Verified Carbon Standard

VCS Module

VMD0059

CO_2 CAPTURE FROM BIOENERGY

Version 1.0

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Sectoral Scope 16: Carbon Capture and Storage

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

CONTENTS

1 SUMMARY DESCRIPTION

This module calculates project emissions ($PE_{Cap,y}$) and leakage emissions ($LE_{Cap,y}$) from bioenergy carbon capture and storage (BECCS) project activities eligible under the most recent version of Verified Carbon Standard (VCS) methodology *VM0049 Carbon Capture and Storage* that result in the capture of carbon dioxide from facilities that generate heat and/or power using 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.

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

Leakage emissions from BECCS ($LE_{Cap,y}$) are calculated in Equation (5) and are based on the increase in biomass consumption during the project relative to the baseline.

This module categorizes the biomass feedstocks consumed at the source facility based on the traceability of the supply chain and demonstrated adherence to the sustainability requirements and safeguards of the VCS Program and those presented in Appendix 1 of this module. BECCS projects consuming both sustainable biomass and non-traceable biomass must use VCS tool *VT0013 Differentiating Reductions and Removals in CCS Projects* to allocate the project and leakage emissions calculated here to the captured CO_2 streams that are derived from each biomass category.

The project and leakage emissions calculated in this module, together with those calculated in the transport and storage modules and allocated according to *VT0013*, are used in *VM0049* to calculate the net mitigation outcomes from BECCS projects.

CO_2 captured and stored by the project activity qualifies as carbon dioxide removals ("removals") if it is derived from sustainable biomass, while captured and stored CO_2 from non-traceable biomass qualifies as greenhouse gas (GHG) emission reductions ("reductions").

2 SOURCES

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

Capture Module

- *VMD0056 CO_2 Capture from Air (Direct Air Capture)*

Transport Module

- *VMD0057 CO_2 Transport for CCS Projects*

Storage Module

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

Other Modules, Tools, and Requirements

- *VMD0033 Estimation of Emissions from Market Leakage*
- *VT0010 Emissions from Electricity Consumption and Generation*
- *VT0012 Accounting non-VCS CO_2 in CCS Projects*
- *VT0013 Differentiating Reductions and Removals in CCS Projects*
- *Geologic Carbon Storage (GCS) Non-Permanence Risk Tool*
- *GCS Requirements*

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

- CDM *TOOL09 Determining the Baseline Efficiency of Thermal or Electric Energy Generation Systems*
- CDM *TOOL10 Tool to Determine the Remaining Lifetime of Equipment*
- CDM *TOOL16 Project and Leakage Emissions from Biomass*

3 DEFINITIONS

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

Bioenergy carbon capture and storage (BECCS) project activities
Project activities that lead to the capture of carbon dioxide from biomass combustion

Biomass
Non-fossilized and biodegradable organic material originating from plants, animals, fungi, and microorganisms (e.g., agricultural and forest residues, purpose-grown organic material, non-fossilized and biodegradable organic fractions of industrial and municipal wastes), and the gases and liquids recovered from the decomposition of organic material

Biomass from waste
Biomass that would have otherwise been discarded or disposed of at the end of a production or harvesting process or post-consumer use, in the absence of a VCS project. This includes biomass that would only be collected for disposal or treatment.

Capture materials
The chemicals and media used to capture carbon dioxide. 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 has been generating heat and/or power from biomass for at least 12 months prior to the project start date

Induced land-use change (ILUC)
Land-use change that may be induced on land areas not included in the project boundary, as a result of shifting of pre-project activities[1]

Ineligible biomass
Biomass feedstocks that do not fall into an acceptable biomass category in Figure 3, or do not meet the sustainability requirements as defined in Appendix 1 of this module, or that have a default induced land-use change (ILUC) value of 30 or greater based on the region of production and intended biomass conversion process, as listed in Section 5 of *CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels*[2]

Mixed feedstock
A composite feedstock comprised of both biomass and fossil-derived materials

New bioenergy source facility
A facility that generates heat and/or power from biomass and that started emitting carbon dioxide from biomass combustion less than 12 months before the project start date

Non-traceable biomass
Biomass feedstocks that do not meet the traceability requirements outlined in Appendix 1 of this module

Sustainable biomass
Biomass feedstocks that meet the sustainability principles and traceability requirements outlined in Appendix 1 of this module

[1] Adapted from CDM *TOOL16 Project and Leakage Emissions from Biomass*

[2] International Civil Aviation Organization. 2024. *CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels*. ICAO. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2006%20-%20Default%20Life%20Cycle%20Emissions%20-%20October%202024.pdf

4 APPLICABILITY CONDITIONS

This module applies to project activities that capture CO_2 from the flue gas of facilities generating heat and/or power from biomass.

This module is applicable under the following conditions:

1) Project activities 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, that would otherwise be decommissioned prior to the project start date, at an existing bioenergy source facility
    c) Expansion of existing capture capacity at an existing bioenergy source facility
2) Capture occurs 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
    d) Cryogenic processes
3) Project activities are designed to regenerate the primary capture fluid or media, such that it is not a one-time use, and a concentrated CO_2 stream is recovered from regeneration and available for subsequent transport (where applicable) and storage.

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

4) Project activities use oxy-fuel combustion capture for power generation.
5) Project activities comprise upgrades to existing BECCS facilities or changes in operational practices leading to improved capture efficiency.

5 PROCEDURES

5.1 Module Boundary

The module boundary includes at least the BECCS facility. It does not include the bioenergy facility generating the emissions captured by the project. Commonly used equipment and processes include:

- equipment used to generate airflow for the capture process (e.g., fans);

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

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

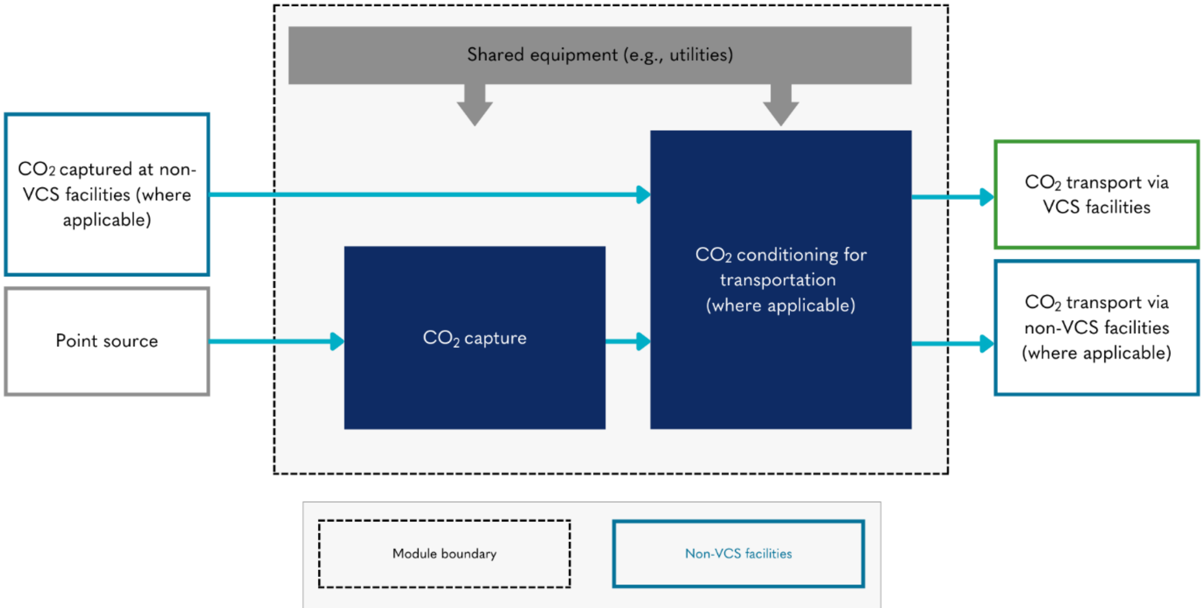
Projects capturing CO_2 from mixed feedstocks or a combination of sustainable and non-traceable biomass feedstocks must use the most recent version of *VT0013* to allocate project emissions and leakage emissions between reductions and removals.

In cases where non-VCS[3] CO_2 flows through the project boundary, the most recent version of VCS tool *VT0012 Accounting non-VCS CO_2 in CCS Projects* must be used to calculate the proportion of project emissions and leakage emissions from project sources associated with that non-VCS CO_2.

The boundary for this module is presented in Figure 1.

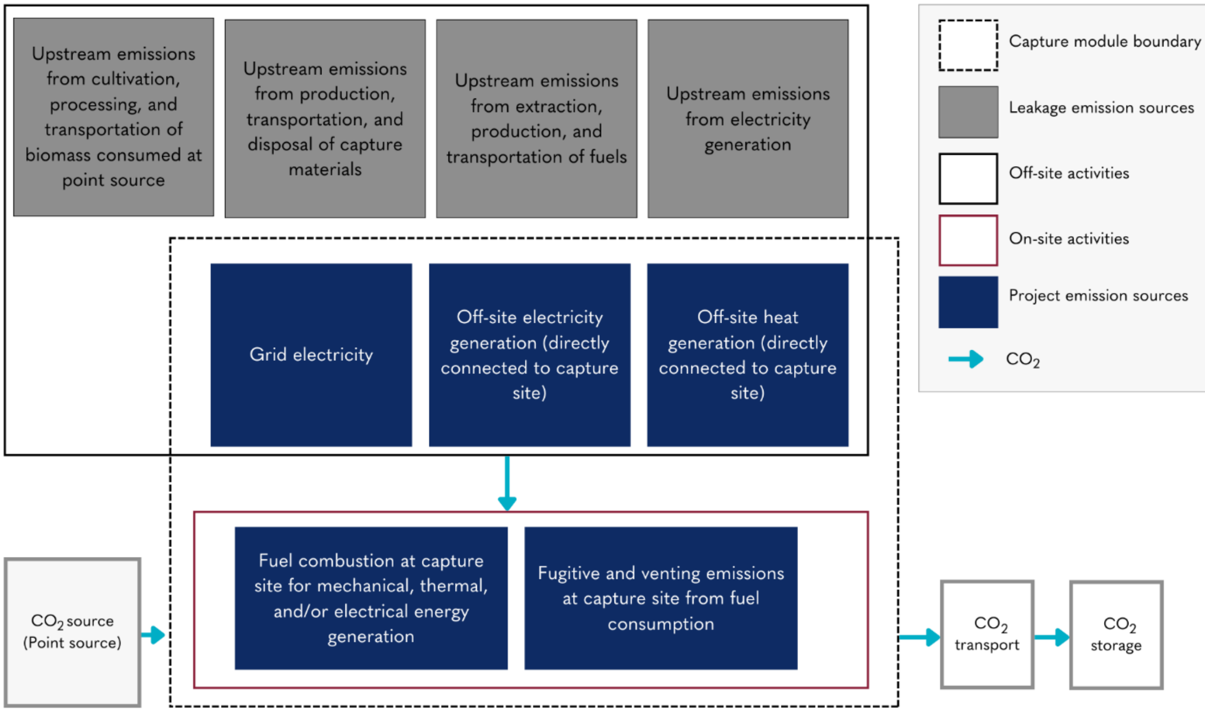
[3] Non-VCS CO_2 is defined in *VT0012* as "Carbon dioxide that flows through a carbon capture and storage (CCS) project boundary and does not generate credits under the VCS Program."

Figure 1. Module boundary for CO_2 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 boundary for CO_2 capture from biogenic sources and leakage emissions



The greenhouse gases included in and excluded from the module boundary are depicted in Table 1.

This module assumes that no capture of CO_2 relevant to the project activities would take place in the baseline scenario. As such, no emissions sources associated with the baseline scenario are included in Table 1 here but are included in the project boundary in *VM0049*.

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

Source		Gas	Included?	Justification/Explanation
Project	Electricity consumption from capture facility	CO_2	Yes	Major emission source
		CH_4	No	Excluded as per VCS tool *VT0010 Emissions from Electricity Consumption and Generation*
		N_2O	No	Excluded as per *VT0010*
		Other	No	Excluded for simplicity; emissions are considered negligible.
	Fuel consumption from capture facility	CO_2	Yes	Major emission source
		CH_4	Yes	Minor 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	No	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 CO_2 is considered for permanent geological sequestration.
		N_2O	No	Excluded from the baseline since only CO_2 is considered for permanent geological sequestration.
		Other	No	Excluded from the baseline since only CO_2 is considered for permanent geological sequestration.
	Fugitive and venting emissions from on-site fuel use	CO_2	No	Excluded for simplicity; emissions are considered negligible.
		CH_4	Yes	Minor emission source
		N_2O	No	Excluded for simplicity; emissions are considered negligible.
		Other	No	Excluded for simplicity; emissions are considered negligible.

5.2 Baseline Scenario

Project proponents must accurately determine the activities and GHG emissions that would have occurred in the absence of the project activity. The baseline scenario identified through the process outlined below is used to inform the assessment of project additionality in Section 7 of *VM0049*.

Project proponents must assess the following alternative scenarios:

Baseline B1: No CO_2 is captured from the bioenergy source facility. This alternative scenario must be considered if either of the following options applies:

a) No capture facility was installed before the project start date.

b) A capture facility was installed at the bioenergy source facility and reached its end of life before the project start date. The most recent version of CDM *TOOL10 Tool to Determine the Remaining Lifetime of Equipment* must be applied to demonstrate that the remaining lifetime of the capture facility was zero before the project start date.

Baseline B2: CO_2 is captured from the bioenergy source facility at historical levels with a capture facility that was operational before the project start, without any expansion of its capture capacity.

Baseline B3: The proposed project activity without being registered under a GHG program.

To identify the baseline scenario from the alternative scenarios, project proponents must

1) remove alternative scenarios that do not comply with mandatory laws and regulations in the jurisdiction where it is located. Alternative scenarios must be compatible with all applicable laws and regulations, including those that have objectives other than GHG emission reductions and/or carbon dioxide removals (e.g., for local air pollution control). Policies that do not have legally binding status must not be considered.
2) demonstrate that the proposed project activity faces a financial barrier following Section 7 of *VM0049*.

The remaining alternative is the baseline scenario and the following applies:

- Project activities that involve the installation and operation of a new capture facility are only eligible if the baseline scenario is B1.
- Project activities that involve the refurbishment of an existing capture facility are only eligible if the baseline scenario is B1.
- Project activities that involve the expansion of existing capture capacity are only eligible if the baseline scenario is B2. In this case, the amount of CO_2 that would have been captured and stored in the absence of the project activity must be accounted for as non-VCS CO_2 in each segment, according to the procedures outlined in the most recent version of *VT0012.*

5.3 Quantification of Project Emissions

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

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

Where:

$PE_{Cap,y}$	=	Project emissions from capture in year *y* (t CO_2e)
$PE_{Comb\_Fuel,y}$	=	Project emissions from fuel combustion to operate on-site and/or third-party (for off-site heat/steam supply) equipment for capture and conditioning processes in year *y* (t CO_2e)
$PE_{Fuel\_FV,y}$	=	Fugitive and venting from on-site fuel use (e.g., natural gas) inside the module boundary in year *y* (t CO_2e)
$PE_{Elec,y}$	=	Project emissions from electricity consumption to operate equipment in the BECCS facility in year *y* calculated using *VT0010* (t CO_2e)

$PE_{nonVCS\ CO2,y}$	=	Project emissions from processes and equipment related to non-VCS sources in year *y* determined using the most recent version of *VT0012*; equal to zero for projects with no non-VCS CO_2 (t CO_2e)

5.3.1 Project Emissions from Fuel Combustion

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

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

Where:

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

Where an emission factor that considers only combustion emissions is not available for a given fuel, a combined emission factor for both combustion and upstream emissions may be used as $EF_{Fuel,d}$ in Equation (2).

Off-site Fuel Consumption

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

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

Where:

$Q_{Cogen,d,y}$	=	Quantity of fuel type *d* used by the cogeneration unit to generate electricity and/or heat in year *y* (m^3 or kg or GJ)
$Heat_{BECCS,y}$	=	Quantity of useful thermal energy supplied to the capture facility by the cogeneration unit in year *y*; equal to zero where only electricity is supplied to the capture facility (MWh)

$Electricity_{BECCS,y}$	=	Quantity of electricity supplied to the capture facility by the cogeneration unit in year *y*; equal to zero where only heat is supplied to the capture facility (MWh)
$Heat_{Cogen,y}$	=	Total quantity of useful thermal energy produced by the cogeneration unit in year *y* (MWh)
$Electricity_{Cogen,y}$	=	Total quantity of electricity produced by the cogeneration unit in year *y* (MWh)
$\eta_{Heat,y}$	=	Efficiency of thermal energy production from cogeneration unit in year *y* determined using the most recent version of CDM *TOOL09 Determining the Baseline Efficiency of Thermal or Electric Energy Generation Systems*
$\eta_{Elec,y}$	=	Efficiency of electricity production from cogeneration unit in year *y* determined using the most recent version of CDM *TOOL09*

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 most recent version of *VT0013*.

Waste Heat

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

5.3.2 Fugitive and Venting Emissions from On-Site Fuel Use

BECCS projects using natural gas on-site must quantify fugitive and venting emissions during facility operations. Quantification is based on component counts and respective emission factors. Fugitive emissions are quantified following the approach in the US Environmental Protection Agency's *Electronic Code of Federal Regulations*, Title 40, Part 98, Subpart W, § 98.233 (r).[4]

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

Equation (4) calculates fugitive and venting emissions for BECCS project activities that use gaseous fuels on-site.

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

Where:

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

$Count_{n,y}$	=	Total number of components *n* in use at the facility during year *y* (unitless)
EF_n	=	Emission factor of fugitive emissions for component *n* (kg CH_4/hr/unit)
$T_{n,y}$	=	Time for which component *n* is pressurized in year *y* (hr)
V_m	=	Vented methane emissions for venting event *m* (t CH_4/event)
0.001	=	Conversion from kilograms to tonnes

5.4 Quantification of Leakage

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

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

Where:

$LE_{Cap,y}$	=	Leakage emissions from capture in year *y* (t CO_2e)
$LE_{Fuel,y}$	=	Leakage emissions from upstream sources related to the fuel consumed in the module boundary in year *y* determined using Equation (6) (t CO_2e)
$LE_{Elec,y}$	=	Leakage emissions from electricity consumption to operate equipment in the capture facility in year *y* calculated using *VT0010* (t CO_2e)
$LE_{Mat,y}$	=	Leakage emissions from capture materials used in the capture process in year *y* determined using Equation (7) (t CO_2e)
$LE_{Biomass,y}$	=	Leakage emissions from the supply of biomass feedstock for energy production in year *y* determined using Equation (8 (t CO_2e)
$LE_{nonVCS\ CO2,y}$	=	Leakage emissions from processes and equipment related to non-VCS sources in year *y* determined using the most recent version of *VT0012*; equal to zero for projects with no non-VCS CO_2 (t CO_2e)

5.4.1 Leakage Emissions from Fuel Consumption ($LE_{Fuel,y}$)

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 (6).

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

Where:

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

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

Where a combined emission factor considering both combustion ($EF_{Fuel,d}$) and upstream emissions ($EF_{Upstream\_Fuel,d}$) for a given fuel is used in Equation (2), Equation (6) is not required for that fuel.

5.4.2 Leakage Emissions from Consumption of Capture Materials ($LE_{Mat,y}$)

Leakage emissions from regeneration and replacement and the related production of capture materials during subsequent years are calculated using Equation (7).

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

Where:

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

5.4.3 Leakage Emissions from Biomass Feedstock Supply to Source Facility ($LE_{Biomass,y}$)

Leakage emissions from biomass feedstock supply ($LE_{Biomass,y}$) are calculated as per Equation (8).

$$LE_{Biomass,y} = LE_{BC,y} + LE_{BT,y} + LE_{BM,y} + LE_{Pr,y} \tag{8}$$

Where:

$LE_{BC,y}$	=	Leakage emissions from the cultivation of biomass feedstock 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* t CO_2e)
$LE_{Pr,y}$	=	Leakage emissions from the processing of biomass in year *y* (t CO_2e)

5.4.3.1 Calculating Increase in Biomass Consumption

Leakage emissions from biomass consumption are based on the relative change in biomass consumption at the source facility between the project and the baseline and are calculated using Equation (9).

$$\Delta Q_{Bio,b,y} = \text{MAX}\left(m_{sb,project,b,y} - m_{sb,base,b}, 0\right) + \text{MAX}\left(m_{nt,project,b,y} - m_{nt,base,b}, 0\right) \tag{9}$$

Where:

$\Delta Q_{Bio,b,y}$	=	Change in mass of total biomass type *b* consumed in year *y* relative to the pre-project period (t)
$m_{sb,project,b,y}$	=	Mass of sustainable biomass type *b* used in year *y* after the project start date (t)
$m_{sb,base,b}$	=	Mass of sustainable biomass type *b* used in the absence of the project; equal to zero for baseline B1 (t)
$m_{nt,project,b,y}$	=	Mass of non-traceable biomass type *b* used in year *y* after the project start date (t)
$m_{nt,base,b}$	=	Mass of non-traceable biomass type *b* used in the absence of the project; equal to zero for baseline B1 (t)

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

5.4.3.2 Calculating Leakage from Biomass Cultivation ($LE_{BC,y}$)

There are two options for calculating leakage emissions from the cultivation of biomass.

Option 1: Embodied Emissions Factor

Use an embodied emissions factor, determined through a life cycle assessment (LCA), in Equation (10) to calculate leakage emissions from cultivation.

$$LE_{BC,y} = \sum_b \left(\Delta Q_{Bio,b,y} \times EF_b\right) \tag{10}$$

Where:

EF_b	=	Embodied emissions factor for biomass type *b*

Option 2: Calculate Leakage Emissions

Use the following steps to calculate leakage emissions.

1) Use Equation (11) to calculate the area of land required to produce the mass of biomass type *b* consumed by project activities ($Area_{cult,b,y}$).

$$Area_{cult,b,y} = \frac{\Delta Q_{Bio,b,y}}{Yield_{b,y}} \tag{11}$$

Where:

$Area_{cult,b,y}$	=	Area required to produce amount of biomass type *b* consumed in year *y* (ha)
$Yield_{b,y}$	=	Mass of biomass produced per unit of area for biomass type *b* obtained from biomass supplier in year *y* (t/ha)

2) Use $Area_{cult,b,y}$ 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 (12) to assign the emissions resulting from biomass cultivation projects as leakage.

$$LE_{BC,y} = \sum_b PE_{BC,b,y} \tag{12}$$

Where:

$PE_{BC,b,y}$	=	Emissions resulting from cultivation of biomass type *b* 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. Project emissions from biomass cultivation, are included to provide a more representative accounting of the emissions that occur outside of the project boundary but are attributable to the BECCS project. Therefore, $PE_{BC,y}$ *determined in* TOOL16 *equals* $LE_{BC,y}$ *in this module.*

5.4.3.3 Calculating Market Leakage ($LE_{BM,y}$)

The process for determining market leakage depends on how the feedstock is categorized in Figure 3 of Appendix 1.

For biomass from waste and biomass products that meet the requirements in Section A1.2, market leakage is considered negligible and therefore $LE_{BM,y} = 0$.

For excess non-traceable biomass feedstock consumed at the source facility, project proponents must use the following sections of *CDM TOOL16*[5] to determine the leakage emissions associated with the market response to the use of additional biomass:

- Section 6.1 of *CDM TOOL16* must be used with the following caveats:
  - Paragraph 47 does not apply
  - Paragraph 48 does not apply. Instead, if either of the indicators determined in paragraph 46 is determined to be greater than 50 per cent, the biomass feedstock is considered ineligible and any CO_2 captured must be treated as non-VCS gas as per *VT0012*.
- Section 6.2 of *CDM TOOL16* must be used with the following caveats:
  - Projects must assume that the alternative scenario for the biomass is B4 in *CDM TOOL16* and use Equation 15 to determine the leakage emissions associated with the diversion of biomass.

In addition, projects must use Equation (13) of this module to determine the leakage emissions from additional transportation of biomass by market actors in response to changes in biomass availability due to the project activities, using the following assumptions:

[5] Section 6.4 of CDM TOOL16 is not included here as the change in emissions from the processing of any additional biomass consumed by the projects is accounted in section 5.4.3.5

- Where the mode of transportation is not known, projects must use DEF_{mode} for transport by Truck (HDV large) of 240 g CO_2/t-km from Section 6 of VCS module *VMD0057 CO_2 Transport for CCS Projects.*
- Where the distance traveled to transport the non-traceable biomass is not known, projects must assume a transportation distance equal to that of the biomass feedstock used by the project that traveled the furthest to reach the source facility.

5.4.3.4 Calculating Leakage from the Transportation of Biomass ($LE_{BT,y}$)

Project proponents must use Equation (13) to determine leakage emissions from the transportation of biomass.

$$LE_{BT,y} = \sum_{b} \sum_{mode} \left(\Delta Q_{Bio,b,y} \times D_{mode,y} \times DEF_{mode} \times 10^{-6} \right) \quad (13)$$

Where:

$D_{mode,y}$	=	Total distance traveled to transport biomass type *b* by different modes (ship, truck, or rail) in year *y* (km)
DEF_{mode}	=	Default emission factor to transport biomass cargo by different modes (ship, truck, or rail), using CO_2 transport emission factors as a proxy (DEF_r from Section 6 of *VMD0057*) (g CO_2/t-km)
10^{-6}	=	Conversion from grams to tonnes

5.4.3.5 Calculating Leakage from Processing of Biomass ($LE_{PR,y}$)

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 processes. Project proponents must use Equation (14) to determine the leakage emissions from biomass processing.

$$LE_{Pr,y} = \sum_{b} (PE_{BP,b,y} + PE_{BRP,b,y}) \quad (14)$$

Where:

$PE_{BP,b,y}$	=	Emissions due to processing of biomass type *b* outside the project boundary in year *y* calculated using CDM *TOOL16* (t CO_2e)
$PE_{BRP,b,y}$	=	Emissions due to processing of residue from biomass type *b* outside the project boundary in year *y* calculated using CDM *TOOL16* (t CO_2e)

Note – Section 5.3 of CDM TOOL16 *quantifies project emissions resulting from biomass processing. Project emissions from biomass processing to provide a more representative accounting of the emissions that occur outside of the project boundary but are attributable to BECCS project activities. Therefore,* $PE_{BP,b,y}$ and $PE_{BRP,b,y}$ *determined in TOOL16 equals* $LE_{PR,,y}$ *in this module.*

5.5 Uncertainty

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

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

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

Uncertainty of measurement error from leakage emissions from the production and processing of biomass feedstocks is considered de minimis where the magnitude of the leakage emissions is less than 2% of the net reduction or removal benefit of the project.

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

6 DATA AND PARAMETERS

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

6.1 Data and Parameters Available at Validation

Data/Parameter	GWP_{CH4}
Data unit	t CO_2e/t CH_4
Description	Global warming potential for CH_4
Equations	(2), (4)
Source of data	Version of IPCC Assessment Report required by *VCS Standard*
Value applied	See the most recent version of the *VCS Standard*.
Justification of choice of data or description of measurement methods and procedures applied	Required by the *VCS Standard*

Purpose of data	Calculation of project emissions
Comments	None

Data/Parameter	GWP_{N2O}
Data unit	t CO_2e/t N_2O
Description	Global warming potential for N_2O
Equations	(2)
Source of data	Version of IPCC Assessment Report required by *VCS Standard*
Value applied	See the most recent version of the *VCS Standard*.
Justification of choice of data or description of measurement methods and procedures applied	Required by the *VCS Standard*
Purpose of data	Calculation of project emissions
Comments	None

Data/Parameter	$m_{sb,base,b}$
Data unit	t
Description	Mass of sustainable biomass type *b* used in the absence of the project
Equations	(9)
Source of data	On-site measurements
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Measured on a dry weight basis 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 facility 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
Comments	If the monitoring period for the project is less than 12 months, this parameter is calculated must align with the period used for $m_{sb,project,b,y}$ to facilitate direct comparison. For baseline B1, $m_{sb,base,b} = 0$

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	(9)
Source of data	On-site measurements
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Measured on a dry basis from belt weigher/weigh bridge or calculated from receipts/invoices. Mass of biomass consumption is calculated as the average annual biomass consumption of the three year period immediately prior to the start date of the project activity. Where a sourcefacility 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
Comments	If the monitoring period for the project is less than 12 months, this parameter is calculated must align with the period used for $m_{nt,project,b,y}$ to facilitate direct comparison. For baseline B1, $m_{nt,base,b} = 0$

6.2 Data and Parameters Monitored

Data/Parameter	$Q_{Fuel,d,y}$
Data unit	m^3 or kg or GJ

Description	Quantity of fuel type *d* used to operate on-site and/or third-party (for off-site heat/steam supply) equipment in year *y*
Equations	(2), (6)
Source of data	Fuel receipts/invoices or flow meter readings
Description of measurement methods and procedures to be applied	Measured from flow meters or calculated from fuel receipts/invoices
Frequency of monitoring/recording	Continuous
QA/QC procedures to be applied	Measuring equipment (e.g., flow meters, weighing scale) must operate within the manufacturer's specified operating conditions and must be routinely calibrated, inspected, and maintained according to manufacturer 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	None

Data/Parameter	$EF_{Fuel,CO2,d}$
Data unit	t CO_2/m^3 or t CO_2/kg or t CO_2/GJ
Description	Carbon dioxide emission factor for combustion of fuel *d*
Equations	(2)
Source of data	The following data sources may be used: 1) Emission factor from *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 2, Chapter 2 Stationary Combustion, Table 2.2[6] 2) Emission factors published by US EPA (2023)[7] or similar source 3) Data provided by the fuel supplier
Description of measurement methods	Use the most recent data published by the above sources when reporting project emissions.

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

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

and procedures to be applied	
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	Equal to zero for fuels derived from sustainable biomass

Data/Parameter	$EF_{Fuel,CH4,d}$
Data unit	t CH_4/m^3 or t CH_4/kg or t CH_4/GJ
Description	Methane emission factor for combustion of fuel *d*
Equations	(2)
Source of data	The following data sources may be used: 1) Emission factor from *2006 IPCC 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 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	None

Data/Parameter	$EF_{Fuel,N20,d}$
Data unit	t N_2O/m^3 or t N_2O/kg or t N_2O/GJ
Description	N_2O emission factor for combustion of fuel *d*
Equations	(2)
Source of data	The following data sources may be used: 1) Emission factor from *2006 IPCC 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 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	None

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

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

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

Calculation method	Monthly supplied heat is determined by summing the quantities from calibrated device readings or fuel receipts/invoices.
Comments	Invoices and/or contracts with the third party must be in place to allow proper data collection.

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

Data/Parameter	$Heat_{Cogen,y}$
Data unit	MWh
Description	Total quantity of useful thermal energy produced by the cogeneration unit in year *y*
Equations	(3)

Source of data	Utility receipts/invoices or metered data for heat produced
Description of measurement methods and procedures to be applied	Direct measurement of steam flows (or other heat transfer fluid) and characteristics at the cogeneration facility, considering energy content in steam and condensate return
Frequency of monitoring/recording	Continuous, aggregated monthly
QA/QC procedures to be applied	Calorimeters must be routinely calibrated, inspected, and maintained according to manufacturer specifications.
Purpose of data	Calculation of project emissions
Calculation method	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
Description	Total quantity of electricity produced by the cogeneration unit in year *y*
Equations	(3)
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 or invoices
Frequency of monitoring/recording	Continuous, aggregated monthly
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	$Count_{n,y}$
Data unit	unitless
Description	Total number of components *n* in use at the facility during year *y*
Equations	(4)
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 the EPA's Electronic Code of Federal Regulations, Title 40, Part 98 Subpart W § 98.233[8]
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 *n* components in use at the facility from facility records (e.g., drawings, parts lists).
Comments	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	Time for which component *n* is pressurized in year *y*
Equations	(4)

[8] Available at: https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-W/section-98.233#p-98.233(a)(1)

Source of data	Records of capture facility (e.g., control systems, recorded operational data)
Description of measurement methods and procedures to be applied	Data from capture facility records
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 $T_{n,y}$ of each component *n*.
Comments	None

Data/Parameter	V_m
Data unit	t CH_4/event
Description	Vented methane emissions for venting event *m*
Equations	(4)
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 project proponent must determine the quantity of vented CH_4 by transient flow rate calculations for compressible fluids appropriate for the expected evolving conditions in the pipeline or component, based on the approximate geometry of the escaping flow and pipelines/components connected to the venting.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Cross-checked based on energy balance related to metered fuel use

Purpose of data	Calculation of project emissions
Calculation method	Determine V_m by direct measurement or estimate using isolated or non-isolated volumes of pipes and equipment. Use appropriate transient flow rate calculations for CH_4 venting events.
Comments	None

Data/Parameter	EF_n
Data unit	kg CH_4/hr/unit
Description	Emission factor of fugitive emissions for component *n*
Equations	(4)
Source of data	Emission factor derived from subpart W of US EPA. 2023. *Mandatory GHG Reporting Program*[9] 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	None

Data/Parameter	$EF_{Upstream\_Fuel,d}$
Data unit	t CO_2e/m^3 or t CO_2e/kg or t CO_2e/GJ

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

Description	Emission factor for upstream sources related to fuel type *d* used in the module boundary
Equations	(6)
Source of data	The value of this parameter may be obtained from the following sources: 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[10] 2) A compliance market-approved tool (e.g., CA-GREET,[11] GHGenius[12]) 3) Emission factors published in peer-reviewed literature[13] representative of the fuels used in BECCS plant operation both temporally and geographically 4) Data provided by the fuel supplier or manufacturer where the data used are consistent with that reported to a regulatory body
Description of measurement methods and procedures to be applied	Use the most recent data published by the above sources when reporting project emissions.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Where peer-reviewed literature is used, it 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	None

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

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

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

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

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

Data unit	kg or m^3 or units
Description	Quantity of make-up capture material *j* consumed by the capture facility in year *y*
Equations	(7)
Source of data	Receipts/invoices or flow meter or weighing scale/equipment readings, depending on capture material type
Description of measurement methods and procedures to be applied	Measured from material flow meters or weighing equipment or calculated from receipts/invoices
Frequency of monitoring/recording	Aggregated annually. As per the flow meter or weighing equipment specification by the manufacturer. Manufacturers must be compliant with relevant ISO standards. Alternatively, the sum of all receipts/invoices for capture materials in year *y* is used.
QA/QC procedures to be applied	Flow meters must be routinely calibrated, inspected, and maintained according to manufacturer specifications.
Purpose of data	Calculation of leakage emissions
Calculation method	N/A
Comments	None

Data/Parameter	EF_j
Data unit	t CO_2/kg or t CO_2/m^3 or t CO_2/units
Description	GHG emissions from the production of capture material *j*
Equations	(7)
Source of data	The value of this parameter may be obtained from the following sources: 1) A life cycle assessment (LCA) conducted by a qualified third party in accordance with the most recent version of ISO 14040, that uses either primary or published and peer-reviewed data[14]

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

	2) Emission factors published in peer-reviewed literature[15] representative of the materials used in BECCS plant operation both temporally and geographically 3) Data provided by the manufacturer where the data used are consistent with that reported to a regulatory body
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. Where peer-reviewed literature is used, it must have been published within a year of reporting project emissions.
Purpose of data	Calculation of leakage emissions
Calculation method	N/A
Comments	See Appendix 2 for examples of data sources.

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	(9)
Source of data	On-site measurement
Description of measurement methods and procedures to be applied	Measured on a dry weight basis from belt weigher/weigh bridge or calculated from receipts or invoices

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

Frequency of monitoring/recording	Aggregated annually or the length of the monitoring period if less than 12 months.
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 manufacturer specifications.
Purpose of data	Calculation of leakage emissions
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	(9)
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 or the length of the monitoring period if less than 12 months.
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
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	EF_b
Data unit	t CH_4/m^3 or t CH_4/kg or t CH_4/GJ
Description	Embodied emissions factor for biomass type *b*
Equations	(10)
Source of data	Output of LCA modeling tool
Description of measurement methods and procedures to be applied	The LCA must be performed by a qualified third party, in accordance with the most recent 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 life cycle 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. Emission 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	None

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	(11)
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 must 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 must be investigated and justified.
Purpose of data	Calculation of leakage emissions
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	None

Data/Parameter	$m_{b,y}$
Data unit	tonnes
Description	Mass of biomass type *b* transported in year *y*
Equations	(13)
Source of data	Receipts or invoices from supplier or transporter of biomass, or on-site measurements
Description of measurement methods and procedures to be applied	Measured from belt weigher/weigh bridge or calculated from receipts/invoices.
Frequency of monitoring/recording	Aggregated annually

QA/QC procedures to be applied	Metering equipment 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
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	None

Data/Parameter	$D_{mode,y}$
Data unit	km
Description	Total distance traveled to transport biomass type *b* by different modes (ship, truck, or rail) in year *y*
Equations	(13)
Source of data	Determined for each delivery of biomass to the emissions point source 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, barges, or ships, the distance must consider both outbound and empty return trips. Where other freight is transported on the return trip, the distance associated with the return trip need not be accounted for. The company transporting the biomass must 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 Where the mode of transport, origin, and destination are the same, the distance between the origin and the destination may 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 used (such as odometers and GPS) must be calibrated as per manufacturer specifications. When using online sources (e.g., maps), the distance between the start and end destination must not be less than the actual distance traveled between those two points.
Purpose of data	Calculation of project emissions
Calculation method	Where distances are measured through devices such as odometers, the distance is the difference between the reading at the start of the trip and the reading at the end of the trip.
Comments	None

6.3 Monitoring of biomass consumption

The project proponent must compile the data evidencing the traceability and categorization of each biomass feedstock consumed at the source facility in the monitoring period as outlined in Appendix 1.

7 REFERENCES

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APPENDIX 1: DEMONSTRATING THE SUSTAINABILITY OF BIOMASS FEEDSTOCKS

Traceability Requirements

For a biomass feedstock to be considered traceable, the project proponent must provide relevant data to the validation/verification body (VVB) about biomass feedstocks used at the emissions source facility in each monitoring period, including biomass type and category, volumes, origin, modes of transportation employed, certification, and chain of custody information as applicable.

Where such information is unavailable for a given quantity of biomass feedstock, that quantity is considered non-traceable biomass.

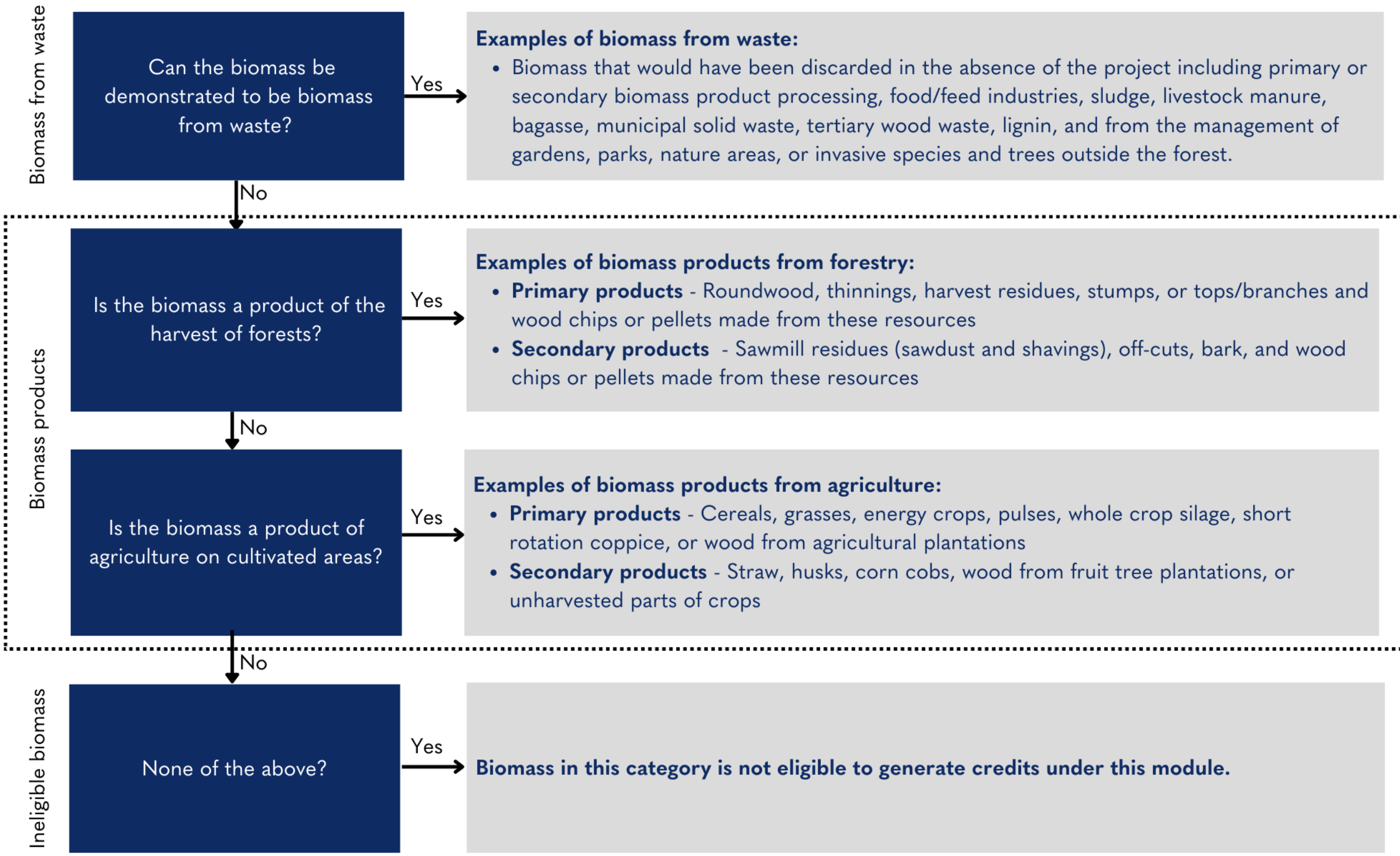
Where biomass types are mixed, a sufficient level of information about each component biomass must be available to allow for a mass-balance approach to determine the properties of the mixture, categorize the biomass, and determine the relevant sustainability requirements for each type.

Categorization

Figure 3 provides a decision key and overview of general biomass categories: biomass from waste, biomass products, and ineligible biomass. Categorization of biomass is necessary to determine the applicable sustainability principles and documentation requirements.

The examples of biomass types listed in Figure 3 are illustrative, not exhaustive. Where a biomass type is not listed, project proponents must use the flowchart in Figure 3 to demonstrate which category the biomass belongs in and provide justification for that categorization.

Figure 3. Biomass categories



A1.1 Biomass from Waste

Biomass feedstocks that meet the traceability requirements of this module and meet the definition of biomass from waste through one of the following scenarios are considered sustainable biomass. Biomass from waste is not required to meet the sustainability requirements in Section A1.2.

Scenario 1

Where the source of biomass can be identified and the biomass is not used in the baseline scenario, the project proponent must demonstrate that the biomass was not used for alternative purposes in the five years preceding the project start date, through one of the following:

1) Verifiable evidence, including historical management plans, receipts, or other records from the areas where the biomass is sourced. These may be supplemented with other forms of evidence such as remote sensing (e.g., satellite imagery) or documentation from comparable sourcing areas

   OR

2) Substantiation via a signed attestation from the manager/landowner or supplier stating that the biomass was not used for alternative purposes in the five years preceding the project start date. This includes sources of biomass that did not exist (e.g., residues from a new food processing mill) before the project start date. The attestation must be supplemented by evidence such as remote sensing (e.g., satellite imagery) or documentation from comparable sourcing areas.

Scenario 2

Where the source of biomass can be identified and some or all of the biomass is used in the baseline scenario, the project proponent must demonstrate that the biomass supply is sufficient to satisfy project demand and there is a reasonable expectation that project demand will not compromise future non-project biomass delivery commitments. This must be demonstrated by one of the following:

a) Verifiable evidence, such as historical management plans, receipts, or other records from the areas where the biomass is sourced from showing that the biomass supply is sufficient to satisfy project demand without compromising future non-project biomass delivery commitments. This must be demonstrated through an analysis of historical biomass volumes delivered annually in the five years preceding the project start date combined with expected project- and non-project-related volumes for the duration of the project crediting period.

   OR

b) Substantiation via a signed attestation from the manager/landowner or supplier stating that the available biomass supply is sufficient to satisfy project-related demand without compromising future biomass delivery commitments. This must be supplemented by evidence such as remote sensing (e.g., satellite imagery) or documentation from comparable sourcing areas and an analysis of historical biomass volumes delivered annually in the five years preceding the project start date combined with expected project- and non-project-related volumes for the duration of the project crediting period.

Scenario 3

Where the biomass is sourced from a biomass residue market with unknown producers, the project proponent must demonstrate that an abundant, unutilized surplus of the same or similar type of biomass exists in the project region.

This must be demonstrated through an analysis showing that the total biomass quantity available is at least 25% greater than the total biomass quantity used (including by the project facility) for that type of biomass. The analysis should be based on an assessment of biomass availability and use in the five years preceding the project start date. Where historical data are not available on an annual basis for the five years preceding the project start date, evidence must include data from at least one year.

This should be complemented with additional evidence demonstrating that the available data are representative of the five years preceding the project start date. The project region should be adjusted to reflect characteristics specific to the biomass type and markets (e.g., wood residues for bioenergy production) where the project is located.

A1.2 Biomass Products Used as Feedstocks

For a biomass feedstock to be considered sustainable, the project proponent must demonstrate that the biomass complies with one of the following:

1) An eligible regulatory program (Section A1.2.1)
2) A regulatory program that is not listed below as eligible, provided the project proponent demonstrates that the regulatory program meets or exceeds the requirements of Section A1.2.3
3) An eligible sustainability certification program (Section A1.2.2)
4) A sustainable certification program that is not listed below as eligible, provided the project proponent demonstrates that the certification program meets or exceeds the requirements of Section A1.2.3
5) The set of sustainability requirements in Section A1.2.3 indicated in Table 1 for the relevant biomass category

A1.2.1 Regulatory Compliance

The following are eligible regulatory programs:

1) UK Renewables Obligation Order[16] 2015 (as amended)
2) EU Renewable Energy Directive (EU) 2023/2413[17] of the European Parliament (as amended)

[16] UK Statutory Instruments. 2015. No. 1947, The Renewables Obligation Order 2015 Schedule 1–3. Guidance available in OFGEM. 2018. Renewables Obligation: Sustainability Criteria, and Department for Business, Energy and Industrial Strategy. 2017. Woodfuel Advice Note v2.

[17] Directive EU - 2023/2413 - EN - Renewable Energy Directive (amending Directive - 2018/2001 - EN)

Biomass must always comply with the most recent applicable regulations in the jurisdiction where it is produced.

A1.2.2 Sustainability Certification

The following are eligible sustainability certifications:

1) Forest biomass:
    a) Forest Stewardship Council (FSC 100% and FSC Mix)
    b) Program for the Endorsement of Forest Certification (100% PEFC)
    c) Sustainable Biomass Program (SBP-Compliant Biomass)
2) Agricultural biomass:
    a) International Sustainability and Carbon Certification (ISCC)
    b) Roundtable on Sustainable Biomaterials (RSB)
    c) RenovaBio

A1.2.3 Sustainability Requirements

Projects must demonstrate that the production and sourcing of each biomass feedstock categorized as a biomass product in Figure 3 meets all of the following sustainability requirements, unless otherwise specified.

1) **Biodiversity:** Biomass feedstock sourcing must respect land use patterns, specifically avoiding regions with high biodiversity or high carbon stocks, and peatlands that have been converted or disturbed. This includes primary or highly biodiverse forests (identified by national authorities), designated nature protection areas (by national laws, international agreements, or the International Union for the Conservation of Nature), highly biodiverse grasslands, wetlands, and continuously forested areas.
2) **Sustainable forest management**: Biomass feedstock management must balance growth and harvesting to ensure long-term forest resource sustainability, implement adaptive measures to maintain forest health and vitality, conserve biodiversity by protecting ecosystems, habitats, and species, protect and restore threatened species and habitats, support genetic diversity through the use of native species and local provenances, and maintain and enhance protective functions, including soil conservation and water quality. Forest regeneration must always occur, and feedstock must not be sourced from primary or old-growth forests. This requirement does not apply to biomass from agriculture.
3) **Soil health:** Biomass feedstock production must maintain or improve soil health. Soil health must at least include soil carbon.
4) **Water:** Feedstock production practices must be employed to preserve or improve water quality, as well as to use water efficiently and prevent the over-extraction of surface or groundwater resources beyond their renewal capacities.

5) **Food security:** Feedstock production must not compromise food security. Feedstock production activities, including agricultural, silvicultural, commercialization, and exploitation activities, must not be conducted in areas with restrictions or embargoes placed due to deforestation.
6) **Social sustainability:** Biomass feedstock sourcing must ensure respect for free, prior, and informed consent (FPIC) and must identify and mitigate negative impact on local communities and economic opportunities. This includes impacts on tenure, Indigenous Peoples, and workers' rights.
7) **Land use, land-use change, and forestry** (**LULUCF):** For biomass sourced from a country party to the Paris Agreement, that has submitted a Nationally Determined Contribution (NDC) covering emissions and removals from agriculture, forestry, and other land use, and that accounts for changes in carbon stock towards the country's commitment, the following applies:

    a) The biomass must not be produced from a converted ecosystem such as where forest or wetland has been converted to agriculture/cropland 10 years or more before the start of the project.[18]

    b) The country must have laws that address the conservation of carbon stocks and provide evidence that emissions from the LULUCF sector do not exceed removals. Alternatively, a management system that ensures the long-term preservation of carbon stocks and sinks is acceptable.

    For biomass from a country/region that is not party to the Paris Agreement, compliance with appropriate management systems (e.g., Green Gold Label (GGL) S5, Sustainable Biomass Program (SBP) or similar) must be demonstrated.

8) **Cascading use:** Project proponents using biomass products from forestry must demonstrate that those feedstocks are used in a manner that reduces resource extraction and maximizes resource efficiency. This requirement does not apply to biomass from agriculture.

A1.3 Ineligible Biomass

Ineligible biomass cannot generate credits under *VM0049* and must not be reported as non-traceable biomass. Emissions captured from the combustion or conversion of ineligible biomass feedstocks must be accounted for and reported as a non-VCS stream in accordance with the most recent version of *VT0012*.

[18] As required by the *VCS Standard*

APPENDIX 2: SECONDARY EMISSIONS DATA SOURCES

A2.1 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
- US electricity baseline
  - Grid Mix Explorer Excel tool: https://netl.doe.gov/energy-analysis/details?id=f0f94954-3627-4e9b-a5c0-c29cfe419d1c
  - openLCA unit processes: https://www.lcacommons.gov/lca-collaboration/Federal_LCA_Commons/US_electricity_baseline/datasets
- Unit Process Library: https://netl.doe.gov/node/2573
- Argonne National Laboratory (ANL) The Greenhouse gases, Regulated Emissions and Energy use in Technologies (GREET) model: https://greet.es.anl.gov/
- 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	US 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.

Data Category	Parameters	DOE and Other Federal Resources
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)

A2.2 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

A2.3 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

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