VCS Tool

VT0013

DIFFERENTIATING REDUCTIONS AND REMOVALS IN CCS PROJECTS

Version 1.0

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Sectoral Scope 16: Carbon Capture and Storage

This tool 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 tool.

CONTENTS

1 SUMMARY DESCRIPTION

This tool calculates GHG emission reductions (“reductions”) and carbon dioxide removals (“removals”) from project activities using mixed feedstocks eligible under the most recent version of VCS methodology *VM0049 Carbon Capture and Storage* and associated modules.

This tool establishes principles and provides procedures for differentiating baseline emissions and allocating project and leakage emissions among activities that result in reductions and removals.

Project and leakage emissions are allocated between reductions and removals in Section 5.4.3.

2 SOURCES

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

Capture Modules

- *VMD0056 CO_2 Capture from Air (Direct Air Capture)*
- *VMD0059 CO_2 Capture from Bioenergy*

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

- *VT0010 Emissions from Electricity Consumption and Generation*
- *VT0012 Accounting Non-VCS CO_2 in CCS Projects*
- *Geologic Carbon Storage (GCS) Non-Permanence Risk Tool*
- *GCS Requirements*

3 DEFINITIONS

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

Alcoholic fermentation
A chemical process used in bioethanol production in which sugars are converted into ethyl alcohol and carbon dioxide in the presence of microorganisms

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).

Non-traceable biomass
Biomass feedstocks that do not meet the traceability requirements outlined in Appendix 1 of *VMD0059 CO_2 Capture from Bioenergy*

Segment
A defined section within a project boundary where separate or comingled CO_2 streams (i.e., VCS and non-VCS CO_2 streams or those eligible for reductions and removals) are captured, processed, transported, or stored

Sustainable biomass
Biomass feedstocks that meet the sustainability principles and traceability requirements outlined in Appendix 1 of *VMD0059 CO_2 Capture from Bioenergy*

4 APPLICABILITY CONDITIONS

This tool is applicable to project activities eligible under the most recent version of *VM0049* that capture, transport, or store mixed streams of CO_2 eligible to generate reductions and removals.

5 PROCEDURES

This section outlines the procedure for determining the separation of captured CO_2 into reductions and removals and allocating project and leakage emissions to each.

5.1 Categorizing Captured CO_2

Capture activities eligible for removals include:

1) direct air capture (DAC), and
2) capture of CO_2 from bioenergy pathways that:
    a) use sustainable biomass as a fuel source directly, or
    b) convert sustainable biomass into a gaseous or liquid fuel through alcoholic fermentation, digestion, pyrolysis, or gasification.

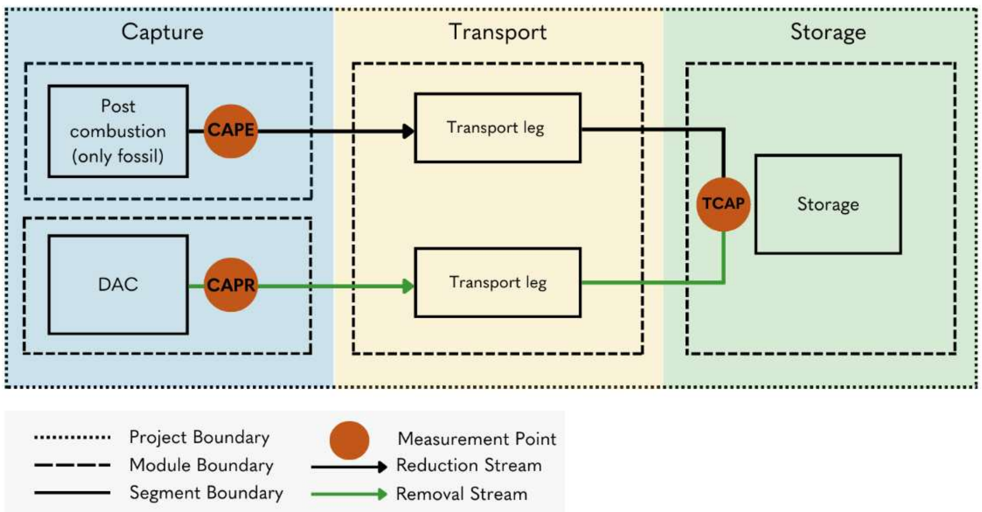
CO_2 captured from the combustion or conversion of non-traceable biomass, the non-biogenic fraction of waste, and fossil fuels must be accounted for as GHG emission reductions.

Project proponents must classify captured CO_2 as either reductions ($CAPE_{c,y}$) or removals ($CAPR_{c,y}$) depending on the feedstock/source of the CO_2 and as described in the following two scenarios.

5.1.1 Scenario 1: Single Feedstocks

In this scenario, each capture facility has a single CO_2 source or feedstock that can categorically be assigned to either reductions ($CAPE_{c,y}$) or removals ($CAPR_{c,y}$). Figure 1 illustrates an example.

Figure 1. Separate reduction (*CAPE*) and removal (*CAPR*) CO_2 streams (*TCAP*: total CO_2 captured)



Equation (1) categorizes the quantity of CO_2 captured as either a reduction or removal for each capture facility under Scenario 1.

$$CAPE_{c,y} \text{ or } CAPR_{c,y} = Q_{CO2,c,y} - Q_{CO2,nonVCS,c,y} \quad (1)$$

Where:

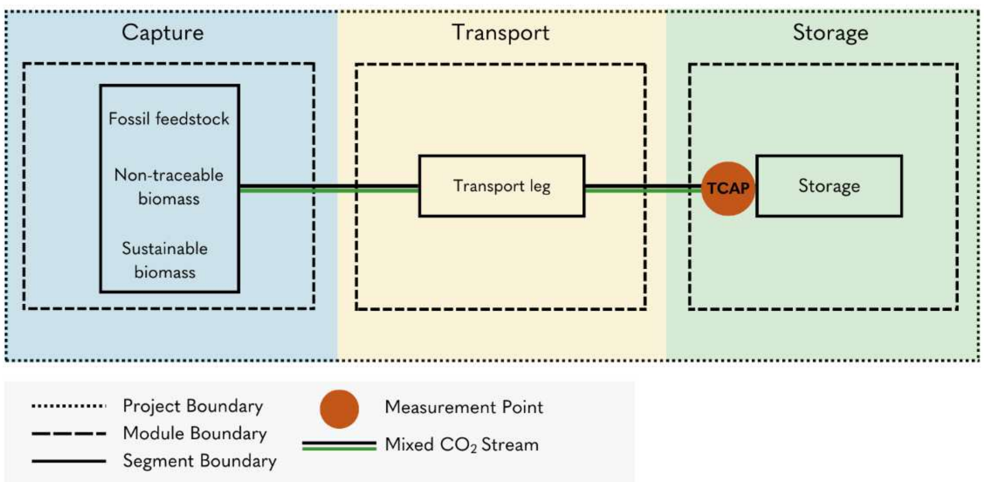
$CAPE_{c,y}$	=	Carbon dioxide captured by capture facility *c* in year *y* that is eligible to be accounted for as a reduction (t CO_2)
$CAPR_{c,y}$	=	Carbon dioxide captured by capture facility *c* in year *y* that is eligible to be accounted for as a removal (t CO_2)
$Q_{CO2,c,y}$	=	Total carbon dioxide captured by capture facility *c* in year *y* (t CO_2)

$Q_{CO2,nonVCS,c,y}$ = Non-VCS carbon dioxide captured in the project boundary at each measurement point c in year y (t CO_2) as determined in *VT0012 Accounting Non-VCS CO2 in CCS Projects*

5.1.2 Scenario 2: Mixed Feedstocks

In this scenario, the captured CO_2 cannot be categorized directly as reductions or removals. Figure 2 illustrates a scenario where captured emissions are derived from mixed feedstocks from a single source.

Figure 2. A mixed reduction (*CAPE*) and removal (*CAPR*) CO_2 stream (*TCAP*: total CO_2 captured)



Equation (2) determines the quantity of CO_2 captured that qualifies as removals for each capture facility under Scenario 2.

$$CAPR_{c,y} = (Q_{CO2,c,y} - - Q_{CO2,nonVCS,c,y}) \times f_{rem-CO2,c,y} \tag{2}$$

Where:

$f_{rem\text{-}CO2,c,y}$ = Fraction of carbon dioxide stream from capture facility c eligible for removals in year *y* as calculated in Equations (5) or (6) as applicable (unitless)

Equation (3) determines the quantity of CO_2 captured that qualifies as a reduction for each capture facility under Scenario 2.

$$CAPE_{c,y} = (Q_{CO2,c,y} - Q_{CO2,nonVCS,c,y}) \times \left(1 - f_{rem-CO2,c,y}\right) \tag{3}$$

Figure 3. Measurement and reporting for combining and separating captured CO_2 streams

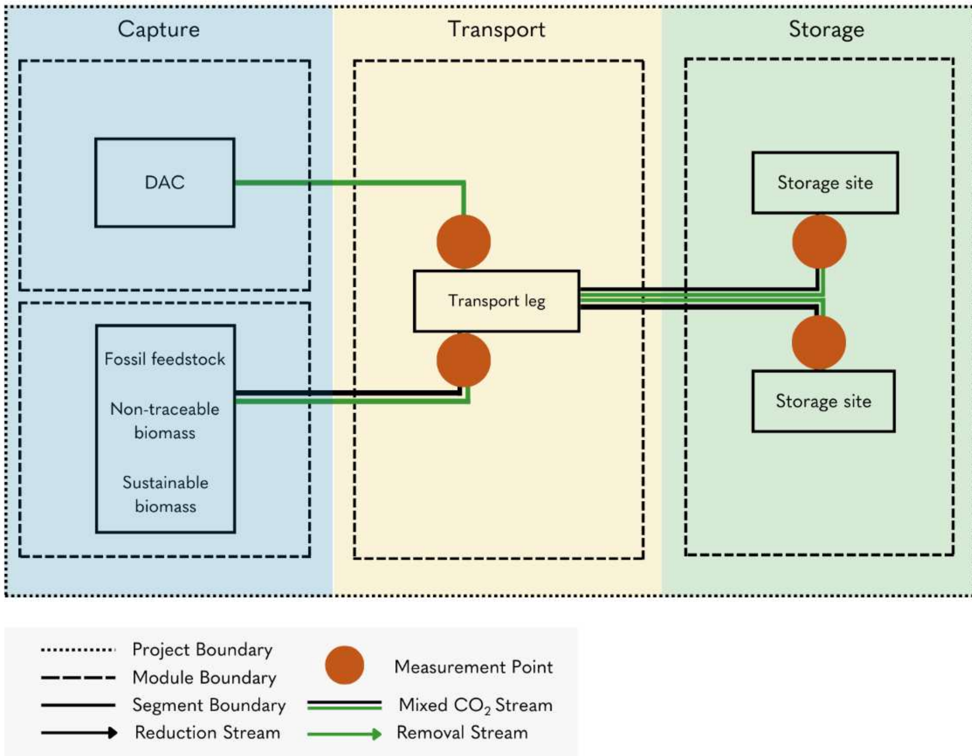


Figure 3Figure 3 illustrates a scenario where CO_2 streams from multiple capture sites and feedstocks are combined for transport, before ultimately being separated for storage. In such cases, the amount and composition of each stream must be determined before streams are comingled within a segment or a CO_2 stream is divided among multiple segments. The procedure for describing segments is outlined in Section 5.45.4.

5.1.3 Determining Total CO_2 Captured

Equation (4) calculates the total amount of CO_2 captured as reductions and removals by the project each year and applies to the scenarios presented in Figures 1–3.

$$TCAP_y = \sum_c CAPE_{c,y} + \sum_c CAPR_{c,y} \tag{4}$$

Where:

$TCAP_y$	=	Total amount of carbon dioxide captured by the project in year y (t CO_2)

5.2 Determining the Fraction of Removals in a CO_2 Stream

This section outlines the procedures for determining the portion of a captured CO_2 stream that represents removals ($f_{rem\text{-}CO2,c,y}$) depending on whether the sustainable biomass component of the feedstock mix is quantified.

5.2.1 Using Emission Source Analysis

This approach is only permissible where:

1) the proportion of biogenic and fossil fuel feedstocks in a mixture is not known, and
2) the biogenic component of the mixture is entirely from sustainable biomass.

Project proponents must use one of the following methods to determine $f_{rem\text{-}CO2,c,y}$ as the biogenic component of the mixture:

a) *ISO 13833:2013 Stationary Source Emissions – Determination of the Ratio of Biomass (Biogenic) and Fossil-derived Carbon Dioxide – Radiocarbon Sampling and Determination*
b) *ISO 18466:2016 Stationary Source Emissions – Determination of the Biogenic Fraction in CO_2 in Stack Gas Using the Balance Method*

5.2.2 Using Mass Balance

Project proponents must use the mass balance approach where:

1) the quantity of sustainable biomass feedstocks in the feedstock mixture is known, and
2) the feedstock mixture includes a non-traceable biomass or fossil component.

Project proponents must calculate $f_{rem\text{-}CO2,c,y}$ based on the applicable end-use as described in Sections 5.2.2.1 and 5.2.2.2.

5.2.2.1 End-Use 1: Combustion

Equation (5) determines the fraction of a CO_2 stream that represents removals ($f_{rem\text{-}CO2,c,y}$) from the combustion of biomass to generate heat and power. This applies to bioenergy and waste-to-energy plants.

$$f_{rem-CO2,c,y} = \frac{\sum_b (m_{sb,b,c,y} \times w_{sb,b,c,y})}{\sum_f (m_{f,c,y} \times w_{f,c,y})} \quad (5)$$

Where:

$m_{sb,b,c,y}$	=	Mass of sustainable biomass type *b*, on a dry basis, generating emissions captured by capture facility *c* in year *y* (t)
$m_{f,c,y}$	=	Mass of each feedstock type *f*, on a dry basis, generating emissions captured by capture facility *c* in year *y*; includes all feedstock types in the mixture (i.e., fossil, sustainable biomass, non-traceable biomass) (t)

$w_{sb,b,c,y}$	=	Weighted average mass fraction of carbon in sustainable biomass type *b*, on a dry basis, captured by capture facility *c* in year *y* (t carbon/t biomass feedstock)
$w_{f,c,y}$	=	Weighted average mass fraction of carbon in feedstock type *f*, on a dry basis, captured by capture facility *c* in year *y* (t carbon/t feedstock)

5.2.2.2 End-Use 2: Conversion

Equation (6) determines the fraction of a CO_2 stream that represents removals ($f_{rem\text{-}CO2,c,y}$) from the conversion of biomass into a biofuel.

$$f_{rem-CO2,c,y} = \frac{\sum_b (m_{sb,b,c,y} \times Y_{CO2,b,y})}{\sum_f (m_{f,c,y} \times Y_{CO2,f,y})} \tag{6}$$

Where:

$m_{sb,b,c,y}$	=	Mass of sustainable biomass type *b*, on a dry basis, generating emissions captured by capture facility *c* in year *y* (t)
$m_{f,c,y}$	=	Mass of each feedstock type *f*, on a dry basis, generating emissions captured by capture facility *c* in year *y*; includes all feedstock types in the mixture (t)
$Y_{CO2,b,y}$	=	Carbon dioxide yield of sustainable biomass feedstock *b*, on a dry basis, in year *y* (Nm^3 CO_2/t)
$Y_{CO2,f,y}$	=	Carbon dioxide yield of feedstock *f*, on a dry basis, in year *y* (Nm^3 CO_2/t)

Project proponents must calculate the CO_2 yield of the biomass feedstocks based on the production method, as follows.

Anaerobic Digestion, Gasification, or Pyrolysis

$$Y_{CO2,b,y} = VS_{b,y} \times Y_{BG,b,y} \times \%CO2_{vol(STP),b} \times \eta_{sep,b} \tag{7}$$

$$Y_{CO2,f,y} = VS_{f,y} \times Y_{BG,f,y} \times \%CO2_{vol(STP),f} \times \eta_{sep,f} \tag{8}$$

Where:

$VS_{b,y}$	=	Volatile solids content, on a dry basis, in biomass type *b* in year *y* (t volatile content/t d.m.)
$VS_{f,y}$	=	Volatile solids content, on a dry basis, in feedstock type *f* in year *y* (t volatile content/t d.m.)
$Y_{BG,b,y}$	=	Volume of biogas/syngas produced from one tonne of volatile solids in biomass type *b*, on a dry basis, in year *y* (Nm^3 biogas or syngas/t volatile solids)
$Y_{BG,f,y}$	=	Volume of biogas/syngas produced from one tonne of volatile solids in feedstock type *f*, on a dry basis, in year *y* (Nm^3 biogas or syngas/t volatile solids)

$\%CO2_{vol(STP),b}$ = Volumetric carbon dioxide fraction in gas flow at standard temperature and pressure (STP) conditions for biomass type *b* (% volume)

$\%CO2_{vol(STP),f}$ = Volumetric carbon dioxide fraction in gas flow at STP conditions for feedstock type *f* (% volume)

$\eta_{sep,b}$ = Efficiency of separation of carbon dioxide from other gases in total gas yield for biomass type *b* (unitless)

$\eta_{sep,f}$ = Efficiency of separation of carbon dioxide from other gases in total gas yield for feedstock type *f* (unitless)

Aerobic Digestion[1]

$$Y_{CO2,b,y} = VS_{b,y} \times Y_{G,b,y} \times \eta_{sep,b} \tag{9}$$

Where:

$Y_{G,b,y}$ = Volume of carbon dioxide produced from one tonne of volatile solids in biomass type *b,* on a dry basis, in year *y* (Nm^3 CO_2/t volatile solids)

Alcoholic Fermentation (Ethanol Production)

$$Y_{CO2,b,y} = Y_{BE,b,y} \times CO2_{vol,BE(STP)} \tag{10}$$

Where:

$Y_{BE,b,y}$ = Ethanol yield of biomass type *b*, on a dry basis, in year *y* (i.e., mass or volume unit of ethanol produced from one tonne of dry matter of biomass type *b*) (L ethanol/t feedstock)

$CO2_{vol,BE(STP)}$ = Carbon dioxide content relative to ethanol at STP conditions (m^3/L ethanol)

$$CO2_{vol,BE(STP)} = \frac{FR_{vol(STP)} \times \%CO2_{vol(STP)}}{Q_{ethanol,y}} \tag{11}$$

Where:

$FR_{vol(STP)}$ = Volumetric flow rate of gas emitted during ethanol production, measured at actual conditions and converted to STP conditions (m^3)

$\%CO2_{vol(STP)}$ = Volumetric carbon dioxide fraction in gas flow at STP conditions (% volume)

$Q_{ethanol,y}$ = Ethanol produced by project activity plant in year *y* (L)

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[1] In aerobic digestion, the amount of CO_2 produced is directly proportional to the volatile solids being digested. Methane is not produced during aerobic digestion. Therefore, $Y_{CO2,b,y}$ is the total CO_2 yield from the volatile solids.

5.3 Allocation of Baseline Emissions to Reductions and Removals

5.3.1 Allocation to Removals

Equation (12) determines the amount of baseline emissions allocated to removals.

$$BE_{CAPR,y} = BE_y \times \frac{\sum_c CAPR_{c,y}}{TCAP_y} \tag{12}$$

Where:

$BE_{CAPR,y}$	=	Baseline emissions associated with removals in year *y* (t CO_2)
BE_y	=	Baseline emissions as determined by Section 8.1 of *VM0049* (t CO_2)

5.3.2 Allocation to Reductions

Equation (13) determines the amount of baseline emissions allocated to reductions.

$$BE_{CAPE,y} = BE_y \times \frac{\sum_c CAPE_{c,y}}{TCAP_y} \tag{13}$$

Where:

$BE_{CAPE,y}$	=	Baseline emissions associated with reductions in year *y* (t CO_2)

5.4 Determining Project and Leakage Emissions for Reductions and Removals

Project proponents must apply the following steps to allocate project and leakage emissions between CO_2 streams eligible for reductions or removals.

1) Step 1: Identify segments
2) Step 2: Identify emissions and CO_2 flows in segments
3) Step 3: Select an option to allocate project and leakage emissions

5.4.1 Step 1: Identify Segments

Project proponents must identify the segments of the project in the project description. Segments allow allocation of project and leakage emissions between CO_2 streams eligible for reductions or removals. The project proponent should aim to maximize the accuracy and simplicity of both measurement and quantification activities when defining segments.

When identifying segments, the following requirements apply:

1) The segment should be defined at the most granular level afforded by the metering equipment (e.g., if multiple pieces of equipment with individual metering are involved in a process, each piece of equipment should be treated as an individual segment).

2) Each activity must not be assigned to more than one segment.
3) Segments must not straddle module boundaries.
4) Descriptions of each segment and its boundaries must be included in the project description.

5.4.2 Step 2: Identify Emissions and CO_2 Flows in Segments

For each segment *g* the project proponent must identify:

1) the amount and composition (i.e., the ratio of gas eligible for reductions and removals) of CO_2 flows entering and exiting the segment.
2) project and leakage emissions as determined in the relevant module for the segment (i.e., capture, transportation, or storage) under *VM0049*.

5.4.3 Step 3: Select Allocation Option

Project proponents must choose one or a combination of the following options (Sections 5.4.3.1–5.4.3.2) to allocate corresponding project and leakage emissions by segment within the project boundary.

5.4.3.1 Option 1: Differentiation Method

This method is permissible for segments where captured CO_2 can be categorized as reductions or removals based on equipment or temporal differentiation. Equipment differentiation means that equipment involved in the processing of captured CO_2 has individual metering and the resulting emissions can be directly attributed to each CO_2 stream. Temporal differentiation means captured CO_2 streams flow at different times and equipment meters have a time resolution sufficient to resolve and attribute the emissions from each period accordingly.

Equations (14), (15), (16), and (17) assign the differentiated portion of project and leakage emissions to either reductions or removals.

$$PE_{CAPR,g,y} = \sum_{D} PE_{CAPR,g,D,y} \quad (14)$$

$$LE_{CAPR,g,y} = \sum_{D} LE_{CAPR,g,D,y} \quad (15)$$

$$PE_{CAPE,g,y} = \sum_{D} PE_{CAPE,g,D,y} \quad (16)$$

$$LE_{CAPE,g,y} = \sum_{D} LE_{CAPE,g,D,y} \quad (17)$$

Where:

$PE_{CAPR,g,y}$	=	Project emissions from segment *g* in year *y* associated with removals ($t\ CO_2$)
$PE_{CAPR,g,D,y}$	=	Project emissions from segment *g* in differentiated equipment *D* or with temporal differentiation *D* associated with removals in year *y* ($t\ CO_2$)
$LE_{CAPR,g,y}$	=	Leakage emissions from segment *g* in year *y* associated with removals ($t\ CO_2$)
$LE_{CAPR,g,D,y}$	=	Leakage emissions from segment *g* in differentiated equipment *D* or with temporal differentiation *D* associated with removals in year *y* ($t\ CO_2$)
$PE_{CAPE,g,y}$	=	Project emissions from segment *g* in year *y* associated with reductions ($t\ CO_2$)
$PE_{CAPE,g,D,y}$	=	Project emissions from segment *g* in differentiated equipment *D* or with temporal differentiation *D* associated with reductions in year *y* ($t\ CO_2$)
$LE_{CAPE,g,y}$	=	Leakage emissions from segment *g* in year *y* associated with reductions ($t\ CO_2$)
$LE_{CAPE,g,D,y}$	=	Leakage emissions from segment *g* in differentiated equipment *D* or with temporal differentiation *D* associated with reductions in year *y* ($t\ CO_2$)

5.4.3.2 Option 2: Mass Balance

This method is permissible for segments where the flows of reductions and removals follow the same pathway within the module or project boundary.

Equations (18) and (19) allocate project and leakage emissions, respectively, from a segment to removals.

$$PE_{CAPR,g,y} = PE_{Total,g,y} \times f_{rem-CO2,g,y} \tag{18}$$

$$LE_{CAPR,g,y} = LE_{Total,g,y} \times f_{rem-CO2,g,y} \tag{19}$$

Where:

$PE_{CAPR,g,y}$	=	Project emissions from segment *g* in year *y* associated with removals ($t\ CO_2$)
$PE_{Total,g,y}$	=	Total project emissions generated from segment *g* in the value chain of project activity in year *y*, calculated as per the relevant module for the segment (i.e., capture, transportation, or storage) under *VM0049* ($t\ CO_2$)
$LE_{CAPR,g,y}$	=	Leakage emissions from segment *g* in year *y* associated with removals ($t\ CO_2$)
$LE_{Total,g,y}$	=	Total leakage emissions generated from segment *g* in year *y*, calculated as per the relevant module for the segment (i.e., capture, transportation, or storage) under *VM0049* ($t\ CO_2$)
$f_{rem-CO2,g,y}$	=	Fraction of carbon dioxide stream from segment *g* eligible for removals in year *y* (unitless)

Equations (20) and (21) allocate project and leakage emissions, respectively, from a segment based on the fraction of the CO_2 stream that qualifies as reductions.

$$PE_{CAPE,g,y} = PE_{Total,g,y} \times \left(1 - f_{rem-CO2,g,y}\right) \quad (20)$$

$$LE_{CAPE,g,y} = LE_{Total,g,y} \times \left(1 - f_{rem-CO2,g,y}\right) \quad (21)$$

Where:

$PE_{CAPE,g,y}$	=	Project emissions from segment *g* in year *y* associated with reductions (t CO_2)
$LE_{CAPE,g,y}$	=	Leakage emissions from segment *g* in year *y* associated with reductions (t CO_2)

Note – The calculation of project emissions and leakage emissions from all the segments within the project boundary is completed in Equations (11) and (12), respectively, of VM0049.

6 DATA AND PARAMETERS

6.1 Data and Parameters Available at Validation

6.2 Data and Parameters Monitored

Data/Parameter	$Q_{CO2,c,y}$
Data unit	t CO_2
Description	Total carbon dioxide captured by capture facility *c* in year *y*
Equations	(1), (2), (3)
Source of data	Calculated as per Section 8.1 of *VM0049*
Description of measurement methods and procedures to be applied	Calculated as $Q_{CO2,x}$ in Section 8.1 of *VM0049*
Frequency of monitoring/recording	As per Section 8.1 of *VM0049*
QA/QC procedures to be applied	As per Section 8.1 of *VM0049*
Purpose of data	Allocation of baseline project and leakage emissions for reductions and removals

Calculation method	Calculated as per Section 8.1 of *VM0049*
Comments	None

Data/Parameter	$m_{sb,b,c,y}$
Data unit	t
Description	Mass of sustainable biomass type *b*, on a dry basis, generating emissions captured by capture facility *c* in year *y*
Equations	(5), (6)
Source of data	Feedstock receipts or meter readings
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	Meters must be operated within the manufacturer's specified operating conditions. Flow meters must be routinely calibrated, inspected, and maintained according to the manufacturer's specifications.
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals for mixed feedstocks
Calculation method	Load cells measure 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	$m_{f,c,y}$
Data unit	t
Description	Mass of each feedstock type *f*, on a dry basis, generating emissions captured by capture facility *c* in year *y*
Equations	(5), (6)
Source of data	Feedstock receipts or meter readings
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	Meters must be operated within the manufacturer's specified operating conditions. Flow meters must be routinely calibrated, inspected, and maintained according to manufacturer specifications.
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals for mixed feedstocks
Calculation method	Load cells measure 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	Includes all feedstock types in the mixture (i.e., fossil, sustainable biomass, non-traceable biomass)

Data/Parameter	$w_{sb,b,c,y}$
Data unit	t carbon/t biomass feedstock
Description	Weighted average mass fraction of carbon in sustainable biomass type *b*, on a dry basis, captured by capture facility *c* in year *y*
Equations	(5)
Source of data	Values provided by the feedstock supplier in invoices are the preferred data source. Where these are unavailable, values may be sourced through measurement by the project proponent or operator of the source facility.
Description of measurement methods and procedures to be applied	Measurements must be carried out at accredited laboratories according to relevant international standards.
Frequency of monitoring/recording	The mass fraction of carbon should be obtained for each feedstock delivery.
QA/QC procedures to be applied	Verify whether the values are within the uncertainty range of the product of the IPCC default values as provided in Chapter 1, Vol. 2 of the most recent version of the *IPCC Guidelines for National Greenhouse Gas Inventories.*[2] Where the values fall below this range, collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The laboratories used for measurements by project proponents must have ISO 17025 accreditation.
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals for mixed feedstocks

[2] In the 2006 version of the IPCC Guidelines, these values can be found in Tables 1.2 and 1.3.

Calculation method	Weighted average annual values should be calculated for each feedstock delivery.
Comments	None

Data/Parameter	$w_{f,c,y}$
Data unit	t carbon/t feedstock
Description	Weighted average mass fraction of carbon in feedstock type *f*, on a dry basis, captured by capture facility *c* in year *y*
Equations	(5)
Source of data	Values provided by the feedstock supplier in invoices are the preferred data source. Where these are unavailable, values may be sourced through measurement by the project proponent or operator of the source facility.
Description of measurement methods and procedures to be applied	Measurements must be carried out at accredited laboratories according to relevant international standards.
Frequency of monitoring/recording	The mass fraction of carbon should be obtained for each feedstock delivery.
QA/QC procedures to be applied	Verify whether the values are within the uncertainty range of the product of the IPCC default values as provided in Chapter 1, Vol. 2 of the most recent version of the *IPCC Guidelines for National Greenhouse Gas Inventories.*[3] Where the values fall below this range, collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The laboratories used for measurements by project proponents must have ISO 17025 accreditation.
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals for mixed feedstocks
Calculation method	Weighted average annual values should be calculated for each feedstock delivery.
Comments	None

Data/Parameter	$VS_{b,y}$ $VS_{f,y}$
Data unit	t volatile content/t dry matter
Description	Volatile solids content, on a dry basis, in biomass type *b* in year *y* Volatile solids content, on a dry basis, in feedstock type *f* in year *y*
Equations	(7), (9)

[3] In the 2006 version of the IPCC Guidelines, these values can be found in Tables 1.2 and 1.3.

	(9)
Source of data	Values provided by the feedstock supplier in invoices are the preferred data source. Where these are unavailable, values may be sourced through measurement.
Description of measurement methods and procedures to be applied	Follow the procedure for determining volatile solids outlined in USDA. 2008. "Agricultural Waste." In *Agricultural Waste Management Field Handbook*.[4]
Frequency of monitoring/recording	Average annual values should be calculated from the metered value for each feedstock delivery.
QA/QC procedures to be applied	Measurements must take place at accredited laboratories according to relevant international standards.
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals in mixed feedstocks
Calculation method	Weighted average annual values should be calculated from the metered value for each feedstock delivery.
Comments	None

Data/Parameter	$Y_{BG,b,y}$ $Y_{BG,f,y}$
Data unit	Nm^3 biogas or syngas/t volatile content Nm^3 biogas or syngas/t volatile content
Description	Volume of biogas/syngas produced from one tonne of volatile solids in biomass type *b*, on a dry basis, in year *y* Volume of biogas/syngas produced from one tonne of volatile solids in feedstock type *f*, on a dry basis, in year *y*
Equations	(7) (8)
Source of data	The value of this parameter may be obtained from the following sources: 1) Measurements from an accredited laboratory according to relevant international standards 2) A compliance market-approved tool relevant to biofuel production (e.g., CA-GREET,[5] GHGenius[6])

[4] Available at: https://directives.nrcs.usda.gov/sites/default/files2/1712930943/17165.pdf

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

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

	3) Yield factors published in peer-reviewed literature[7] representative of the fuel production method and of feedstocks used both temporally and geographically
Description of measurement methods and procedures to be applied	Use the most recent data available from the above data sources at the time of reporting project emissions.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Use the most recent data available from the above data sources at the time of reporting project emissions.
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals for mixed feedstocks
Calculation method	N/A
Comments	None

Data/Parameter	$\eta_{sep,b}$ $\eta_{sep,f}$
Data unit	unitless
Description	Efficiency of separation of carbon dioxide from other gases in total gas yield for biomass type *b* Efficiency of separation of carbon dioxide from other gases in total gas yield for feedstock type *f*
Equations	(7), (9) (8)
Source of data	Derived from process design or operational data, industry benchmarks, or experimental results. For further information, consult relevant technical literature on gas separation technologies and efficiency assessments.
Description of measurement methods and procedures to be applied	Separation efficiency is determined based on the specific technology used for CO_2 capture and separation, operational conditions, and gas composition. It may be obtained from manufacturer specifications, pilot plant data, or through calculation based on gas properties and separation technology performance.
Frequency of monitoring/recording	At validation and upon installation of a new separation system
QA/QC procedures to be applied	Relevant measurement equipment must be operated according to manufacturer's specifications.

[7] 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*.

Purpose of data	Calculation of baseline and project emissions
Calculation method	As required by the source of data
Comments	None

Data/Parameter	$Y_{G,b,y}$
Data unit	Nm^3 CO_2/t volatile content
Description	Volume of carbon dioxide produced from one tonne of volatile solids in biomass type *b,* on a dry basis, in year *y*
Equations	(9)
Source of data	The value of this parameter may be obtained from the following sources: 1) Measurements from an accredited laboratory according to relevant international standards 2) A compliance market-approved tool relevant to biofuel production (e.g., CA-GREET,[5] GHGenius[6]) 3) Yield factors published in peer-reviewed literature[7] representative of the fuel production method and of feedstocks used both temporally and geographically
Description of measurement methods and procedures to be applied	Use the most recent data available from the above data sources at the time of reporting project emissions.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Use the most recent data available from the above data sources at the time of reporting project emissions.
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals for mixed feedstocks
Calculation method	N/A
Comments	None

Data/Parameter	$Y_{BE,b,y}$
Data unit	L ethanol/t feedstock
Description	Ethanol yield of biomass type *b*, on a dry basis, in year *y* (i.e., mass or volume unit of ethanol produced from one tonne of dry matter of biomass type *b*)
Equations	(10)
Source of data	The value of this parameter may be obtained from the following sources:

	1) Measurements from an accredited laboratory according to relevant international standards; 2) A compliance market-approved tool relevant to biofuel production (e.g., CA-GREET,[5] GHGenius[6]) 3) Yield factors published in peer-reviewed literature[7] representative of the fuel production method and of feedstocks used both temporally and geographically.
Description of measurement methods and procedures to be applied	Use the most recent data available from the above data sources at the time of reporting project emissions.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Use the most recent data available from the above data sources at the time of reporting project emissions.
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals for mixed feedstocks
Calculation method	N/A
Comments	None

Data/Parameter	$\%CO2_{vol(STP)}$
Data unit	% volume
Description	Volumetric carbon dioxide fraction in gas flow at STP conditions
Equations	(11)
Source of data	Calculated as per Section 8.1 of *VM0049*
Description of measurement methods and procedures to be applied	As per Section 8.1 of *VM0049*
Frequency of monitoring/recording	As per Section 8.1 of *VM0049*
QA/QC procedures to be applied	As per Section 8.1 of *VM0049*
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals in mixed feedstocks
Calculation method	Calculated as per Section 8.1 of *VM0049*
Comments	None

Data/Parameter	$FR_{vol(STP)}$
Data unit	m^3
Description	Volumetric flow rate of gas emitted during ethanol production, measured at actual conditions and converted to STP conditions
Equations	(11)
Source of data	Calculated as per Section 8.1 of *VM0049*
Description of measurement methods and procedures to be applied	As per Section 8.1 of *VM0049*
Frequency of monitoring/recording	As per Section 8.1 of *VM0049*
QA/QC procedures to be applied	As per Section 8.1 of *VM0049*
Purpose of data	Calculation and differentiation of emissions associated with reductions and removals for mixed feedstocks
Calculation method	Calculated as per Section 8.1 of *VM0049*
Comments	None

Data/Parameter	$Q_{ethanol,y}$
Data unit	Liter
Description	Ethanol produced by project activity plant in year *y*
Equations	(11)
Source of data	On-site measurements
Description of measurement methods and procedures to be applied	Mass flow rates must be determined by using commercially available devices that measure the mass flow rate of a fluid flowing through a measurement channel. Common types of mass flow meters include Coriolis meters, thermal meters, impeller meters, and twin turbine meters. Volumetric flow rates must be determined by using commercially available devices that measure the flow rate of a fluid flowing through a measurement channel. Common types of mass flow meters include rotameters, turbine meters, orifice meters, wedge meters, ultra-sonic flow meters, and vortex flow meters.
Frequency of monitoring/recording	Monitored continuously (i.e., one measurement at least every 15 minutes)
QA/QC procedures to be applied	The metering equipment must be installed and calibrated in accordance with the specifications of either local/national standards or the manufacturer. Where local/national standards or the manufacturer specification is not available, international standards (e.g., IEC, ISO) may be followed.

Purpose of data	Calculation and differentiation of emissions associated with reductions and removals in mixed feedstocks
Calculation method	Direct measurement (preferred) or calculated from several measurements where it is demonstrated that the result is sufficiently accurate (i.e., 2% uncertainty at a 90% confidence interval)
Comments	Refer to US EPA (2010) for further guidance.

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DOCUMENT HISTORY

Version	Date	Comment
v1.0	22 April 2025	Initial version