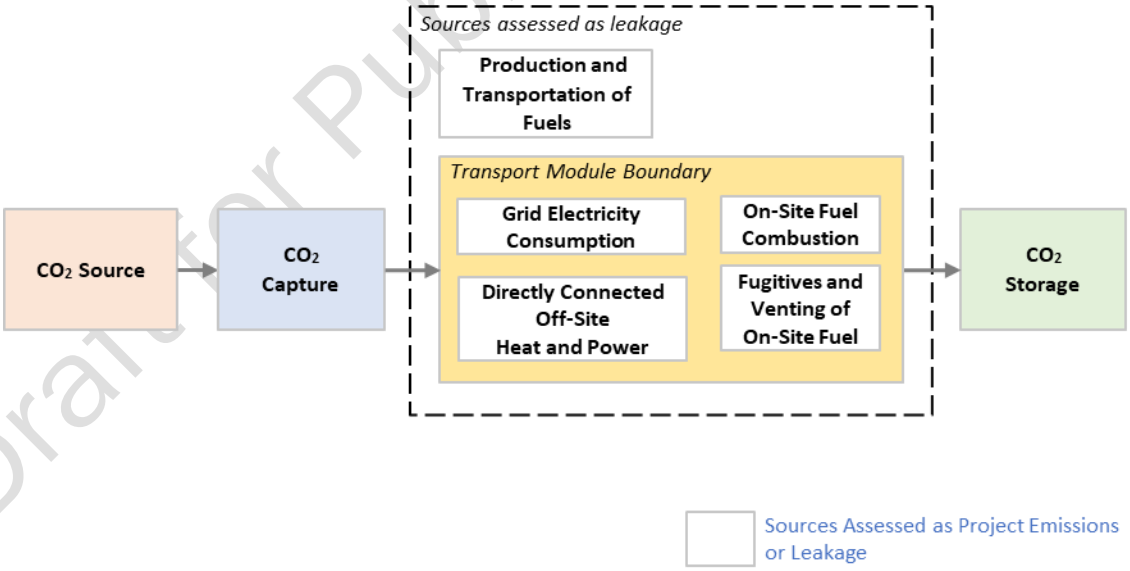

Figure 2: Boundary for Primary and Secondary Project Activity Effects

The GHGs included in or excluded from the module boundary are depicted in Table 1.

Table 1: GHG Sources Included or Excluded from the Project Boundary

Source		Gas	Included?	Justification/Explanation
Project	Electricity consumption	CO_2	Yes	Major emission source
		CH_4	Yes	Significant upstream emission source
		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	Significant upstream emission source
		N_2O	Yes	Included for completeness
		Other	No	Excluded for simplicity, emissions are considered negligible.
	CO_2 stream processing	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 reductions since only injected CO_2 volumes are quantified as the baseline emissions.
		CH_4	No	Excluded as also not considered under the baseline scenario.
		N_2O	No	Excluded as also not considered under the baseline scenario.
		Other	No	Excluded for simplicity, emissions are considered negligible.

6 QUANTIFICATION PROCEDURES

Total project emissions of the transported CO_2 are calculated as per Equation (1) :

$$PE_{Tra,y} = \sum_{t} PE_{Tra,t,y} + \sum_{s} PE_{Tra,s,y} - PE_{nonVCS\ CO2,y} \quad (1)$$

Where:

$PE_{Tra,y}$	=	Total project emissions from CO_2 transportation in year *y* (tCO_2e)
$PE_{Tra,t,y}$	=	Total project emissions for transport segments in the year *y* (tCO_2e)
$PE_{Tra,s,y}$	=	Total project emissions from the operation of intermediate storage *i* the year *y* (tCO_2e)
t	=	Transport segment index
s	=	Intermediate storage index
$PE_{nonVCS\ CO2,y}$	=	Project emissions from processes and equipment related to non-VCS sources. in year y (tCO_2e) to be determined as per the latest version of the *VMT00XX: Tool for Baseline Quantification and Allocation of Project Emissions in Projects with VCS and non-VCS-CO2 flows in Carbon Capture and Storage Projects*. For projects without non-VCS CO_2, $PE_{nonVCS\ CO2,y}$= 0 (tCO_2e)

Project emissions from intermediate storage sites and transport segments include those from grid electricity consumption, combustion of fossil fuel, and consumption of heat.

This module provides two options for the calculation of GHG emissions from the transport segments and intermediate storage sites. Option A provides procedures for direct monitoring while Option B provides default values that may only be used when the transport segment(s) or intermediate storage site(s) meet the conditions in Section 6.2.

6.1 Option A: Direct Monitoring of Fuel, Electricity and Heat Consumption

Project emissions associated with a transport segment are calculated as per Equations (2):

$$PE_{Tra,t,y} = PE_{Comb\_Fuel,y} + PE_{Elec,y} \quad (2)$$

Where:

$PE_{Comb\_Fuel,y}$	=	Project emissions from fuel combustion to operate equipment for transport or intermediate storage processes in the year y (tCO_2e).
$PE_{Elec,y}$	=	GHG emissions from electricity consumption to operate transport or intermediate storage processes in the year y (tCO_2e).

Project emissions from fossil fuel consumption for CO_2 transport via trucks, rail, or ships must consider both outbound and empty return trips.

Project emissions from transport segments and intermediate storage are calculated as follows.

Project emissions associated with intermediate storage are calculated as per Equations **Error! Reference source not found.**):

$$PE_{Tra,s,y} = PE_{Comb\_Fuel,y} + PE_{Elec,y} \quad (3)$$

6.1.1 Project emissions from fuel combustion

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

$$PE_{Comb\_Fuel,y} = \sum_i (Q_{Fuel,i,y} \times EF_{Fuel,CO2,i}) + \sum_i (Q_{Fuel,i,y} \times EF_{Fuel,CH4,i}) \times GWP_{CH_4} + \sum_i (Q_{Fuel,i,y} \times EF_{Fuel,N2O,i}) \times GWP_{N_2O} \quad (4)$$

Where:

$PE_{Comb\_Fuel,y}$	=	Project emissions from fuel combustion for mobile equipment, on and off-site power and heat generation in year y (tCO_2e)
$Q_{Fuel,i,y}$	=	Quantity of each type of fuel i for on-site and off-site mobile equipment, power and heat generation in year y (m^3 or kg or GJ)
$EF_{Fuel,CO2,i}$	=	CO_2 emission factor of fuel i in year y (tCO_2/m^3, tCO_2/kg or tCO_2/GJ)
$EF_{Fuel,CH4,i}$	=	CH_4 emission factor of fuel i in year y (tCH_4/m^3, tCH_4/kg or t CH_4/GJ)
$EF_{Fuel,N2O,i}$	=	N_2O emission factor of fuel i in year y (tN_2O/m^3, tN_2O/kg or tN_2O/GJ)
GWP	=	Global warming potential (for CH_4 and N_2O respectively)

If power or heat are supplied from a directly connected off-site facility, $Q_{Fuel,i,y}$ must be determined as a proportion of the total fuel used to generate the total electricity and heat generated by the directly connected facility with the following equation:

$$Q_{Fuel,i,y} = Q_{fuel\_cogen,i,y} \times \frac{(Heat_{Tra,y} + Electricity_{Tra,y})}{(Heat_{cogen,y} + Electricity_{cogen,y})} \quad (5)$$

Where:

$Q_{fuel\_cogen,i,y}$	=	Total mass of a fuel type i used by the Cogeneration unit to generate electricity and/or heat in year y (metric tons/year)
$Heat_{Tra,y}$	=	Quantity of useful thermal energy supplied to the transport facility by the Cogeneration unit in year y (MWh/year)
$Electricity_{Tra,y}$	=	Quantity of electricity supplied to the transport facility by the Cogeneration unit in year y (MWh/year). Equals zero if only heat supplied to the transport facility

$Heat_{cogen,y}$ = Total quantity of useful thermal energy produced by the Cogeneration unit in year y (MWh/year)

$Electricity_{cogen,y}$ = Total quantity of electricity produced by the Cogeneration unit in year y (MWh/year)

Project emissions from the consumption of waste heat can be assumed to be zero for heat sources that meet the criteria of waste heat in the baseline section.

Where biofuel or biomass is used, it must comply with the definition and conditions of renewable and sustainable biomass as provided by the latest version of *VMD00XX: CO_2 Capture from Biogenic Sources*. Otherwise, emissions from the combustion of biofuel or biomass must be accounted for per Equation (4).

6.1.2 Project emissions from electricity consumption

Project emissions from electricity consumption are calculated according to the following Equation (6).

$$PE_{Elec,y} = Q_{Elec,y} \times EF_{Upstream\_Elec} \quad (6)$$

Where:

$PE_{Elec,y}$ = Project emissions from consumption of electricity to operate equipment in the transport module the year y (tCO_2e).

$Q_{Elec,y}$ = Total metered electricity usage to operate equipment in the transport module in year y (MWh/year).

$EF_{Upstream\_Elec}$ = Emissions factor for electricity generation (tCO_2e/MWh).

For on-site or directly connected off-site electricity generation, the emissions related to electricity consumption must be determined based on the related fuel consumption as per the provisions under the parameters $PE_{Comb\_Fuel,y}$ and $PE_{Fuel,y}$. See Section 6.1.1 for guidance on determining fuel use for electricity from cogeneration related to CCS project activities below.

For grid electricity consumption, published emission factors from regional compliance market-approved tools, and/or data published by State or National government agencies must be used Project proponents must reference the sources used and provide evidence of the electricity procurement.

Renewable energy (i.e., wind, solar, hydro) from a directly connected, off-grid captive source is deemed to have no emissions. Project proponents must provide evidence of a direct connection.

For electricity consumption from a dedicated geothermal power plant, CO_2 emissions from the release of non-condensable gases must be considered in the emission factor.

6.2 Option B: Default Values

Project emissions associated with a transport segment may be calculated as per Equation (7), if the transport segment:

- Uses trucks as the transport mode, and the most likely route has a one-way travel distance shorter than 40km;
- Uses rail as the transport mode, the most likely route does not cross a national border, and has a one-way travel distance shorter than 80km;
- Uses barges as the transport mode, and the most likely route has a one-way travel distance shorter than 100km; or
- Uses ships (not barges) as the transport mode, and the most likely route has a one-way travel distance shorter than 200km.

$$PE_{Tra,t,y} = \sum_{t}(D_{t,y} \times MCO2_{Tra,t,y} \times DEF_t) \times 10^{-6} \quad (7)$$

Where:

$PE_{Tra,t,y}$	=	Total project emissions to operate transport segments in the year *y* (tCO_2)
$D_{t,y}$	=	Length of the transport segment *t* (km)
$MCO2_{Tra,t,y}$	=	Mass of CO_2 transported by the transport segments in the year *y* (t)
DEF_t	=	Default emission factor for CO_2 transportation by the segment *t* (gCO_2/t km)
t	=	Transport segment index

Total project emissions from an intermediate storage site, i, may be calculated as per Equation (8), if:

- The intermediate storage facility does not consume fossil fuels or heat generated off-site (e.g., steam imported); and
- The aggregated mass of CO_2e emissions from all the intermediate CO_2 storage facilities in the project operating at peak power consumption is less than 5% of the injected mass of CO_2 at the project's design throughput.

$$PE_{tra,s,y} = \sum_{s} PP_{s.y} \times T_{s,y} \times EF_{Elec} \quad (8)$$

Where:

$PE_{tra,s,y}$	=	Project emissions to operate intermediate storage *i* in the year *y* (tCO_2e)
$PP_{s.y}$	=	Peak power consumption of the intermediate storage *i* in the year *y* (MW).
$T_{s,y}$	=	Usage time of intermediate storage *i* by the project activity in year *y* (hours)
EF_{Elec}	=	Emissions factor for electricity generation (tCO_2e/MWh).
s	=	Intermediate storage index

6.3 Quantification of Leakage

Total leakage emissions of the transported CO_2 are calculated as per Equation (9) :

$$LE_{Tra,y} = \sum_{t} LE_{Tra,t,y} + \sum_{s} LE_{Tra,s,y} \quad (9)$$

Where:

$LE_{Tra,y}$	=	Leakage emissions from CO_2 transportation in year *y* (tCO_2e)
$LE_{Tra,t,y}$	=	Leakage emissions for transport segments in the year *y* (tCO_2e)
$LE_{Tra,s,y}$	=	Leakage emissions from the operation of intermediate storage *i* the year *y* (tCO_2e)
t	=	Transport segment index
s	=	Intermediate storage index

Leakage emissions from intermediate storage sites and transport segments include those from grid electricity consumption, combustion of fossil fuel, and consumption of heat.

This module provides two options for calculating GHG emissions from the transport segments and intermediate storage sites. Option A provides procedures for direct monitoring. Option B provides default values that may only be used when the transport segment(s) or intermediate storage site(s) meet the conditions in Section . Leakage emissions must be quantified when Option A is used to calculate project emissions. Leakage emissions are not required to be quantified when Option B is used, since the default factors include sufficient conservativeness.

6.3.1 Leakage of Fuel, Electricity and Heat Consumption

Leakage emissions associated with a transport segment are calculated as per Equation (10):

$$LE_{Tra,t,y} = LE_{Fuel,y} + LE_{Elec,y} \quad (10)$$

Where:

$LE_{Fuel,y}$ = Leakage GHG emissions from upstream fuel consumption for transport or intermediate storage processes in the year y (tCO_2e).

$LE_{Elec,y}$ = Leakage GHG emissions from upstream electricity consumption to operate transport or intermediate storage processes in the year y (tCO_2e).

Leakage emissions from upstream fossil fuel consumption for CO_2 transport via trucks, rail, or ships must consider both outbound and empty return trips.

Leakage emissions associated with intermediate storage are calculated as per Equation (11) :

$$LE_{Tra,s,y} = LE_{Fuel,y} + LE_{Elec,y} \quad (11)$$

6.3.2 Leakage emissions from fuel consumption

Upstream emissions from the production and transportation of fuel to the transport facilities and directly connected offsite facilities are calculated using Equation (12).

$$LE_{Fuel,y} = \sum (Q_{Fuel,i,y} \times EF_{Upstream\_Fuel,i,y}) \quad (12)$$

Where:

$LE_{Fuel,y}$ = Leakage GHG emissions from upstream sources related to fuel consumed in on-site equipment in the year y (tCO_2e).

$Q_{Fuel,i,y}$ = Quantity of fuel type i used in the transport module equipment and/or third party (for offsite heat/steam supply) in year y (m^3 or Kg or GJ)

$EF_{Upstream\_Fuel,i,y}$ = Emission factor for upstream sources related to fuel type i used in the transport module equipment in year y (tCO_2e/m^3, tCO_2e/Kg or tCO_2e/GJ)

If power and heat are supplied from an off-site facility, $Q_{Fuel,i,y}$ must be determined as a proportion of the total fuel used to generate the total electricity and heat generated by the directly connected facility using Equation (5).

Projects where no separate information on $EF_{Fuel,i}$ and $EF_{Upstream\_Fuel,i,y}$ is available may use a combined emission factor and apply it in Equation (4) accordingly.

The emission factor for the production, processing, and transport of fuel used for transport or used by a third party to provide heat or steam to the transport facility must be accounted for using a life cycle analysis (LCA) that is consistent with the transport module boundaries (i.e., primary and secondary effects).

6.3.3 Leakage emissions from electricity consumption

Emissions from upstream electricity consumption are calculated according to the following Equation (13).

$$LE_{Elec,y} = Q_{Elec,y} \times EF_{Upstream\_Elec} \quad (13)$$

Where:

$LE_{Elec,y}$	=	Leakage emissions from consumption of electricity to operate equipment in the transport module the year y (tCO_2e).
$Q_{Elec,y}$	=	Total metered electricity usage to operate equipment in the transport module in year y (MWh/year).
$EF_{Upstream\_Elec}$	=	Emissions factor for upstream GHG sources related to electricity generation (tCO_2e/MWh).

For on-site or directly connected off-site electricity generation, the emissions related to electricity consumption must be determined based on the related fuel consumption considering project and leakage emissions as described in this module.

For grid electricity consumption, published emission factors from regional compliance market-approved tools, and/or data published by State or National government agencies must be used Project proponents must reference the sources used and provide evidence of the electricity procurement.

For directly connected wind, solar or hydropower plants that are off-grid captive plants, energy supplied is deemed to have no emissions. Project proponents must provide evidence of a direct connection.

For electricity consumption from a dedicated geothermal power plant, CO_2 emissions from the release of non-condensable gases must be considered in the emission factor.

Projects where no separate information on EF_{Elec} and $EF_{Upstream\_Elec}$ is available may use a combined emission factor and apply it in Equation (4) accordingly.

7 DATA AND PARAMETERS

7.1 Data and Parameters Available at Validation

Additional data and parameters are defined in the respective *VM00XX Methodology for Carbon Capture and Storage* and related tools (VCS and CDM) as applicable.

Data / Parameter	GWP_{CH4}
Data unit	t CO_2e/t CH_4
Description	Global warming potential for CH_4
Equations	(4)
Source of data	The latest version of the VCS Standard
Value applied	See the latest version of the VCS Standard
Justification of choice of data or description of measurement methods and procedures applied	Unless otherwise directed by the VCS Program, the latest version of the VCS Standard requires that CH_4 must be converted using the 100-year global warming potential derived from the IPCC Fourth Assessment Report.
Purpose of Data	Calculation of project emissions
Comments	

Data / Parameter	GWP_{N2O}
Data unit	t CO_2e/t N_2O
Description	Global warming potential for CH_4
Equations	(4)
Source of data	The latest version of the VCS Standard
Value applied	See the latest version of the VCS Standard
Justification of choice of data or description of measurement methods and procedures applied	Unless otherwise directed by the VCS Program, the VCS Standard requires that N_2O must be converted using the 100-year global warming potential derived from the IPCC Fourth Assessment Report.
Purpose of Data	Calculation of project emissions
Comments	

Data / Parameter	DEF_t

Data unit	g CO_2/t km
Description	The default emission factor to transport one tonne CO_2 1 km either by ship, truck, or rail.
Equations	(7)
Source of data	For default values of truck and rail: CDM Tool 12*: Project and leakage emissions from transportation of freight* For default values of ships and barges: Figure 8.6 of Chapter 8 Transport. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Default factors include embodied upstream emissions.
Value applied	See table below
Justification of choice of data or description of measurement methods and procedures applied	Default values for trucks and rail: CDM is an approved program under the VCS. Methodologies and Tools of CDM can be directly used in the VCS. Default values for ships and barges: IPCC provides a range of emission intensity for different ship types and barges. Considering the lower possible density of CO_2 stream transported by the ships and barges as compared to other cargoes, the next higher value of the y-axis is considered for conservativeness.
Purpose of Data	Calculation of project emissions
Comments	-

Transport Modality	DEF_m (g CO_2/t km)
Light Vehicles (<=26 t Gross Vehicle Mass)	300
Heavy Vehicles (>26 t Gross Vehicle Mass)	160
Rail	160
Ships (not barges)	60
Barges	120

Data / Parameter	$PP_{i,y}$
Data unit	Kilowatt (kW)
Description	Peak power consumption of the intermediate storage *i* used in the year *y* (kW).
Equations	(8)
Source of data	Design specifications for all equipment on-site

Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The manufacturer's specification would provide the appropriate value for peak power.
Purpose of Data	Calculation of project emissions
Comments	-

7.2 Data and Parameters Monitored

Data / Parameter:	$Q_{Fuel,i,y}$
Data unit:	m^3, Kg or GJ in a year y
Description:	Quantity of each fuel type i used in the transport module
Equations	(4) and (12)
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:	Aggregated annually
QA/QC procedures to be applied:	Flow meters must be operated within the manufacturer's specified operating conditions at all times. Flow meters must be routinely calibrated, inspected, and maintained according to the manufacturer's specifications.
Purpose of data:	Calculation of project and leakage emissions
Calculation method:	Volumetric gas flow meter readings must be corrected for temperature and pressure. The fuel consumption must be adjusted as follows: For transport via trucks, rail, or ships, the distance must consider both outbound and empty return trips. If another freight is transported on the return trip,

	then the distance associated with the return trip need not be accounted for. The company supplying or transporting the CO_2 should provide data to the project proponent about the mode(s) of transportation used, the total number of tonnes delivered, and the total distance traveled. Where the transportation process incurs stops that are not part of the direct trip, their added distances must be included (e.g., a ship transporting CO_2 that detours to collect another cargo from another site before arriving at the storage site).
Comments:	

Data / Parameter:	$EF_{Fuel,CO2,i}$
Data unit:	tCO_2/m^3, tCO_2/Kg or tCO_2/GJ
Description:	CO_2 Emission factor from the combustion of fuel i in year y
Equations	(4)
Source of data:	The following data sources may be used: 1) Emission factor prescribed by 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. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved May 18, 2022, from https://www.ipcc.ch/report/ar6/wg1/; 2) Emission factors published by US EPA or similar source; https://www.epa.gov/climateleadership/ghg-emission-factors-hub; or 3) Data provided by the fuel supplier.
Description of measurement methods and procedures to be applied:	Use the latest 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:	

Data / Parameter:	$EF_{Fuel,CH4,i}$
Data unit:	tCH_4/m^3, t CH_4/Kg or t CH_4/GJ
Description:	CH_4 Emission factor from the combustion of fuel i in year y
Equations	(4)
Source of data:	The following data sources may be used: 1) Emission factor prescribed by 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. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved May 18, 2022, from https://www.ipcc.ch/report/ar6/wg1/; 2) Emission factors published by US EPA or a similar source, https://www.epa.gov/climateleadership/ghg-emission-factors-hub; or 3) Data provided by the fuel supplier.
Description of measurement methods and procedures to be applied:	Use the latest 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:	

Data / Parameter:	$EF_{Fuel,N2O,i}$
Data unit:	tN_2O/m3, tN_2O/Kg or tN_2O/GJ
Description:	N_2O Emission factor from the combustion of fuel i in year y
Equations	(4)
Source of data:	The following data sources may be used:

	1) Emission factor prescribed by 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. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved May 18, 2022, from https://www.ipcc.ch/report/ar6/wg1/; 2) Emission factors published by US EPA or a similar source, https://www.epa.gov/climateleadership/ghg-emission-factors-hub; or 3) Data provided by the fuel supplier.
Description of measurement methods and procedures to be applied:	Use the latest 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:	

Data / Parameter:	$EF_{Upstream\_Fuel,i,y}$
Data unit:	tCO_2e/m^3, tCO_2e/Kg or tCO_2e/GJ
Description:	The upstream emission factor of fuel type i used in the transport module in year y
Equations	(12)
Source of data:	The options for satisfying this requirement are as follows: • Option 1) A qualified third-party may conduct an LCA in accordance with ISO 14040 and 14044, latest edition, that uses either primary or published and peer-reviewed data[3]; or

[3] Peer-reviewed literature means reviewed scientific literature published in reputable environmental and/or climate science journals. State or National government data on the carbon intensities of the fuels are also acceptable sources of data for determining emissions factors for fuels used by the transport facility.

	• Option 2) The embodied emission factor for each fuel type can be calculated using regional compliance market-approved methods or equivalent (e.g., CA-GREET in the California Low Carbon Fuel Standard[4] and GHGenius in the British Colombia Renewable and Low Carbon Fuel Requirements Regulation[5]; or • Option 3) Emission factors published in peer-reviewed literature[5] that are representative both temporally and geographically of the transport plant operation.
Description of measurement methods and procedures to be applied:	Use the latest 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 latest data published by the above sources at the time of reporting project emissions. In the case of peer-reviewed literature, the literature must have been published within a year of reporting project emissions. It must be temporally and geographically representative of the transport facility
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	See also Section 0.

Data / Parameter:	$Q_{fuel\_cogen,i,y}$
Data unit:	*m^3, Kg or GJ*
Description:	Quantity of fuel consumed in the Cogeneration unit

[4] CA-GREET (https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation) is adapted from the open-source Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (https://greet.es.anl.gov/) from Argonne National Laboratory (https://www.anl.gov/) based out of Lemont, Illionis in the United States.

[5] GHGenius (https://www.ghgenius.ca/index.php/modelling-resources/about-ghgenius) is an open-source LCA model developed and maintained by (S&T) Squared Consultants Inc. and can be used to analyze the emissions of many contaminants associated with the production and use of traditional and alternative transportations fuels.

Equations	(5)
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:	Aggregated annually
QA/QC procedures to be applied:	Flow meters must be operated within the manufacturer's specified operating conditions at all times. Flow meters must be routinely calibrated, inspected, and maintained according to the manufacturer's specifications.
Purpose of data:	Calculation of project emissions
Calculation method:	See above
Comments:	Invoices and/or contracts with the third party have to be in place to allow proper data collection.

Data / Parameter:	$Heat_{Tra,y}$
Data unit:	*MWh*
Description:	Quantity of useful heat consumed by the transport module
Equations	(5)
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.
Frequency of monitoring/recording:	Aggregated annually
QA/QC procedures to be applied:	Calorimeter must be routinely calibrated, inspected, and maintained according to manufacturer specifications.

Purpose of data:	Calculation of project emissions
Calculation method:	See above
Comments:	Invoices and/or contracts with the third party have to be in place to allow proper data collection.

Data / Parameter:	$Electricity_{Tra,y}$
Data unit:	*MWh*
Description:	Quantity of electricity consumed by the transport module
Equations	(5)
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:	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:	See above
Comments:	Invoices and/or contracts with the third party have to be in place to allow proper data collection.

Data / Parameter:	$Heat_{cogen,y}$
Data unit:	*MWh*
Description:	Quantity of total useful heat produced by the Cogeneration unit
Equations	(5)
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 taking into consideration energy content in steam and condensate return.
Frequency of monitoring/recording:	Aggregated annually
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:	See above
Comments:	Invoices and/or contracts with the third party have to be in place to allow proper data collection.

Data / Parameter:	$Electricity_{cogen,y}$
Data unit:	*MWh*
Description:	Quantity of electricity produced by the Cogeneration unit
Equations	(5)
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:	Aggregated annually
QA/QC procedures to be applied:	Invoices and/or contracts with the third party
Purpose of data:	Calculation of project emissions
Calculation method:	See above
Comments:	Invoices and/or contracts with the third party have to be in place to allow proper data collection.

Data / Parameter:	$Q_{Elec,y}$
Data unit:	*MWh*
Description:	Quantity of electricity consumed by the transport module
Equations	(6) and (13
Source of data:	Utility receipts/invoices or metered data for off-grid use.
Description of measurement methods and procedures to be applied:	Measured from electricity meters or calculated from receipts/invoices. Engineering estimates based on equipment size and manufacturer efficiency estimates can be used for equipment where it can be demonstrated that the specific electricity consumption of the equipment is less than 1% of the total electricity consumption.
Frequency of monitoring/recording:	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 and leakage emissions
Calculation method:	The electricity consumption must be adjusted as follows: For transport via trucks, rail, or ships, the distance must consider both outbound and empty return trips. If another freight is transported on the return trip, then the distance associated with the return trip need not be accounted for. The company supplying or transporting the CO_2 should provide data to the project proponent about the mode(s) of transportation used, the total number of tonnes delivered, and the total distance traveled. Where the transportation process incurs stops that are not part of the direct trip, their added distances must be included (e.g., a ship transporting CO_2 that detours to collect another cargo from another site before arriving at the storage site).
Comments:	

Data / Parameter:	$EF_{Upstream\_Elec}$
Data unit:	tCO_2e/MWh

Description:	Emissions factor for electricity generation including upstream emissions from electricity generation and transport
Equations	(13
Source of data:	The following data sources may be used: 1) For grid electricity consumption, regional emission factors from Compliance tools, and data published by State or National government must be used. Examples of such tools/sources are listed in Appendix I of *VMD00XX: CO_2 Capture from Air (Direct Air Capture)*. 2) Renewable energy (i.e. wind, solar, hydro) from a dedicated/off-grid captive source is deemed to have no emissions. 3) For electricity consumption from a dedicated geothermal power plant, CO_2 emissions from the release of non-condensable gases must be considered in the emission factor as provided by the operator of the geothermal power plant.
Description of measurement methods and procedures to be applied:	In line with data sources used.
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Use the latest published data or tools by the sources at the time of reporting project emissions.
Purpose of data:	Calculation of leakage emissions
Calculation method:	N/A
Comments:	

Data / Parameter:	$D_{t,y}$
Data unit:	Kilometer (km)
Description:	Trip distance traveled by the transport segment *t* in the year *y* within the module boundary defined in section 5.1.
Equations	(7)
Source of data:	Determined for each CO_2 transportation segment for a reference trip using the vehicle odometer or equivalent measurement device. (e.g.,

	using handheld/mounted global positioning systems (GPS)), online sources (maps)
Description of measurement methods and procedures to be applied:	For transport via trucks, rail, or ships, the distance must consider both outbound and empty return trips. If another freight is transported on the return trip, then the distance associated with the return trip need not be accounted for. The company supplying or transporting the CO_2 should provide data to the project proponent about the mode(s) of transportation used, the total number of tonnes delivered, and the total distance traveled. Where the transportation process incurs stops that are not part of the direct trip, their added distances must be included (e.g., a ship transporting CO_2 that detours to collect another cargo from another site before arriving at the storage site).
Frequency of monitoring/recording:	Continuous. If the mode of transport origin and destination are the same, the distance between the origin and the destination can be multiplied by the total number of trips taken during the monitoring period.
QA/QC procedures to be applied:	• To be updated when the distance changes. • Devices (such as odometers and, GPS) used should be calibrated as per the manufacturer's specifications. • When using online sources (e.g., maps), the distance between the start/end destination is not less than the actual distance.
Purpose of data:	Calculation of project emissions
Calculation method:	When distances are measured through devices such as odometers, the distance is the difference between readings at the start of the module boundary and the reading at the end of the module boundary.
Comments:	Applicable only to Option B and when the project emissions from transport modes (trucks, ships, and rail) are separate from emissions to operate intermediate storage and other equipment.

Data / Parameter:	$MCO2_{Tra,m,y}$
Data unit:	Tonnes (t)
Description:	Mass of CO_2 transported by each mode of transport
Equations	(7)
Source of data:	Measurement
Description of measurement methods	Mass of CO_2: As per the criteria and procedures established in *VM00XX: Methodology for Carbon Capture and Storage* When CO_2 is transported in containers/tanks that are not part of the mode of transport used (e.g., a train transporting CO_2 in a container

and procedures to be applied:	attached to the train), the weight of the container/tank must be included in the total mass transported.
Frequency of monitoring/recording:	Continuous
QA/QC procedures to be applied:	As per the criteria and procedures established in *VM00XX: Methodology for Carbon Capture and Storage* *Calculated and/or replaced per the manufacturer's specifications*
Purpose of data:	Calculation of project emissions
Calculation method:	As per the criteria and procedures established in *VM00XX: Methodology for Carbon Capture and Storage*
Comments:	Applicable only to Option B and when trucks, ships, and rail are used. This is not applicable to transport via pipeline.

Data / Parameter:	$T_{s,y}$
Data unit:	hours
Description:	Hours (h) for which the intermediate storage s is used in year y
Equations	(8
Source of data:	Measurement
Description of measurement methods and procedures to be applied:	The time of intermediate storage used for the project activities. Time in minutes must always be rounded up to the next hour. E.g., 1 hour 10 mins must be considered as 2 hours. When the exact number of hours that intermediate storage is used cannot be determined, the default assumption is that the intermediate storage has operated throughout the year.
Frequency of monitoring/recording:	Aggregated yearly
QA/QC procedures to be applied:	N/A
Purpose of data:	Calculation of project emissions
Calculation method:	-
Comments:	-

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