MODULE FOR CO_2 CAPTURE FROM BIOENERGY COMBUSTION

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Title	Module for CO_2 Capture from Bioenergy Combustion
Version	Draft for Public Consultation
Date of Issue	29-Feb-2024
Type	☒ Module ☐ Tool
Sectoral Scope	16. Carbon Capture and Storage
Developer	CCS+ Initiative
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CONTENTS

1 SOURCES

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 Module for CO_2 Capture from Air (Direct Air Capture)*
- *VMD00XX Module for CO_2 Capture from Bioproduction Processes*
- *VMD00XX Module for CO_2 Capture from Post combustion Flue Gases in Fossil Fuel Power and Heat Generation*
- *VMD00XX Module for CO_2 Capture from Industrial Processes*
- *VMD00XX Module for CO_2 Capture from Oil and Gas Production and Processing*
- *VMD00XX Module for CO_2 Capture from Precombustion Processes in Fossil Fuel Power and Heat Generation*
- *VMD00XX Module for CO_2 Capture from Oxyfuel Combustion in Fossil Fuel Power and Heat Generation*

Transport Module(s)

- *VMD00XX Module for CO_2 Transport*

Storage Modules

- *VMD00XX Module for CO_2 Storage in Saline Aquifers and Depleted Hydrocarbon Reservoirs*

Other Modules/Tools

- *VT00XX Tool for Differentiating Reductions and Removals in CCS Projects*
- *VT00XX Tool for Non-VCS CO_2 in Carbon Capture and Storage Projects*
- *VMD0033 Estimation of Emissions from Market Leakage*
- *GCS Non-Permanence Risk Tool*

VCS Program Requirements

- *Geologic Carbon Storage (GCS) Requirements*

This methodology uses the latest versions of the following CDM tools:

- CDM *TOOL16 Project and leakage emissions from biomass*
- CDM *TOOL12 Project and leakage emissions from transportation of freight*

2 SUMMARY DESCRIPTION OF THE MODULE

This module calculates project emissions ($PE_{Cap,y}$) and leakage emissions ($LE_{Cap,y}$) from eligible bioenergy carbon capture and storage (BECCS) project activities that result in the capture of carbon dioxide from facilities that generate heat and power using sustainable biomass feedstocks.

This module establishes applicability conditions, defines the project baseline and the module boundary to determine the material project emission sources for quantification, and provides associated monitoring procedures.

3 DEFINITIONS

In addition to the definitions set out in the *VCS Program Definitions* and *VM00XX Methodology for Carbon Capture and Storage*, the following definitions apply to this module.

Anaerobic digestion
The microbial breakdown of organic material in the absence of oxygen. Organic compounds emitted during anaerobic decomposition are mainly methane (CH_4) and lesser amounts of carbon dioxide (CO_2).

Capture materials
The chemicals and media used by a bioenergy carbon capture and storage (BECCS) process to capture CO_2. Depending on the technology, this may include capture solvents, solid sorbents, membranes or 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.

Existing bioenergy source facility
A facility that generates power, or co-generates heat and power, from biomass or the biomass component of a mixed feedstock, and from which CO_2 originates, that started operation more than 12 months before the project start date.

High ILUC risk biomass
Biomass that is determined to have high indirect land-use change (ILUC) according to the criteria in Article 3 of the Delegated Regulation on indirect land-use change ((EU) 2019/807)[1]. High ILUC-risk biomass is ineligible for use in this module.

[1] Article 3 - Commission Delegated Regulation (EU) 2019/807 of 13 March 2019 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council as regards the determination of high indirect land-use change-

Ineligible biomass
Biomass feedstocks that meet the definition of high ILUC risk biomass, do not fall into an acceptable biomass category as defined in Appendix 1 of *VT00XX Tool for Differentiating Reductions and Removals in CCS Projects*, or that cannot meet cascading use and LULUCF criteria.

New bioenergy source facility
A facility that generates power, or co-generates heat and power, from biomass or the biomass component of a mixed feedstock, and from which CO_2 originates, that started operation less than 12 months before the project start date.

Non-traceable biomass
Biomass feedstocks that do not meet the definition of "sustainable biomass" due to a failure to meet the traceability requirements outlined in Appendix 2 of *VT00XX Tool for Differentiating Reductions and Removals in CCS Projects.*

Sustainable biomass
Biomass feedstocks that meet the sustainability principles and traceability requirements outlined in Appendix 2 of *VT00XX Tool for Differentiating Reductions and Removals in CCS Projects.*

4 APPLICABILITY CONDITIONS

This module applies to project activities that capture CO_2 from the flue gas of facilities generating, or co-generating, heat and power from biomass or the biomass component of a mixed feedstock.

This module is applicable under the following conditions:

1) Project activities must capture CO_2 from flue gas from a bioenergy source facility. Capture must occur 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. Electrochemical processes; or
    d. Cryogenic processes.
2) Project activities must regenerate the primary capture fluid or media, such that it is not a one-time use or disposable material, and that a concentrated CO_2 stream is

risk feedstock for which a significant expansion of the production area into land with high carbon stock is observed and the certification of low indirect land-use change-risk biofuels, bioliquids and biomass fuels recovered from regeneration and available for subsequent transport (where applicable) and storage.

3) Project activities must include at least one of the following:
    a. Installation and operation of a new capture facility at a new or existing bioenergy source facility,
    b. Refurbishment of an existing capture facility at an existing bioenergy source facility that would otherwise be decommissioned prior to the project start date, or
    c. Expansion of the existing capture capacity at an existing bioenergy source facility.
4) The project activity must transfer biogenic carbon from short-term to long-term carbon pools.

This module is not applicable under either of the following conditions:

1) Project activities use oxy-fuel combustion capture for power generation.
2) Project activities comprise upgrades to existing BECCS facilities or changes in operational practices leading to improved capture efficiency.
3) Project activities that use ineligible biomass.

5 MODULE BOUNDARY

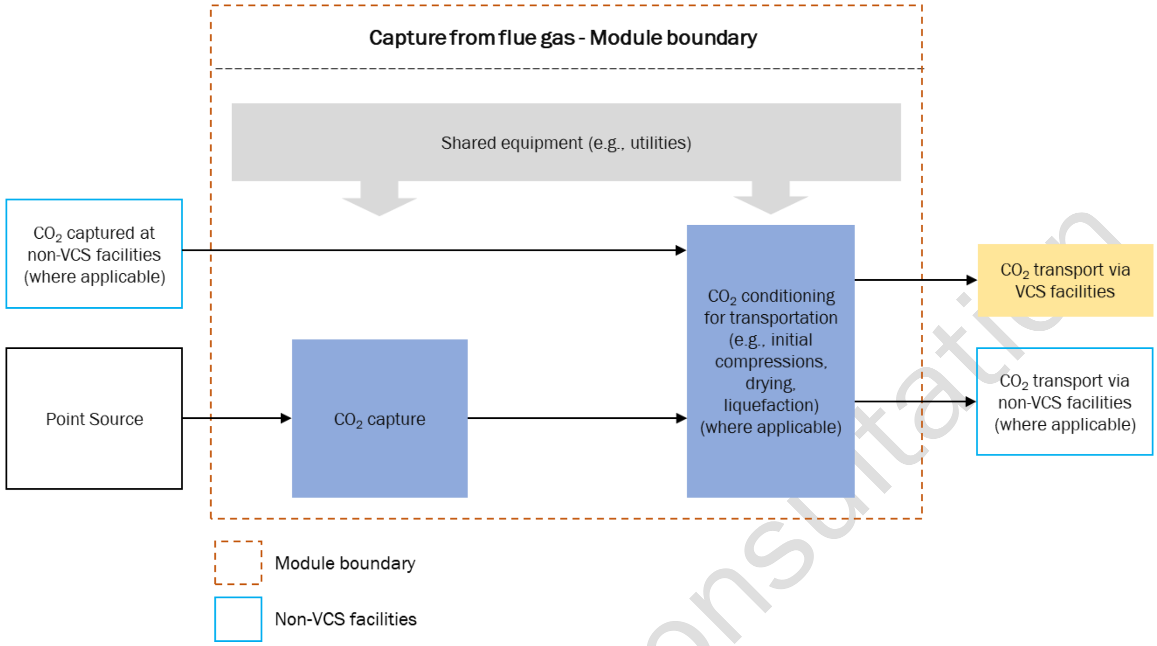
The spatial extent of the module boundary includes the capture facility (Figure 1).

Commonly used equipment and processes include:

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

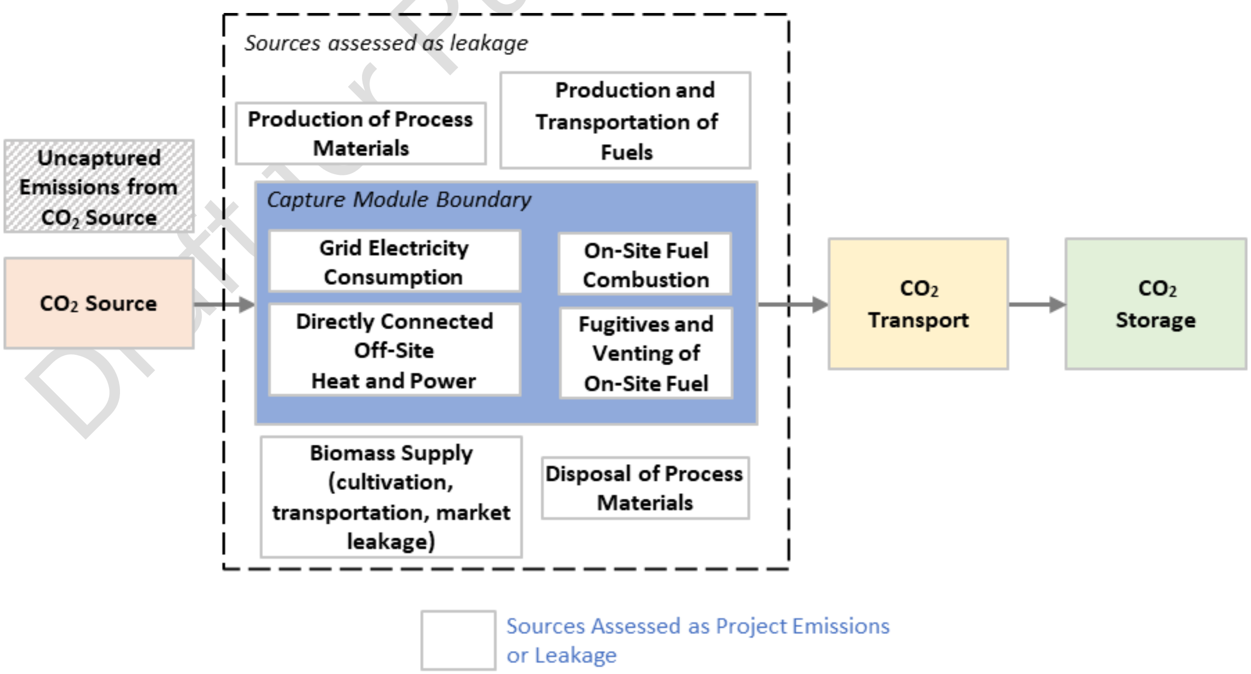
Transportation segments are not considered in this module. Please refer to the latest version of *VMD00XX Module for CO_2 Transport* for further details of the module boundary of the capture and transport segments.

Figure 1: Module Boundary for Capture from Biogenic Sources



Sources of GHG emissions for this module that must be accounted for as project and leakage emissions are depicted in Figure 2.

Figure 2: Project and Leakage Emissions Boundary for CO_2 Capture from Biogenic Sources



The greenhouse gases included in and 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
Baseline	CO_2 emitted into the atmosphere	CO_2	Yes	CO_2 captured under the project activity would not have been captured in the absence of the project.
		CH_4	No	Only CO_2 is considered under the baseline. This is conservative.
		N_2O	No	Only CO_2 is considered under the baseline. This is conservative.
		Other	No	Only CO_2 is considered under the baseline. This is conservative.
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.
	Fugitive and venting emissions from 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 from the baseline since only CO2 is considered for

				permanent geological sequestration.
		N_2O	No	Excluded from the baseline since only CO2 is considered for permanent geological sequestration.
		Other	No	Excluded from the baseline since only CO2 is considered for permanent geological sequestration.
	Fugitive and venting emissions from on-site fuel use	CO_2	Yes	Major emission source
		CH_4	Yes	Significant emission source
		N_2O	Yes	Included for completeness
		Other	No	Excluded for simplicity, emissions are considered negligible.

6 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: CO_2 would not be emitted into the atmosphere in the flue gas of a bioenergy source facility. Carbon stored in biomass feedstocks that would have been relevant to the project remain in a fast carbon cycle, decaying and remitting to the atmosphere in the short-term.

Projects must justify the use of the B1 baseline by providing credible evidence to demonstrate that in the absence of the project activity, one of the following scenarios would have most likely occurred.

1) No bioenergy source facility would exist and therefore, no new capture facility would be installed.
2) An existing capture facility would be decommissioned.

Baseline B2: CO_2 would have been emitted to the atmosphere in the flue gas of an existing bioenergy source facility from the combustion of the biomass feedstocks that would have been relevant to the project.

Projects must justify the use of the B2 baseline by providing credible evidence to demonstrate that in the absence of the project activity, one of the following scenarios would have most likely occurred.

1) There would be no increase in the capture capacity of the existing capture facility.
2) No new capture facility would be installed at the existing source facility.

Waste Heat: If heat is considered wasted in the baseline scenario, the proponent must demonstrates that all the following apply:

a) The heat source originates from the bioenergy source facility or offsite;

b) The heat was not otherwise used at the heat source, or was not delivered, sold, or used by a consumer prior to the project start date; and

c) The heat was dissipated to ambient heat sinks prior to the project start date.

7 QUANTIFICATION PROCEDURES

The process for quantifying project emissions $PE_{cap,y}$ and leakage emissions $LE_{cap,y}$ for capture from bioenergy source facilities for BECCS is outlined in the following sections.

7.1 Quantification of Project Emissions

Equation (1) calculates total project emissions.

$$PE_{Cap,y} = PE_{Comb\_Fuel,y} + PE_{Fuel\_FV,y} + PE_{Elec,y} - PE_{nonVCS\ CO2,y} \quad (1)$$

Where:

$PE_{Cap,y}$	=	Project emissions from capture in year *y* (t CO_2e)
$PE_{Comb\_Fuel,y}$	=	Project emissions from on-site fuel combustion in year *y* (t CO_2e)
$PE_{Fuel\_FV,y}$	=	Project emissions from fugitive, venting and other operational emissions related to on-site fuel use (e.g., natural gas use) in the physical boundary of the capture facility in year *y* (t CO_2e)
$PE_{Elec,y}$	=	Project emissions from electricity consumption to operate capture and conditioning processes in year *y* (t CO_2e)
$PE_{nonVCS\ CO2,y}$	=	Project emissions associated with non-VCS sources in year *y* determined using the latest version of *VT00XX Tool for Non-VCS-CO_2 in Carbon Capture and Storage Projects*; for projects without non-VCS CO_2, $PE_{nonVCS\ CO2,y}$= 0 (t CO_2e)

7.1.1 Project Emissions from Fuel Combustion

Equation (2) calculates project emissions from fossil fuel combustion for mobile equipment, and off-site heat and power generation.

$$PE_{Comb_{Fuel},y} = \sum_i (\Delta Q_{Fuel,i,y} \times EF_{Fuel,CO2,i}) + \sum_i (\Delta Q_{Fuel,i,y} \times EF_{Fuel,CH4,i}) \times GWP_{CH_4} + \sum_i (\Delta Q_{Fuel,i,y} \times EF_{Fuel,N2O,i}) \times GWP_{N_2O} \quad (2)$$

Where:

$PE_{Comb\_Fuel,y}$	=	Project emissions from fuel combustion to operate equipment for capture and conditioning processes in year *y* (t CO_2e)
$\Delta Q_{Fuel,i,y}$	=	Change in quantity of fuel type *i* used to operate on-site and/or third-party (for off-site heat/steam supply) equipment in year *y* relative to the baseline (m^3 or kg or GJ)
$EF_{Fuel,CO2,i}$	=	CO_2 emission factor for combustion of fuel *i* in year *y* (t CO_2/m^3 or t CO_2/kg or t CO_2/GJ)
$EF_{Fuel,CH4,i}$	=	CH_4 emission factor for combustion of fuel *i* in year *y* (t CH_4/m^3 or t CH_4/kg or t CH_4/GJ)
$EF_{Fuel,N2O,i}$	=	N_2O emission factor for combustion of fuel *i* in year *y* (t N_2O/m^3 or t N_2O/kg or t N_2O/GJ)
GWP	=	Global warming potential

$$\Delta Q_{Fuel,i,y} = \max\left(Q_{Fuel,project,i,y} - Q_{Fuel,base,i}, 0\right) \quad (3)$$

Where:

$Q_{Fuel,project,i,y}$	=	Quantity of fuel type *i* used in capture facility equipment and/or third party (for off-site heat/steam supply) in year *y* in project activities (m^3 or kg or GJ)
$Q_{Fuel,base,i}$	=	Quantity of fuel type *i* used in capture facility equipment and/or third party (for off-site heat/steam supply) in the absence of the project; for baseline B1, $Q_{Fuel,base,i} = 0$ (m^3 or kg or GJ)

Off-site Fuel Consumption

The quantity of power or heat supplied from a directly connected off-site facility, $Q_{Fuel,i,y}$, is determined using Equation (4). For baseline B2, Equation (4) must be calculated for project activities (i.e., $Q_{Fuel,project,i,y}$) and for the pre-project period (i.e., $Q_{Fuel,base,i,y}$) for use in Equation (3).

$$Q_{Fuel,i,y} = Q_{Fuel\_cogen,i,y} \times \frac{\left(Heat_{BECCS,y} + Electricity_{BECCS,y}\right)}{\left(Heat_{cogen,y} + Electricity_{cogen,y}\right)} \quad (4)$$

Where:

$Q_{Fuel,i,y}$	=	Mass of fuel type *i* used by a third-party energy source to provide electricity and/or thermal energy to the capture facility in year *y* (t/yr)
$Q_{Fuel\_cogen,i,y}$	=	Total mass of fuel type *i* used by the energy unit to generate electricity and/or heat in year *y* (t/yr)
$Heat_{BECCS,y}$	=	Quantity of useful thermal energy supplied to the capture facility by the energy facility unit in year *y* (MWh/yr)

$Electricity_{BECCS,y}$	=	Quantity of electricity supplied to the capture facility by the facility unit in year *y* (MWh/yr)
$Heat_{cogen,y}$	=	Total quantity of useful thermal energy produced by the energy facility unit in year *y* (MWh/yr)
$Electricity_{cogen,y}$	=	Total quantity of electricity produced by the energy facility unit in year *y* (MWh/yr)

On-site Fuel Combustion

Projects capturing CO_2 from on-site fossil fuel combustion in addition to biogenic CO_2 must follow the guidance provided by the latest version of *VT00XX Tool for Differentiating Reductions and Removals in CCS Projects*.

Waste Heat

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

Biogenic Fuel Sources

Emissions from sustainable biomass are considered zero as defined in the latest version of *VT00XX Tool for Differentiating Reductions and Removals in CCS Projects.*

7.1.2 Fugitive and Venting Emissions from On-Site Fuel Use

Equation (5) calculates fugitive and venting emissions for BECCS projects that use gaseous fuels on-site.

$$PE_{Fuel\_FV,y} = \left(\sum_{n} Count_{n,y} \times EF_{component\ n} \times T_{n,y} \times 0.001 + \sum_{m} V_m\right) \times GWP_{CH_4} \quad (5)$$

Where:

$PE_{Fuel\_FV,y}$	=	Fugitive and venting emissions from on-site fuel use in year *y* (t CO_2e)
$Count_{n,y}$	=	Total number of *n*th components at the facility in use during year *y* (unitless)
$EF_{component\ n}$	=	Emission factor of fugitive emissions for component *n*.
$T_{n,y}$	=	Pressurized time of component *n* in year *y* (hr)
V_m	=	Vented CH_4 emissions for *m*th venting event (t CH_4/event)
0.001	=	Conversion from kg to t

7.1.3 Project Emissions from Electricity Consumption

Project emissions from electricity consumption may be derived from on-site and off-site sources. 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.

Note: This section is subject to change upon the release of Verra's Electricity Tool and is included for completeness only.

Project emissions from electricity consumption are calculated using Equation (6)

$$PE_{Elec,y} = \sum_{s} \Delta Q_{Elec,s,y} \times EF_{Elec,s} \tag{6}$$

Where:

$PE_{Elec,y}$	=	Project emissions from electricity consumption to operate equipment in the BECCS module in year *y* (t CO_2e)
$\Delta Q_{Elec,y}$	=	Change in electricity consumption between the project and pre-project period in year *y* (MWh/yr)
$EF_{Elec,s}$	=	Emissions factor for electricity generation from source *s*, including upstream emissions from electricity generation and transport (t CO_{2e}/MWh)

$$\Delta Q_{Elec,s,y} = \max\left(Q_{Elec,project,s,y} - Q_{Elec,base,s,},0\right) \tag{7}$$

Where:

$Q_{Elec,project,s,y}$	=	Total electricity from source *s* used to operate equipment in the capture facility in year *y* for project activities (MWh/yr)
$Q_{Elec,base,s,}$	=	Total electricity from source *s* used to operate equipment in the capture facility at maximum capture capacity in baseline; for baseline B1, $Q_{Elec,base,s}$ = 0 (MWh/yr)

7.2 Quantification of Leakage

The approach to determining leakage emissions in the following sections depends on the baseline scenario.

For B1, there is no consumption of energy, materials, or biomass in the absence of the project, so leakage emissions are based on the total amount of consumption in the project for all categories.

For B2, energy, materials and biomass may have been consumed in the absence of the project, so leakage emission calculations are based on the increase in consumption in the project relative to the period before the project. Where there is no increase in consumption in the project relative to the pre-project period, leakage emissions for all categories are set to zero.

Equation (8) calculates the leakage emissions associated with the project.

$$LE_{Cap,y} = LE_{Fuel,y} + LE_{Elec,y} + LE_{Mat,y} + LE_{biomass,y} + LE_{non-biogenic,y} - LE_{nonVCS\ CO2,y} \quad (8)$$

Where:

$LE_{Cap,y}$ = Leakage emissions from capture in year y (tCO_2e)

$LE_{Fuel,y}$ = Leakage emissions from fuel consumption to operate equipment in the capture facility in year *y* (t CO_2e)

$LE_{Elec,y}$ = Leakage emissions from electricity consumption to operate equipment in the capture facility in year *y* (t CO_2e)

$LE_{Mat,y}$ = Leakage emissions from capture materials used in the BECCS process in year *y* (t CO_2e)

$LE_{biomass,y}$ = Leakage emissions from biomass supply to the source facility in year *y* (t CO_2e)

$LE_{non-biogenic,y}$ = Leakage emissions from non-biogenic fuel supply to the source facility in year *y* calculated using *VMD00XX Module for CO_2 Capture from Post-combustion Flue Gases in Fossil Fuel Power and Heat Generation* (t CO_2e)

$LE_{nonVCS\ CO2,y}$ = Leakage emissions from processes and equipment related to non-VCS sources in year *y* determined as per the latest version of *VT00XX Tool for non-VCS-CO2 in Carbon Capture and Storage Projects*; for projects without non-VCS CO_2, $LE_{nonVCS\ CO2,y}$= 0 (t CO_2e)

7.2.1 Leakage Emissions from Fuel Consumption

Upstream emissions related to fuel for use at the capture facility or fuel use by a third-party supplying heat or steam to the capture facility are calculated using Equation (9).

$$LE_{Fuel,y} = \sum_i (\Delta Q_{Fuel,i,y} \times EF_{Upstream\_Fuel,i,y}) \quad (9)$$

Where:

$LE_{Fuel,y}$ = Leakage emissions from upstream sources related to fuel consumed in on-site equipment in year *y* (t CO_2e)

$\Delta Q_{Fuel,i,y}$ = Change in quantity of fuel type *i* used in capture facility equipment and/or by a third party (for off-site heat/steam supply) in year *y* as determined in Equation (3 (m^3 or kg or GJ)

$EF_{Upstream\_Fuel,i,y}$	=	Emission factor for upstream sources related to fuel type *i* used in capture facility and/or by a third party (for off-site heat/steam supply) in year *y* (t CO_2e/m^3 or t CO_2e/kg or t CO_2e/GJ)

In cases of heat or steam supply by a third party, $\Delta Q_{Fuel,i,y}$ denotes only the proportion of fuel used to generate heat or steam for the capture facility. This quantity must be calculated using the allocation principle outlined in Equation (4).

7.2.2 Leakage Emissions from Upstream Fuels for Electricity Consumption

Leakage emissions from electricity consumption are calculated according to Equation (10).

$$LE_{Elec,y} = \sum_{i} (\Delta Q_{Elec,y} \times EF_{Upstream\_Elec}) \tag{10}$$

Where:

$LE_{Elec,y}$	=	Leakage emissions from electricity consumption to operate equipment in capture facility in year *y* (t CO_2e)
$\Delta Q_{Elec,y}$	=	Change in quantity of electricity usage to operate equipment in the capture facility in year *y* as determined in Equation (7 (MWh/yr)
$EF_{Upstream\_Elec}$	=	Emissions factor for upstream GHG sources related to electricity generation (t CO_2e/MWh)

7.2.3 Leakage Emissions from Consumption of Capture Materials

Leakage emissions from the replacement of capture materials are calculated per Equation (11).

$$LE_{Mat,y} = \sum_{j} (\Delta Q_{Mat,j,y} \times EF_{Mat,j}) \tag{11}$$

Where:

$LE_{Mat,y}$	=	Leakage emissions from consumption of a capture material in the capture facility in year *y* (t CO_2e)
$\Delta Q_{Mat,j,y}$	=	Change in quantity of make-up capture material *j* consumed by capture facility in year *y* (kg or m^3 or units)
$EF_{Mat,j}$	=	GHG emissions from the production of capture material *j* (t CO_2e/kg or t CO_2e/m^3 or t CO_2e/unit)

$$\Delta Q_{Mat,j,y} = \max(Q_{Mat,project,j,y} - Q_{Mat,base,j}, 0) \tag{12}$$

Where:

$Q_{Mat,project,j,y}$	=	Quantity of capture material *j* consumed by capture facility in year *y* in project activities (kg or m^3 or units)
$Q_{Mat,base,i}$	=	Quantity of make-up capture material *j* consumed by capture facility in the absence of the project; for baseline B1, $Q_{Mat,base,j}$ = 0 (kg or m^3 or units)

7.2.4 Leakage Emissions from Biomass Feedstock Supply to the Source Facility

Leakage emissions from biomass feedstock supply ($LE_{biomass,y}$) are calculated as per Equation (13).

$$LE_{biomass,y} = LE_{BC,y} + LE_{BR,y} + LE_{BT,y} + LE_{BM,y} + LE_{Pr,y} \tag{13}$$

Where:

$LE_{biomass,y}$	=	Leakage emissions from biomass feedstock supply to the source facility in year *y* (t CO_2e)
$LE_{BC,y}$	=	Leakage emissions from the cultivation of biomass feedstock in a dedicated plantation in year *y* (t CO_2e)
$LE_{BT,y}$	=	Leakage emissions from the transportation of biomass feedstock to a source facility in year *y* (t CO_2e)
$LE_{BM,y}$	=	Leakage emissions from market leakage from the use of biomass feedstock in year y determined in accordance with Appendix 1 (t CO_2e).
$LE_{Pr,y}$	=	Leakage emissions from the processing of biomass in year y (t CO_2e)

7.2.4.1 Calculating Increase in Biomass Consumption

Leakage emissions from biomass consumption are based on the relative change in biomass consumption between the project and the baseline.

Equation (14) calculates the total increase in biomass consumption in the project activities.

$$\Delta Q_{Bio,y} = \sum_b \max(m_{sb,project,b,y} - m_{sb,base,b}, 0) + \sum_b \max(m_{nt,project,b,y} - m_{nt,base,b}, 0) \tag{14}$$

Where:

$\Delta Q_{Bio,y}$	=	Change in mass of total biomass consumed relative to the pre-project period in year *y* (t)

$m_{sb,project,b,y}$	=	Mass of sustainable biomass type *b* used after the project start date in year *y* (t)
$m_{sb,base,b}$	=	Mass of sustainable biomass type *b* used in the absence of the project; for baseline B1, $m_{sb,base,b}$= 0 (t)
$m_{nt,project,b,y}$	=	Mass of non-traceable biomass type *b* used after the project start date in year *y* (t)
$m_{nt,base,b}$	=	Mass of non-traceable biomass type *b* used in the absence of the project; for baseline B1, $m_{nt,base,b}$ = 0 (t)

If $\Delta Q_{Bio,y}$ = 0, then $LE_{biomass,y}$ is set to zero and no further leakage calculations are required.

7.2.4.2 Calculating Leakage from Biomass Cultivation in a Dedicated Plantation

There are two options for calculating leakage emissions from the cultivation of biomass in a dedicated plantation.

Option 1: Embodied Emissions Factor

Use an embodied emissions factor determined through a lifecycle assessment (LCA) in Equation (15) to calculate leakage emissions from cultivation.

$$LE_{BC,y} = \left(m_{sb,project,b,y} - m_{sb,base,b}\right) \times EF_b \quad (15)$$

Where:

$LE_{BC,y}$	=	Leakage emissions resulting from cultivation of biomass feedstock in a dedicated plantation in year *y* (t CO_2e)
$m_{sb,project,b,y}$	=	Mass of sustainable biomass type *b* used after the project start date in year *y* (t)
$m_{sb,base,b}$	=	Mass of sustainable biomass type *b* used in the absence of the project; for baseline B1, $m_{sb,base,b}$ = 0 (t)
EF_b	=	Embodied emissions factor for biomass *b*

Option 2: Calculate Leakage Emissions

Calculate leakage emissions using CDM TOOL16[2] as follows:

1) Use Equation (16) to calculate the area of land required to produce the mass of biomass *b* consumed by the project activities ($Area_{cultivation,b,y}$).

$$Area_{cultivation,b,y} = \left(m_{sb,project,b,y} - m_{sb,base,b}\right) \times Yield_{b,y} \quad (16)$$

[2] Available at: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-16-v5.0.pdf

Where:

$Area_{cultivation,b,y}$	=	Area required to produce amount of biomass b consumed in year y (ha)
$m_{sb,project,b,y}$	=	Mass of sustainable biomass type b used after the project start date in year y (t).
$m_{sb,base,b}$	=	Mass of sustainable biomass type b used in the absence of the project (t). For baseline B1, $m_{sb,base,b}$ = 0.
$Yield_{b,y}$	=	Mass of biomass produced per unit of area for biomass type b obtained from biomass supplier in year y (t/ha).

2) Use $Area_{cultivation,b,y}$ or relevant emissions data reported under a regulatory framework (e.g., the European Union's Renewable Energy Directive, RED III) to calculate the emissions resulting from biomass cultivation projects using Section 5.1 of CDM TOOL16.
3) Use Equation (17) to assign the emissions resulting from biomass cultivation projects as leakage.

$$LE_{BC,y} = \sum_{b} PE_{BC,b,y} \tag{17}$$

Where:

$LE_{BC,y}$	=	Leakage emissions resulting from cultivation of biomass feedstock in a dedicated plantation in year *y* (t CO_2e)
$PE_{BC,b,y}$	=	Emissions resulting from cultivation of biomass b in a dedicated plantation in year y calculated using Section 5.1 of CDM TOOL16

Note – Section 5.1 of CDM TOOL16 quantifies project emissions resulting from the cultivation of biomass at a dedicated plantation. The project emissions from biomass cultivation, rather than the leakage attributed to leakage in Section 6.1 of TOOL16, are included here as this approach provides a more conservative accounting of the emissions that are directly attributable to the BECCS project. Therefore, $PE_{BC,y}$ determined in TOOL16 equals $LE_{BC,,y}$ in this module.

7.2.4.3 Calculating Leakage from Transportation to an Emissions Source Facility

Proponents must use CDM *TOOL12 Project and leakage emissions from transportation of freight*[3] to determine leakage emissions from the transportation of biomass. TOOL12 provides the option to use a default emissions factor or fuel consumption data to determine

[3] Available at: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-12-v1.pdf

transportation emissions. Proponents reporting fuel consumption or transportation emissions under a regulatory framework (e.g., EU-RED III) must use that reported data in TOOL12.

Equation (18) assigns the emissions determined using TOOL12 to leakage in this module.

$$LE_{BT,y} = LE_{TR,m} \quad (18)$$

Where:

$LE_{BT,y}$	=	Leakage emissions from the transportation of biomass resulting from project activities in year *y* (t CO_2e)
$LE_{TR,m}$	=	Emissions from the transportation of biomass resulting from project activities in year *y* calculated using CDM TOOL12 (t CO_2e)

7.2.4.4 Calculating Leakage from Processing of Biomass

Typical processing of biomass and its residues can include mechanical (e.g., sorting, grinding), thermo-chemical (e.g., drying, vapor explosion, acid or alkali treatments), and biological process. Proponents must use CDM *TOOL16* Project and leakage emissions from biomass[4] to determine leakage emissions from the processing of biomass, LE_{Pr}, according to Equation (19)

$$LE_{Pr,y} = \begin{cases} PE_{BP,y} \\ PE_{BRP,y} \end{cases} \quad (19)$$

Where:

$LE_{Pr,y}$	=	Leakage emissions from the processing of biomass in year y (t CO_2e)
$PE_{BP,y}$	=	Emissions due to processing of biomass outside the project boundary in year *y* calculated using CDM TOOL16 (t CO_2e)
$PE_{BRP,y}$	=	Emissions due to processing of biomass residues outside the project boundary in year *y* calculated using CDM TOOL16 (t CO_2e)

8 DATA AND PARAMETERS

8.1 Data and Parameters Available at Validation

[4] Available at: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-16-v2.pdf

Additional data and parameters are defined in *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	(2)
Source of data	Most recent version of the 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	Unless otherwise directed by the VCS Program, the most recent 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 N_2O
Equations	(2)
Source of data	The most recent version of the 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	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	$Q_{Fuel,base,i}$
Data unit	m^3, kg or GJ
Description	Quantity of fuel type *i* used in capture facility equipment and/or by a third party (for off-site heat/steam supply) in the absence of the project
Equations	(3
Source of data	On-site measurements
Valued applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Measured from flow meters or calculated from fuel receipts or invoices. Quantity of fuel type *i* is calculated as the average annual fuel consumption during the three years immediately prior to the start date of the project activity. Where a project has been operational for less than three years, the average consumption of fuel may be calculated over the actual operational period.
Purpose of data	Calculation of leakage emissions
Comments	

Data/Parameter	$m_{sb,base,b}$
Data unit	t
Description	Mass of sustainable biomass type *b* used in the absence of the project
Equations	(14) (15) (16)
Source of data	On-site measurements
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Measured from belt weigher/weigh bridge or calculated from receipts/invoices. Mass of biomass consumption is calculated as the average annual biomass consumption during the three years immediately prior to the start date of the project activity. Where a project has been operational for less than three years, the average consumption of biomass may be calculated over the actual operational period.
Purpose of data	Calculation of leakage emissions from increased biomass consumption in existing source facilities

Comments	N/A

Data/Parameter	$m_{nt,base,b}$
Data unit	t
Description	Mass of non-traceable biomass type *b* used in the absence of the project
Equations	(14)
Source of data	On-site measurements
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Measured from belt weigher/weigh bridge or calculated from receipts/invoices. Mass of biomass consumption is calculated as the average annual biomass consumption during the three years immediately prior to the start date of the project activity. Where a project has been operational for less than three years, the average consumption of biomass may be calculated over the actual operational period.
Purpose of data	Calculation of leakage emissions from increased biomass consumption in existing source facilities
Comments	N/A

Data/Parameter	$Q_{Elec,base,s}$
Data unit	MWh
Description	Quantity of total electricity from source s used to operate equipment in the capture facility at maximum capture capacity in baseline
Equations	(7)
Source of data	On-site measurements or Estimation from system design specifications
Valued applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Measured from electricity meters or calculated from receipts/invoices. Engineering estimates based on equipment size and manufacturer efficiency estimates may be used for equipment where it is

	demonstrated that the specific electricity consumption of the equipment is less than 1 percent of total electricity consumption. Quantity of total electricity is calculated as the electricity consumption of the capture facility at maximum capture capacity.
Purpose of data	Calculation of project and leakage emissions
Comments	Take into consideration the uncertainty associated with determination of electricity consumption. For further guidance project proponent may refer to instructions provided in the VCS Electricity tool.

Data/Parameter	$Q_{Mat,base,j}$
Data unit	t
Description	Quantity of capture material *j* consumed by the capture facility in the absence of the project
Equations	(12
Source of data	On-site measurements
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Measured from material flow meters or weighing equipment or calculated from receipts or invoices. Mass of capture material consumption is calculated as the average annual material consumption during the three years immediately prior to the start date of the project activity. Where a project has been operational for less than three years, the average consumption of capture material may be calculated over the actual operational period.
Purpose of data	Calculation of leakage emissions
Comments	N/A

8.2 Data and Parameters Monitored

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

Data/Parameter	EF_b

Data unit	t CH_4/m^3, t CH_4/kg or t CH_4/GJ
Description	Embodied emissions factor for biomass b
Equations	(15)
Source of data	Output of LCA modelling tool
Description of measurement methods and procedures to be applied	The LCA must be performed by a qualified third party, in accordance with the latest version of ISO 14040 using a functional unit appropriate to the form of biomass (i.e., solid, gaseous or liquid). A sensitivity analysis of the LCA results must be conducted to identify the lifecycle stages, material, or energy inputs (sensitive parameters) that have the most significant impact on overall emissions intensity and to identify the threshold of materiality for changes in those sensitive parameters. Emissions factors determined in this manner must be updated at least every three years or when there is a material change in any of the sensitive parameters.
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	$EF_{Fuel,CO2,i}$
Data unit	t CO_2/m^3, t CO_2/kg or t CO_2/GJ
Description	CO_2 emission factor for combustion of fuel i in year y
Equations	(2)
Source of data	The following data sources may be used:

	1) Emission factor from IPCC (2006) Guidelines for National Greenhouse Gas Inventories, Volume 2, Chapter 2 Stationary Combustion, Table 2.2[5] 2) Emission factors published by US EPA (2023)[6] or similar source; or 3) Data provided by the fuel supplier.
Description of measurement methods and procedures to be applied	Use the most recent data published by the above sources when 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	t CH_4/m^3, t CH_4/kg or t CH_4/GJ
Description	CH_4 emission factor for combustion of fuel *i* in year *y*
Equations	(2)
Source of data	The following data sources may be used: 1) Emission factor from IPCC (2006) Guidelines for National Greenhouse Gas Inventories, Volume 2, Chapter 2 Stationary Combustion, Table 2.2; 2) Emission factors published by US EPA (2023) or similar source; or 3) Data provided by the fuel supplier.

[5] Available at : https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

[6] Available at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

Description of measurement methods and procedures to be applied	Use the most recent data published by the above sources when 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	$EF_{Fuel,N20,i}$
Data unit	t N_2O/m^3, t N_2O/kg or t N_2O/GJ
Description	N_20 emission factor for combustion of fuel *i* in year *y*
Equations	(2)
Source of data	The following data sources may be used: 1) Emission factor from IPCC (2006) Guidelines for National Greenhouse Gas Inventories, Volume 2, Chapter 2 Stationary Combustion, Table 2.2; 2) Emission factors published by US EPA (2023) or similar source; or 3) Data provided by the fuel supplier.
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	

Data/Parameter	$EF_{Upstream\_Fuel,i,y}$
Data unit	t CO_2e/m^3, t CO_{2e}/kg or t CO_{2e}/GJ
Description	Emission factor for upstream sources related to fuel type *i* used in the capture facility and/or by a third party (for off-site heat/steam supply) in year *y*
Equations	(9)
Source of data	The following data sources may be used: 1) An 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; 2) Calculations of embodied emission factor for each fuel type, using regional compliance market-approved methods or equivalent (e.g., CA-GREET in the California Low Carbon Fuel Standard and GHGenius in the British Colombia Renewable and Low Carbon Fuel Requirements Regulation), or 3) Emission factors published in peer-reviewed literature that are representative of the BECCS plant operation both temporally and geographically.
Description of measurement methods and procedures to be applied	Use the most recent data published by the sources when reporting project emissions.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Use the most recent data published by the above sources when reporting project emissions. In the case of peer-reviewed literature, the literature must have been published within a year of reporting project emissions and must be temporally and geographically representative of the capture facility.
Purpose of data	Calculation of project emissions

Calculation method	N/A
Comments	

Data/Parameter	$Q_{Fuel\_cogen,i,y}$
Data unit	t/yr
Description	Total mass of fuel type *i* used by the energy unit to generate electricity and/or heat in year *y*
Equations	(4)
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 or invoices
Frequency of monitoring/recording	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	$Heat_{BECCS,y}$
Data unit	MWh/yr
Description	Quantity of useful thermal energy supplied to the capture facility by the energy facility unit in year *y*
Equations	(4)

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	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	$Electricity_{BECCS,y}$
Data unit	MWh/yr
Description	Quantity of electricity supplied to the capture facility by the facility unit in year *y*
Equations	(4)
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	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.

Data/Parameter	$Heat_{Cogen,y}$
Data unit	MWh/yr
Description	Total quantity of useful thermal energy produced by the energy facility unit in year *y*
Equations	(4)
Source of data	Utility receipts/invoices or metered data for heat produced
Description of measurement methods and procedures to be applied	Measured from flowmeters or calculated from receipts or invoices
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	Monthly heat production is determined by summing the quantities from calibrated device readings
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/yr
Description	Total quantity of electricity produced by the energy facility unit in year *y*
Equations	(4)
Source of data	Utility receipts/invoices or metered data for off-grid use
Description of measurement methods	Measured from electricity meters or calculated from receipts or invoices

and procedures to be applied	
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	Monthly electricity production is determined by summing the quantities from calibrated device readings
Comments	Invoices and/or contracts with the third party must be in place to allow proper data collection.

Data/Parameter	$EF_{elec,s}$
Data unit	t CO_2e/MWh
Description	Emissions factor for electricity generation for source s, including upstream emissions from electricity generation and transport
Equations	(6)
Source of data	For grid electricity consumption, regional emission factors from compliance tools and data published by state or national governments must be used. Examples of such tools/sources are listed in Appendix 2. 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. Renewable energy (i.e., wind, solar, hydro) from a dedicated/off-grid captive source is deemed to have no emissions.
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 most recent published data or tools by the sources when reporting project emissions.

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

Data/Parameter	$Q_{Fuel,Project,i,y}$
Data unit	m^3, kg or GJ
Description	Quantity of fuel type *i* used in capture facility equipment and/or by a third party (for off-site heat/steam supply) in year *y*in project activities (m^3 or kg or GJ)
Equations	(3)
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 or invoices
Frequency of monitoring/recording	Continuously
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	

Data/Parameter	$EF_{Upstream\_Elec}$
Data unit	t CO_2e/MWh
Description	Emissions factor for upstream GHG sources related to electricity generation

Equations	(10)
Source of data	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 2. 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. Renewable energy (i.e., wind, solar, hydro) from a dedicated/off-grid captive source is deemed to have no emissions.
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 most recent published data or tools by the sources when reporting project emissions.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	

Data/Parameter	$Q_{Elec,project,s,y}$
Data unit	MWh/yr
Description	Quantity of total metered electricity from source s used to operate equipment in capture facility in year *y* in project activities (MWh/yr)
Equations	(7)
Source of data	Utility receipts/invoices or metered data for off-grid use[7]
Description of measurement methods	Measured from electricity meters or calculated from receipts or invoices Engineering estimates based on equipment size and manufacturer efficiency estimates may be used for equipment where it is

[7] For PPAs, separate guidelines to be developed (in progress).

and procedures to be applied	demonstrated that the specific electricity consumption of the equipment is less than 1 percent 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	Aggregate annual electricity use from source s through calibrated meter readings or utility receipts/invoices.
Comments	

Data/Parameter	$Q_{Mat,project,j,y}$
Data unit	kg or m^3 or units
Description	Quantity of capture material *j* consumed by the capture facility in year *y*
Equations	(12)
Source of data	Receipts/invoices or flow meter or weighing scale/equipment readings, as applicable
Description of measurement methods and procedures to be applied	Measured from material flow meters or weighing equipment or calculated from receipts or 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 over year *y* may be used.
QA/QC procedures to be applied	Measuring equipment (e.g., flow meters, weighing scale) must be routinely calibrated, inspected and maintained according to manufacturer specifications.
Purpose of data	Calculation of leakage emissions
Calculation method	Annually sum the quantity of make-up capture material 'i' using calibrated flow meters, weighing scales, or receipts/invoices.

Comments	

Data/Parameter	$EF_{Mat,j}$
Data unit	t CO_2/kg, t CO_2/m^3 or t CO_2/units
Description	GHG emissions from the production of capture material *j*
Equations	(11)
Source of data	Emissions from the production of capture material must be calculated using one of the following sources: 1) A compliance market-approved tool; open-source compliance tools include CA-GREET[8] and GHGenius[9] 2) A third-party audited assessment that aligns with ISO 14044 guidelines 3) Data published in peer-reviewed literature, such as scientific journals
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 when reporting project emissions. In the case of peer-reviewed literature, the literature must have been published within a year of reporting project emissions.
Purpose of data	Calculation of leakage emissions
Calculation method	Use the latest compliance tool (e.g., CA-GREET, GHGenius) or third-party ISO 14044 audited assessment for GHG emissions from capture material 'i' production.
Comments	

[8] 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/

Data/Parameter	$Count_{n,y}$
Data unit	Number
Description	Total number of *n*th components at the facility in use during year *y*
Equations	(5)
Source of data	Records of capture 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 Title 40 – Protection of Environment, Chapter I – Environmental Protection Agency Subchapter C Part 98 Subpart W § 98.233 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 capture facility.
Purpose of data	Calculation of project emissions
Calculation method	Annually count all nth components in use at the facility from facility records (e.g., drawings, parts lists).
Comments	The potential sources for fugitive emissions in the capture facility include components such as valves, pipe fittings/connectors, open-ended pipes, pressure relief valves, flanges, meters and instruments.

Data/Parameter	$T_{n,y}$
Data unit	hours
Description	Pressurized time of component *n* in year *y*
Equations	(5)
Source of data	Records of capture facility (e.g., control systems, recorded operational data)
Description of measurement methods	Data from capture facility records

and procedures to be applied	
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Use the most recent data available from the capture facility.
Purpose of data	Calculation of project emissions
Calculation method	Use annual operational records to determine Tn,y of component n.
Comments	

Data/Parameter	V_m
Data unit	t CH_4/event
Description	Vented CH_4 emissions for *m*th venting event
Equations	(5)
Source of data	Data from the capture 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 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	Determine V_i by direct measurement, or estimate using isolated or non-isolated volumes of pipes and equipment. Use appropriate transient flow rate calculations for CH4 venting events.

Comments	

Data/Parameter	$EF_{component,n}$
Data unit	kg CH_4/hr/component
Description	Emission factor of fugitive emissions for component used at the facility
Equations	(2)
Source of data	Emission factor derived from subpart W of US EPA (2023), Mandatory GHG Reporting Program[10], or equivalent nationally appropriate regulations
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	

Data/Parameter	$m_{sb,project,b,y}$
Data unit	t
Description	Mass of sustainable biomass type *b* used after the project start date in year *y*
Equations	(14), (15), (16)
Source of data	On-site measurement

[10] For more information see: https://www.epa.gov/ghgreporting/subpart-w-petroleum-and-natural-gas-systems

Description of measurement methods and procedures to be applied	Measured from belt weigher/weigh bridge or calculated from receipts or invoices.
Frequency of monitoring/recording	Aggregated annually
QA/QC procedures to be applied	Flow or weight meters must be operated 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 leakage emissions from increased biomass consumption in existing source facilities
Calculation method	Load cells measure the feedstock weight on the belt and send a signal to the integrator, which receives the input in the form of electrical pulses from a belt speed sensor. From the data sources of weight and speed, the mass rate of feedstock is calculated and the total mass of feedstock in the whole year is obtained.
Comments	N/A

Data/Parameter	$m_{nt,project,b,y}$
Data unit	t
Description	Mass of non-traceable biomass type *b* used after the project start date in year *y*
Equations	(14)
Source of data	On-site measurement
Description of measurement methods and procedures to be applied	Measured from belt weigher/weigh bridge or calculated from receipts or invoices
Frequency of monitoring/recording	Aggregated annually
QA/QC procedures to be applied	Flow or weight meters must be operated 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 leakage emissions from increased biomass consumption in existing source facilities
Calculation method	Load cells measure the feedstock weight on the belt and send a signal to the integrator, which receives the input in the form of electrical pulses from a belt speed sensor. From the data sources of weight and speed, the mass rate of feedstock is calculated and the total mass of feedstock in the whole year is obtained.
Comments	N/A

Data/Parameter	$Yield_{b,y}$
Data unit	t/ha
Description	Mass of biomass produced per unit of area for biomass type *b* obtained from biomass supplier in year y
Equations	(16
Source of data	Yield data for individual feedstock provided by feedstock producer
Description of measurement methods and procedures to be applied	Yield data should be obtained through direct measurements or estimates based on historical yield data, adjusted for known factors affecting yield (e.g., weather conditions, agronomic practices). Where direct measurements are not feasible, estimates should be derived from comparable regions or cultivation practices.
Frequency of monitoring/recording	Annually, at the end of each growing season, to capture the yield data for that year's harvest.
QA/QC procedures to be applied	Yield data provided by feedstock producers should be verified through a combination of random sampling and comparison with regional averages or historical data for similar biomass types and cultivation conditions. Any significant deviations should be investigated and justified.
Purpose of data	Calculation of leakage emissions from the cultivation of biomass
Calculation method	Calculated by dividing the total harvested biomass by the cultivated area for each biomass type b. This should reflect the actual yield realized during the year, incorporating any adjustments for losses or gains in biomass quality or quantity.
Comments	

9 REFERENCES

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APPENDIX 1: DETERMINATION OF MARKET LEAKAGE

Emissions from market leakage must be determined for each biomass feedstock generating CO_2 captured through the project activities.

Proponents must use one of following approaches based on how each feedstock consumed is categorized in Table 5 of Appendix 1 of *VT00XX Tool for Differentiating Reductions and Removals in CCS Projects*.

As High-ILUC biomass is ineligible for projects using this module, it is not considered here.

Categories: Forest and Agricultural Primary

Market leakage is considered zero (i.e., $LE_{BM,y}$ = 0) if:

1. The biomass can be demonstrated to comply with a regulatory scheme which includes provisions to prevent market leakage, (e.g., EU RED III); **if not, then**,
2. The biomass has been certified in accordance with a certification scheme which includes provisions to prevent market leakage, (e.g., Sustainable Biomass Program (SBP), International Sustainability and Carbon Certification (ISCC), etc.).

For biomass feedstocks that do not meet the requirements in Approaches 1 and 2, market leakage ($LE_{BM,y}$) must be determined using *VMD0033 Estimation of Emissions from Market Leakage.*[11]

Categories: All waste, residues, and non-forest or non-agricultural primary biomass

The risk of market leakage from these categories is considered negligible and therefore $LE_{BM,y}$ = 0.

[11] Available at: https://verra.org/methodologies/vmd0033-estimation-of-emissions-from-market-leakage/

APPENDIX 2: SECONDARY EMISSIONS DATA SOURCES

A1.1 Established Tools and Datasets for CCS Projects in the United States

Many secondary emission datasets (also known as Life Cycle Inventory (LCI) data sources) exist in both the public and commercial (e.g., ecoinvent, GaBi) sectors. 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)
    - NETL's Upstream Natural Gas LCA Modeling: https://netl.doe.gov/energy-analysis/details?id=0bf24fd4-3d4c-47cd-bac4-90787d4a4c1f
    - Gate-to-grave saline aquifer storage model: https://netl.doe.gov/energy-analysis/details?id=94309bc8-0539-42d3-9c13-01f2f34f27e3
- U.S. 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/
- United States 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/
- United States Environmental Protection Agency Environmentally-Extended Input-Output (USEEIO) Models: https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-models

Table 2. Key Secondary Emissions Data Collection Processes, Parameters, and Data Sources Modified from Cooney DOE (2022)

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 both 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	U.S. Electricity Baseline (NETL) – regionalized consumption mixes with options to customize technological representation ANL GREET
Consumables – Heat	For on-site combustion: direct emissions must be included in BECCS 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 must be accounted.	NETL ANL GREET Federal LCA Commons
Non-Consumables – Construction/Capital Activities	Amounts (mass or dollar value) 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, Federal LCA Commons Alternatively, estimating data based on purchasing may 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, estimating data based on purchasing may leverage the US EEIO approach

CO_2 compression, transport, injection, Monitoring, Reporting and Verification	Initial on-site compression of the captured CO_2 must be included in the BECCS 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 all vary by site and may be parameterized if desired to evaluate geographic/geologic variability	NETL gate-to-grave assessment of saline aquifer storage of CO_2
Waste management	Handling, transporting, and managing process wastes from BECCS operations	US LCI for landfilling or incineration; GREET or NETL for transport
Land use change	Site disturbance/clearing to facilitate BECCS 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 of the 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: https://op.europa.eu/en/publication-detail/-/publication/7d6dd4ba-720a-11e9-9f05-01aa75ed71a1

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: https://www.canada.ca/en/environment-climate-change/services/managing-pollution/fuel-life-cycle-assessment-model.html#toc0