Draft VCS Methodology

VM0043

CO_2 UTILIZATION IN CONCRETE PRODUCTION

Draft Version 2.0

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Sectoral Scopes 4: Manufacturing industries, 6: Construction, and 17: Other Engineered Removals

Version 1.0 of this methodology was developed by Carbon Cure and Carbonomics.

Version 1.1 of this methodology was developed by Carbon Cure, Carbonomics and Verra.

Version 2.0 of this methodology was developed by Verra with support from CarbonCure.

CONTENTS

1 SUMMARY DESCRIPTION

Project Category	a. Manufacturing industries b. Construction c. Other Engineered Removals
Project Activity Type	a. Capture and utilization in products or processes for storage b. Building material substitution
Additionality	Activity method
Crediting Baseline	Project method
Mitigation Outcome	Reductions and Removals

This methodology is globally applicable to project activities that capture CO_2 from the atmosphere and/or a point source and store it in ready-mix and precast concrete, thereby resulting in CO_2 reductions and/or removals from concrete production. The CO_2 reacts with calcium and magnesium ions in cement to form stable carbonates, which are stored in concrete via a process known as CO_2 mineralization. The CO_2 would have otherwise been emitted to or remained in the atmosphere. This process makes the concrete stronger, enabling optimization of the concrete mix design and steam curing process.

In addition to the above activity, the methodology supports optional activities that further reduce cement use and/or direct energy consumption in concrete production. These include the use of supplementary cementitious materials not diverted from existing uses, process water containing dissolved CO_2, reductions in process-related emissions from steam curing, and the mineralization of CO_2 into recycled concrete aggregate feedstocks.

2 SOURCES

This methodology is based on the following methodologies/documents:

- CDM methodology, AMS-III.BA, *Recovery and recycling of materials from E-Waste, v2.0*
- *VM0031 Methodology for Precast Concrete Production using Sulphur Substitute, v1.0*
- *VM0040 Methodology for Greenhouse Gas Capture and Utilization in Plastic Materials, v1.0*

This methodology uses the following modules and tools:

- *VMD0056 CO_2 Capture from Air (Direct Air Capture)*
- *VMD0059 CO_2 Capture from Bioenergy*
- *VMD0062 CO_2 Capture from Natural Gas Processing*

- *VMD0057 CO_2 Transport for CCS Projects*
- *VT0011 Electricity System Emission Factors*

3 DEFINITIONS

Captured CO_2
Carbon dioxide captured from the atmosphere or a point source that would have otherwise remained in or been emitted to the atmosphere. Captured CO_2 from the atmosphere or from sustainable biomass point source emissions are eligible to be labelled as carbon dioxide removals. All other captured CO_2 is a GHG emission reduction.

Cement
Portland cement, Portland limestone cement, or blended cement. Blended cement also includes supplementary cementitious materials. Portland cement, the most common, is a hydraulic cement powder made by grinding a clinker comprised of calcinated limestone and other secondary ingredients, including up to 5% limestone. This methodology will simply use the term cement to refer to all types.

Cement replacement
A material that can fully replace Portland cement as the binder in concrete, often referred to as alternative cementitious material (ACM).

Clinker
A dark grey nodular material made by heating ground limestone and clay at a temperature of about 1400°C - 1500°C. The nodules are ground up to a fine powder to produce cement, with a small amount of gypsum added to control the setting properties.

CO_2 mineralization
CO_2 mineralization refers to the chemical reaction by which introduced CO_2 combines with calcium- or magnesium-based compounds in concrete or its component materials to form stable carbonate minerals, such as calcium carbonate or magnesium carbonate. The location of the CO_2 mineralization can either be where the final concrete product is produced (e.g., ready-mix plant) or at another location where the additives/SCM are processed with CO_2 introduction, which is then transported to the final concrete product production site.

Component materials
Component materials are the ingredients of concrete (like concrete additives and aggregates) in which CO_2 can be introduced and mineralized, which are subsequently incorporated into ready-mix concrete or precast concrete products. These materials also include inputs into new concrete from process water and recycled concrete aggregates (see definition below).

Concrete/ Concrete products
Concrete/Concrete products are materials traditionally composed of coarse aggregates (e.g., sand, gravel), cement or cement replacement, and possibly supplementary cementitious materials that harden upon addition of water and subsequent curing to form a stone-like substance. Concrete/concrete products are used in several forms, including ready mix and pre-cast (drycast and wetcast).

Feedstock
The CO_2 captured as part of project activities used along with other materials to produce concrete.

Mix design
The masses of ingredients, including cement (or cement replacement), sand, gravel, aggregates, water, and any other additives used to produce a unit of concrete of a given type and compressive strength. This mix design could be used in the project activity and would then be referred to as the project mix design. In addition, the mix design could be what would have occurred in the absence of the project activity, which is then referred to as the baseline mix design. The baseline mix design is determined in order to assess how much cement would have been used in the baseline scenario. The same mix design can be used at multiple facilities.

Mix design categories
Classifications of concrete mix designs, defined by the specific masses of cement (or cement replacement), sand, gravel, aggregates, water, and additives required to produce concrete of a particular type and compressive strength.

Precast concrete
Concrete that is cast in a mold and then cured in a controlled environment in a manufacturing plant, instead of mixing and pouring it at the construction site. Examples include concrete masonry, hardscapes, and reinforced concrete elements.

Process Water[1]
Recycled or recovered wastewater resulting from concrete production operations, which includes wash water from truck mixers, reclaimer system water, and slurry or sludge water.

Ready mix concrete
Concrete that is batched (precise ingredient measurement) and mixed in a centralized concrete batching plant according to a specified mix design and then transported to the construction site in a fresh, plastic state for placing and curing at the point of use, rather than being mixed on-site. Examples include concrete slabs, beams, columns, walls and pavements.

Recycled concrete aggregate (RCA)
Recycled Concrete Aggregate (RCA) is produced by processing hardened concrete (end of service life or returned) to have a size grading that allows it to be reused. The RCA is

[1] Definition derived from ASTM C1602, available at: https://store.astm.org/c1602_c1602m-22.html

commonly used as a road base or filling material or as a substitute for virgin aggregates. RCA is typically composed of coarse aggregates (crushed rocks), and mortar (cementitious material, sand, and water) that adhere to the aggregates. Acceptable sources of RCA are defined by relevant concrete jurisdictions and can vary from country to country based on their specifications.

Steam curing
Concrete curing process in which concrete elements are exposed to water vapor under controlled temperature conditions, either at atmospheric pressure or elevated pressure, in order to accelerate strength development and curing. Steam curing typically requires thermal energy, supplied through the combustion of fossil fuels, to generate and maintain the required steam conditions.

Steam Methane Reforming[2]
A process that converts gaseous and liquid hydrocarbons, primarily methane, into hydrogen-rich gas through reforming reactions typically conducted at temperatures of 800–1000 °C and pressures of 13–20 bar.

Supplementary cementitious material (SCM)
Material that is a by-product of another industrial process and that contributes to the properties of a cementitious mixture through hydraulic or pozzolanic activity, or both, without the need for additional thermal processing or calcining. Examples include pozzolans like fly ash, slag cement, silica fume, biogenic limestone, biochar etc.

Waste CO_2
Carbon dioxide from an anthropogenic source that would have otherwise been emitted to the atmosphere.

4 APPLICABILITY CONDITIONS

This methodology is applicable under the following conditions:

1) The project manufactures ready-mix concrete and/or precast concrete products for sale and use in the commercial market.
2) The project mineralizes CO_2 in concrete/concrete products and component materials[3] during the production of concrete.
3) If optional activities are included in the project, cement use in mix designs and/or direct energy consumption during concrete production are reduced. Eligible optional activities are limited to one or a combination of the following:
   a) use of supplementary cementitious materials not diverted from existing uses

[2] Definition derived from this source: https://www.sciencedirect.com/topics/engineering/steam-methane-reformer

[3] Wherever the methodology mentions "concrete/concrete products and component materials", the term "component materials" refers to recycled concrete aggregates and reclaimed water (optional activities) in line with the definition above.

b) use of process water with dissolved CO_2

c) reduction of process-related CO_2 emissions from steam curing

d) mineralization of CO_2 into recycled concrete aggregate feedstocks

4) The project is implemented at:

a) a new (greenfield) concrete production facility; or

5) an existing (brownfield) concrete production facility that did not mineralize CO_2 into component materials prior to the initial crediting period start date.

6) The project involves the capture of CO_2 from the atmosphere and/or a point source that would have otherwise remained in or been emitted to the atmosphere (respectively) through the operation of new or existing CO_2 capture facilities.

This methodology is not applicable under the following conditions:

7) Recycled concrete is used in the baseline mix design.

8) CO_2 is generated for the sole purpose of capture and storage into concrete/concrete products and component materials.

5 PROJECT IMPLEMENTATION

5.1 Project Start Date

When determining the project start date, the earliest of the following must be used, as applicable:

1) Signing a contract for the purchase and/or installation of new CO_2 injection/mineralization equipment (and related infrastructure) in the concrete production facility(ies)

2) Start of commercial operation of the CO_2 injection/mineralization equipment in the concrete production facility(ies)

3) Signing the CO_2 procurement contract(s) between the concrete production facility(ies) and the CO_2 supplier(s)

5.2 Initial Crediting Period Start Date

The initial crediting period start date is determined by the date on which the first batch of concrete is produced using CO_2 injection/mineralization under the project activity.

Project proponents must provide evidence by verifiable records of the production start dates, such as appropriately dated concrete production logs (including control system data/SCADA logs), batch records, operational reports, etc.

Where CO_2 injection/mineralization has not commenced before the project validation, the project proponents must provide an estimated start date and determine the real initial crediting period start date once CO_2 injection/mineralization starts.

5.3 Crediting Period Renewal

Project proponents must renew the project crediting period in accordance with the VCS Program rules.

Note — Under the VCS Standard, projects may be eligible for additional crediting period renewals where specified in the applied methodology. Verra may revise this methodology to allow further crediting period renewals under specific conditions, such as high operating costs and no or limited revenues other than from carbon credit sales.

5.4 Methodology Transition

Projects transitioning from previous versions of *VM0043* to this version must follow the VCS Program rules.

6 PROJECT BOUNDARY

The spatial extent of the project boundary encompasses:

- The project facility where concrete/concrete products and component materials are produced
- The facilities from which the CO_2 feedstock is sourced
- The facilities where displaced Portland cement is manufactured

The greenhouse gases included in or excluded from the project boundary are shown in Table 1 below.

Table 1. GHG Sources and sinks accounted for as baseline, project, and leakage emissions

	Source	Type	Gas	Included?	Justification/Explanation
Baseline	Passive CO_2 mineralization	Sink	CO_2	Yes	CO_2 that is naturally mineralized into concrete without project intervention.
			CH_4	No	Not Applicable
			N_2O	No	Not Applicable
			Other	No	Not Applicable
	CO_2 emitted from industrial processes (that is captured in the project)	Source	CO_2	Yes	CO_2 is the main gas that can be captured by carbon capture and utilization technology
			CH_4	No	Only CO_2 captured and sequestered into concrete is considered for this methodology

			N_2O	No	Only CO_2 captured and sequestered into concrete is considered for this methodology
			Other	No	Other GHGs (HFCs, PFCs, SF_6) are not used in this process.
	Cement production process and energy consumption	Source	CO_2	Yes	CO_2 process emissions occur as a by-product of the calcination process, where a calcium or magnesium carbonate such as limestone is heated with clay to form clinker (primarily calcium oxide) and CO_2. The heat required for the calcination process is typically supplied from the combustion of fossil fuels, resulting in the emission of further CO_2
			CH_4	No	Excluded for simplicity, emissions are considered negligible.
			N_2O	No	Excluded for simplicity, emissions are considered negligible.
			Other	No	Other GHGs (HFCs, PFCs, SF_6) are not used in this process.
	Steam curing	Source	CO_2	Yes	CO_2 is the main gas emitted by natural gas or other fuels used for steam curing, which may be reduced by the project activity.
			CH_4	No	Excluded for simplicity, emissions are considered negligible.
			N_2O	No	Excluded for simplicity, emissions are considered negligible.
			Other	No	Other GHGs (HFCs, PFCs, SF_6) are not used in this process.
Project	Atmospheric CO_2 (that is captured in the project)	Sink	CO_2	Yes	CO_2 that is captured directly from the atmosphere and stored in concrete.
			CH_4	No	Not Applicable
			N_2O	No	Not Applicable
			Other	No	Not Applicable
	Electricity consumption	Source	CO_2	Yes	Electricity is used to power a facility manufacturing concrete products and component materials. CO_2 is

	(concrete production)				the primary emission from electricity combustion. This relates only to the incremental increase in the use of equipment needed to sequester the CO_2. This does not refer to the entire facility itself.
			CH_4	No	Excluded for simplicity, emissions are considered negligible.
			N_2O	No	Excluded for simplicity, emissions are considered negligible.
			Other	No	Other GHGs (HFCs, PFCs, SF_6) are not used in this process.
	Fossil fuel consumption (concrete production)	Source	CO_2	Yes	Natural gas or liquid/solid fuels are used to power a facility manufacturing concrete/concrete products and component materials. CO_2 is the primary emission from fossil fuel combustion. This relates only to the incremental increase in the use of equipment needed to sequester the CO_2. This does not refer to the entire facility itself.
			CH_4	No	Excluded for simplicity, emissions are considered negligible.
			N_2O	No	Excluded for simplicity, emissions are considered negligible.
			Other	No	Other GHGs (HFCs, PFCs, SF6) are not used in this process.
	Cement production process and energy consumption	Source	CO_2	Yes	CO_2 process emissions occur as a by-product of the calcination process, where a calcium or magnesium carbonate such as limestone is heated with clay to form clinker (primarily calcium oxide) and CO_2. The heat required for the calcination process is typically supplied from the combustion of fossil fuels, resulting in the emission of further CO_2

			CH_4	No	Excluded for simplicity, emissions are considered negligible.
			N_2O	No	Excluded for simplicity, emissions are considered negligible.
			Other	No	Other GHGs (HFCs, PFCs, SF_6) are not used in this process.
	Electricity and fuel consumption (capturing, compressing and transporting CO_2)	Source	CO_2	Yes	Main GHG associated with capturing, compressing and transporting CO_2. Note also that the default factors for transportation emissions (tCO_2e/tonne-km) includes all GHGs from transportation.
			CH_4	No	Excluded for simplicity, emissions are considered negligible.
			N_2O	No	Excluded for simplicity, emissions are considered negligible.
			Other	No	Other GHGs (HFCs, PFCs, SF_6) are not used in this process.

7 BASELINE SCENARIO

The baseline scenario is the continuation of manufacturing ready-mix or pre-cast concrete products through traditional processes (i.e., not using CO_2 capture and utilization technology for reduced cement use).

Follow the steps in this section to determine the baseline scenario. This includes activities related to both concrete use as well as optionally, the fate of CO_2, which are necessary to define emission reductions or carbon removals in the project.

7.1 Step 1: Determine the Applicable Geographic Area

Determine the applicable geographic area to apply when taking each of the subsequent steps.

The default applicable geographic area is the entire host country. The project proponent may choose to limit the applicable geographic area to a specific geographic area within the host country. In this case, the project proponent must justify the essential distinctions between the applicable geographic region and the rest of the host country that lead to different investment or implementation conditions specific to the project activity. Relevant factors may include:

- Market access for concrete, resource availability including CO_2, or concrete input materials
- Infrastructure development, transport limitations, and accessibility
- Subsidies, policies, laws, or regulations
- Climatic, topographic, or geological differences
- Socioeconomic conditions

7.2 Step 2: Identify Alternatives to the Project Activity

Concrete

Proponents must identify a project mix design or mix design category (MD/C) for each batch of ready-mix concrete or pre-cast concrete product in the project and corresponding alternative baseline mix designs. The same MD/C (project or baseline) can be utilized at multiple facilities.

When there are several mix designs, they may be categorized to simplify the testing. When mix designs are categorized, each project MD/C, must have corresponding alternative baseline MD/Cs, and the MD/C must be used (individual mix designs cannot be used with MD/Cs. Minor variations in the ratio of ingredients within different batches of concrete of the same MD/C can be considered the same MD/C.

CO_2

Proponents must identify all CO_2 suppliers that are able to supply the project with bulk CO_2 meeting product specifications in the applicable geographic area.

For all identified CO_2 suppliers (which include bulk suppliers) in the applicable geographic region, categorize them as either new or existing. New suppliers are those that were brought online after the project start date, existing suppliers are those that were brought online before the project start date.

For all identified CO_2 suppliers, that are categorized as existing, describe what would have happened to CO_2 procured from this source in the absence of the project with a brief justification. Here, the reasonable alternatives to the project activity include, but are not restricted to:

1) continuation of CO_2 emissions to the atmosphere from commercial or industrial facilities (like an ethanol production plant[4])
2) capture of CO_2 for other uses/applications (like beverage carbonation, food processing etc.) or permanent geological storage (like a geological reservoir/well[5])

[4] For example, from a particular ethanol plant in the region, the CO_2 would have otherwise been emitted to the atmosphere because this ethanol plant operates responsively to market demand, emits the CO_2 when not needed, and captures less than 100% of its nameplate capture capacity.

[5] Where CO_2 is sourced from a well, which is connected to a geologic reservoir, the CO_2 would have otherwise stayed underground because it produced only for CO_2 offtakers.

3) implementation of the proposed project without being registered under the VCS or any other carbon offset standard

7.3 Step 3: Eliminate Alternatives

Concrete

Eliminate alternative MD/Cs that meet at least one of the following requirements:

1) The baseline MD/C does not meet national performance standards, codes, and regulations. If these do not exist at the jurisdictional level, equivalent international standards, codes and regulations that are required by the product design specification are acceptable.

2) The 28-day compressive strength of the project MD/C concrete is less than the 28-day compressive strength of the alternative baseline MD/C concrete. Other performance metrics may be used in addition to the 28-day compressive strength.

3) The alternative baseline MD/C includes CO_2 mineralization in concrete/concrete products and component materials.

4) The alternative baseline MD/C includes eligible optional activities (identified in Section 4 above) that were undertaken at an existing (brownfield) concrete production facility prior to project implementation, at a rate representative of pre-project operations, defined as being within +/-30% of the historical rate.

CO_2

Eliminate alternative scenarios for CO_2 that are categorized as existing and do not include emission to the atmosphere (for emission reductions), or CO_2 staying in the atmosphere (for carbon removals), as the fate of CO_2 in the absence of the project.

Examples of sources that must be eliminated include, but are not limited to, the following:

- CO_2 taken from a well, which is connected to a geologic reservoir, where the CO_2 would have otherwise stayed underground;
- CO_2 captured from an industrial source where that CO_2 would have otherwise been captured and then injected into a geologic reservoir; and
- CO_2 that is diverted from other durable storage applications that do not include those that result in its eventual release to the atmosphere by design or through intended or expected uses, such as use in beverage carbonation, food processing, or other short-lived industrial applications.
- CO_2 generated for the purpose of capture
- CO_2 sourced from DAC plant(s) that would otherwise be directed to permanent storage.

The project proponent must demonstrate evidence to justify that *the remaining sources of CO_2 would have been released to or remain in the atmosphere (i.e.,* CO_2 sources that are new, or those existing that include emission to the atmosphere or CO_2 staying in the atmosphere as the fate in the absence of the project).

7.4 Step 4: Select Baseline from Remaining Alternatives

Concrete

Where projects have concrete batches with multiple alternative baseline MD/C's meeting the above criteria, the MD/C with the lowest cement content must be chosen for conservativeness.

In cases where project proponents are claiming GHG reductions from lower steam curing requirements, the project description documents must clearly explain the baseline level of steam curing that took place prior to the project activity. The project description must also provide a contrast between the baseline and project scenarios by clearly describing baseline steam curing and how the project activity is reducing or eliminating that process.

CO_2

Where projects procure CO_2 directly from an alternative source of CO_2 that has not been eliminated (an eligible source), that source is the baseline.

Where projects procure some or all of their CO_2 from suppliers with unknown sources, and there are no ineligible sources in the applicable geographic area:

1) Where all sources in the applicable geographic area are emission reduction sources (capture from emissions), the baseline scenario is capture from emissions.
2) Where all sources in the applicable geographic area are carbon removal sources, (capture from atmosphere or biogenic emissions), the baseline scenario is CO_2 staying in atmosphere.
3) Where some sources in the applicable geographic area are emission reductions and others are carbon removals, the baseline scenario is capture from emissions.

Where projects procure some or all their CO_2 from suppliers with unknown sources, and there are ineligible sources in the applicable geographic area, emission reductions or carbon removals from CO_2 mineralization into cement is not eligible as part of the project.

In addition, the amount of CO_2 from an unknown or ineligible source that is supplied to the project but lost (for instance, possibly through physical leakage) and not mineralized must be considered a project emissions, as determined in Section 9.2.5.

8 ADDITIONALITY

This methodology uses an activity method for the demonstration of additionality.

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the applicable version of the *VCS Standard*.

Project proponents must demonstrate regulatory surplus for the following activities, as applicable:

1) CO_2 capture from point sources in the applicable geography region,
2) CO_2 injection into concrete for each concrete production facility
3) For all additional activities at each concrete production facility, including:
    a) use of supplementary cementitious materials not diverted from existing uses
    b) use of process water with dissolved CO_2
    c) reduction of process-related CO_2 emissions from steam curing
    d) mineralization of CO_2 into recycled concrete aggregate feedstocks

Where the project proponent demonstrates regulatory surplus for all components listed above, proceed to the next step. Otherwise, the project activity is not additional.

Step 2: Positive List

The applicability conditions of this methodology represent the positive list. The project must demonstrate that it meets all of the applicability conditions, and in so doing, it is deemed to conform to the positive list.

The positive list was established using the activity penetration option (Option A in the *VCS Methodology Requirements*[6]). Justification for the activity method is provided in Appendix I.

9 QUANTIFICATION OF REDUCTIONS AND REMOVALS

9.1 Baseline Emissions

Emissions in the baseline scenario are associated with four components. The first component is the emissions associated with the production of Portland cement ($BE_{cement,y}$). The second component is the CO_2 that is captured and sequestered in the ready-mix or pre-cast concrete/concrete products and component materials produced by the project activity ($CR_{CO2,cap}$ or $BE_{CO2,cap}$). The third component is the CO_2 that would have been naturally mineralized in ready-mix or pre-cast concrete products in the absence of the project activity

[6] Section 3.5.10 of the *VCS Methodology Requirements, v5.0*

(passive carbonation) ($BCS_{passive}$). The fourth component is CO_2 emissions due to energy consumed for baseline steam curing ($BE_{SC,y}$).

Baseline emissions, associated with reductions, are calculated using the equation below and further discussed in the sections below.

$$BE_{ER,y} = BE_{cement,y} + BE_{SC,y} + BE_{CO2,cap,y} \quad (1)$$

Where:

$BE_{ER,y}$	= Baseline emissions in the baseline associated with reductions in year y (tCO_2e)
$BE_{cement,y}$	= Baseline emissions from the amount of cement that would have been used in absence of the project, in year y (tCO_2e)
$BE_{SC,y}$	= Baseline emissions associated with steam curing cement in the baseline, in year y (tCO_2e)
$BE_{CO2,cap,y}$	= Baseline emissions captured in the project that would have been emitted in absence of the project, in year y (tCO_2e)

These components, along with carbon removal in the baseline and passive carbonation are described in the sections below.

9.1.1 Cement Production ($BE_{cement,y}$):

The first component of the baseline emissions calculation is the displacement of conventional cement production by the project activity. These baseline emissions are calculated in the equation below. The amount of displacement is calculated by determining the quantity of cement that would have been used in the absence of the project and multiplying that by the emissions factor of the cement.

$$BE_{cement,y} = \sum_i (Q_{cement,i,b,y} \times EF_{cement}) \times (1 - DF_{UD}) \quad (2)$$

Where:

$BE_{cement,y}$	= Emissions from the production of Portland cement that would have been used in the absence of the project (tCO_2e) in year y
$Q_{cement,i,b,y}$	= Quantity of Portland cement that would have been used in the baseline for concrete produced using a project mix design *i* in year y (tonnes)
EF_{cement}	= Emissions factor of Portland cement production (tCO_2e/tonne of cement).
DF_{UD}	= Discount factor for upstream displacement (6.5%)

Determining $Q_{cement,i,b,y}$: Project proponents must use a testing procedure that measures the cement required to produce concrete products and component materials with equivalent or better functional or compressive strength per industry standards, such as ASTM Volume 04.02. This procedure involves comparing the compressive strength of concrete with and without the project activity to establish a cement use ratio between the project scenario and the baseline scenario applicable to all project concrete produced with mix design *i*.

Where concrete products do not utilize compressive strength as a metric, project proponents must apply the appropriate ASTM tests to determine functional equivalence. The testing process is outlined in Appendix II. Note that the equations below refer to concrete mix designs, which include both ready-mix and pre-cast concrete products.

$$Q_{cement,i,b,y} = Q_{cement\ i,p,y} \times \frac{\sum_n Q_{cement,b,i,test\ n}}{\sum_n Q_{cement,p,i,test\ n}} \quad (3)$$

Where:

$Q_{cement,i,p,y}$	= Quantity of Portland cement used in the project scenario for concrete produced using a project mix design *i* in year y (tonnes).
$Q_{Cement,p,i,test\ n}$	= Quantity of Portland cement used (e.g., tonnes) to prepare project compressive strength or equivalent test specimen *n* for concrete produced using project mix design *i.*
$Q_{Cement,b,i,test\ n}$	= Quantity of Portland cement used (e.g., tonnes) to prepare baseline compressive strength or equivalent test specimen *n* for concrete produced using a baseline mix design, that results in a concrete of equivalent compressive strength to project mix design *i.*

9.1.2 Baseline steam curing ($BE_{SC,y}$):

In certain cases, the project activity may result in reduced energy requirements for steam curing relative to the baseline scenario. This may occur where reductions in cement content lead to a lower need for steam curing or eliminate the requirement altogether, thereby reducing associated fossil fuel or electricity consumption.

The quantification of baseline emissions from steam curing is applicable only to existing concrete production facilities with at least three years of historical production data. The equations presented below are defined in the MD/C. Baseline emissions from fossil fuel use associated with steam curing must be calculated using the following equation:

$$BE_{SC,y} = \sum_i Q_{concrete,i,p,y} \times BEF_{SC,i} \quad (4)$$

Where:

$BEF_{SC,i}$	= Baseline emissions factor for steam curing for the MD/C i (tCO_2/t concrete produced)

The baseline emissions factor for steam curing must be calculated using the following equation (in terms of the average of the last three years):

$$BEF_{SC,i} = \frac{\sum_x (\sum_a (Q_{ffsc,a,x} \times FC_a \times EF_a) + (Q_{elec,x} \times EF_{elec,x}))}{\sum_x Q_{Concrete,i,b,x}} \quad (5)$$

Where:

X	= Index value denote historical years (1,2,3 corresponding to the last three years before the implementation of the project activity) (-)
$Q_{concrete,i,b,x}$	= Quantity of concrete produced for the baseline MD/C which project MD/C *i* is replacing (tonnes)

$Q_{ffSC,a,x}$ = Quantity of fossil fuel a used for steam curing for MD/C *i* in year x (volume of liquid fuel, mass of solid fuel or cubic meters of natural gas)

FC_a = Energy content of fuel type a combusted (TJ/unit of fuel)

EF_a = Emission factor of fuel type a (tCO_2/TJ)

$Q_{elec,x}$ = Quantity of electricity used for steam curing for MD/C *i* in year x (MWh)

$EF_{elec,x}$ = Emissions intensity of the electricity in year x (tCO_2/MWh)

9.1.3 Captured CO_2 ($CR_{CO2,cap}$ or $BE_{CO2,cap}$):

If CO_2 is captured from the atmosphere through direct air capture or bioenergy[7] carbon capture technologies, the project is eligible to generate carbon dioxide removals. If this is sought, the source of CO_2 must be recorded to make this distinction, and $CR_{CO2,cap}$ must be determined.

If CO_2 is captured from flue gases resulting from fossil fuel combustion or other industrial processes (e.g., cement, blue hydrogen production), it results in emission reductions and $BE_{CO2,cap}$ must be determined.

There are three options for determining the amount of CO_2 captured and mineralized in concrete or concrete products and component materials.

Option 1: Empirical Quantification of Mineralized CO_2 in Concrete: Direct chemical analysis of hardened concrete[8] samples must be performed to determine the quantity of CO_2 injected and mineralized in concrete or concrete products produced under the project activity.

The following two measurement methods are allowed under this option:

1. **Thermogravimetric Analysis (TGA)**
   TGA is an analytical technique used to quantify CO_2 chemically bound in hardened concrete by measuring mass changes in a prepared sample under controlled heating conditions. TGA must be conducted within defined temperature ranges used to identify mass loss attributable to carbonate decomposition in accordance with generally accepted thermal analysis standards, such as ASTM E1131-20[9] or equivalent national or international standards.

2. **Acid Digestion Methods**
   Acid Digestion is an analytical method used to quantify carbonate-bound CO_2 in hardened concrete by chemically dissolving specific carbonate phases via treatment with

[7] To be eligible for the removal label, the CO_2 sourced from bioenergy carbon capture must be from renewable biomass that is sustainably sourced, for example this includes CO_2 from ethanol production facilities using renewable biomass feedstocks that are sustainable sourced.

[8] Hardened concrete is defined as the concrete that has set and cured, exhibiting specific properties such as density, which can vary based on aggregate composition and mix proportions, generally ranging from 1670 kg/m³ to over 2510 kg/m³ depending on the materials used (source: https://www.sciencedirect.com/topics/engineering/hardened-concrete).

[9] ASTM E1131-20: Standard Test Method for Compositional Analysis by Thermogravimetry, available here: https://store.astm.org/e1131-20.html

a strong acid. Acid digestion methods must involve controlled dissolution of carbonate minerals using acid and quantification of the released CO_2, consistent with established cement and concrete chemical analysis procedures, such as ASTM C114-24[10] or equivalent national or international standards.

The baseline emissions and carbon dioxide removals are calculated using the equations below:

$$BE_{CO2,cap,y} = \sum_{i} [Q_{concrete,i,p,y} \times CO2_{mineralized,i,y}] \quad (6a)$$

And/or

$$CR_{CO2,cap,y} = \sum_{i} [Q_{concrete,i,p,y} \times CO2_{mineralized,i,y}] \quad (6b)$$

Where:

$BE_{CO2,cap,y}$ = Baseline emissions from the capture of CO_2 (tCO_2e) in year y

$CR_{CO2,cap,y}$ = Carbon dioxide removals from the capture of CO_2 (tCO_2e) from the atmosphere in year y

$Q_{Concrete,i,p,y}$ = Quantity of concrete products produced by the project for product MD/C *i* in year y (tonnes)

$CO2_{mineralized,i,y}$ = Quantity of CO_2 mineralized per unit of concrete of MD/C *i* in year y (tCO_2/kg of concrete in the sample)

The project proponent must clearly document the selected measurement method in the project documents. The project proponent must demonstrate that the sampling strategy is representative of production and must document the sampling frequency, number of samples, sample locations, and sample preparation procedures. All sampling and preparation procedures must be consistent with relevant standards for concrete testing and materials characterization, including applicable provisions of ASTM C172/C172M[11], ISO 1920-1[12] or equivalent national or international standards for concrete sampling.

Option 2: Testing to Determine Quantity of Carbon Embedded in Concrete: Determining the amount of CO_2 sequestered into the concrete products and component materials involves the testing of concrete samples using a carbon analyzer. This device can ascertain the level

[10] ASTM C114-24: Standard Test Methods for Chemical Analysis of Hydraulic Cement, available here: https://store.astm.org/c0114-24.html

[11] ASTM C172/C172M: Standard Practice for Sampling Freshly Mixed Concrete, available here: https://store.astm.org/c0172_c0172m-17.html

[12] ISO 1920-1:2004: Sampling of fresh concrete, available here: https://www.iso.org/standard/29097.html

of carbon embedded in a sample of concrete products. The difference between the carbon contents of the baseline sample and the project sample indicates the additional CO_2 that is embedded in the project concrete. The testing procedure is detailed in Appendix IV. The results of the tests are used in the equations below:

$$BE_{CO2,cap,y} = \sum_i [Q_{concrete,i,p,y} \times (C_{project\ sample,i,y} - C_{baseline\ sample,i,y}) \times \frac{44}{12}] \quad (7a)$$

or

$$CR_{CO2,cap,y} = \sum_i [Q_{concrete,i,p,y} \times (C_{project\ sample,i,y} - C_{baseline\ sample,i,y}) \times \frac{44}{12}] \quad (7b)$$

Where:

$Q_{Concrete,i,p,y}$	= Quantity of concrete products produced by the project for product mix design *i* in year y (tonnes).
$C_{project\ sample,i,y}$	= Carbon content of samples of concrete products for each design mix *i* in year y taken from the project activity (tC/kg of concrete in the sample)
$C_{baseline\ sample,i,y}$	= Carbon content of samples of concrete products for each design mix *i* in year y that are not using the project activity technology (tC/kg of concrete in the sample)

Option 3: Determination based on mineralization efficiency or CO_2 dosage threshold: In some cases, one concrete manufacturer may be producing too many mix designs for the testing to be feasible or practical. In this case, project proponents may use a default based on either the percentage of CO_2 injected into the process (as determined by a meter) and actually mineralized (mineralization efficiency), or the upper limit for CO_2 dosage as a percentage by weight of cement (CO_2 dosage threshold).

For determining the mineralization efficiency, tests have been carried out as outlined in Appendix VI. These tests show quite a range of results in terms of the efficiency of the uptake of CO_2 into the concrete, and there appears to be little correlation between the efficiency of mineralization and the percentage of CO_2 injected. However, the lowest test result is 76%, meaning that about three-quarters of the CO_2 that is injected into the process is actually mineralized into the concrete. As a conservative default, the assumed efficiency of mineralization is set at 60%, which is applicable for both ready-mix and precast concrete.

For determining the CO_2 dosage threshold, CarbonCure’s internal testing and operational experience across pilot trials and customer deployments have indicated that the observed CO_2 injection dosages typically fall within a range of approximately 0.1–0.7% by weight of cement. On this basis, a value of 0.7% by weight of cement (bwc) has been adopted as a conservative default upper-bound dosage.

Under this option, the baseline emissions and carbon dioxide removals are calculated using the equations below:

$$BE_{CO2,cap,y} = \sum_i min\left(Q_{CO2,meter,s,y}, Q_{cement,i,p,y} \times d\right) \times \eta \quad (8a)$$

$$CR_{CO2,cap,y} = \sum_i min\left(Q_{CO2,meter,s,y}, Q_{cement,i,p,y} \times d\right) \times \eta \quad (8b)$$

Where:

$Q_{CO2,meter,s,y}$	= Amount of CO_2 injected from source s in year y into the concrete production process, as determined by a flow meter (tCO_2) at the project activity location
$Q_{cement,i,p,y}$	= Quantity of Portland cement used in the project for concrete produced using a project MD/C i in year y (tonnes)
d	= Default upper limit for CO_2 dosage as a percentage by weight of the Portland cement used (tCO_2/tonne of cement). The value of this parameter is 0.007.
η	= Conservative default for the efficiency of CO_2 mineralization into the concrete (%). The value of this parameter is 60%.

9.1.4 Passive carbonation ($BCS_{passive}$):

The project proponent must account for passive carbonation, defined as the quantity of atmospheric CO_2 that would have been naturally mineralized in concrete products in the absence of the project activity (i.e., without CO_2 injection into concrete). Passive carbonation must be conservatively determined across the crediting period using one of the following three options:

Option 1: Baseline carbonation kinetics modelling under ambient exposure conditions:

The project proponent must use carbonation kinetics model that represents the natural diffusion of atmospheric CO_2 into concrete and its reaction with cementitious phases under ambient exposure conditions. The model must exclude the influence of intentional CO_2 injection or accelerated CO_2 curing environments.

The model must reflect baseline concrete production practices relevant to the project activity and include the following aspects (inter alia):

- cement type and content,
- binder type and composition,
- water-to-binder ratio, and
- expected exposure conditions during curing, storage, and early service life stages (till application on a construction site), if available.

Carbonation rates, diffusion coefficients, or equivalent parameters should be derived from site-specific measurements, and if not available, from peer-reviewed literature, recognized national/international standards, or industry reports. The project proponent must justify the selected source of data.

All assumptions, parameter values, and boundary conditions must be transparently documented in the project documents.

Where feasible, the project proponent should validate or calibrate the model using the results of the site-specific observations or control measurements under Option 2 below.

Option 2: direct measurement of carbonation in sample concretes:

The project proponent must directly measure the change in carbonate content of representative concrete samples before and after exposure to ambient conditions during the monitoring period. The exposure period of concrete samples must be no less than 90 consecutive days and may be extended up to the full monitoring period, where feasible. The duration must reflect project-specific factors such as feedstock composition, local climate (temperature, humidity, precipitation), and expected carbonation kinetics.

Where site-specific data or literature indicates slower carbonation rates than reference carbonation rates for comparable concrete types under typical ambient conditions reported in credible literature, the exposure period must be extended accordingly to ensure representative and statistically significant results. If samples are exposed for less than the full monitoring period, the measured uptake must be extrapolated to the entire monitoring period using validated carbonation models or correction factors supported by site-specific environmental data and peer-reviewed literature.

For this option, the baseline emissions due to passive carbon are calculated using the equation below:

$$BCS_{passive} = \sum_i Q_{Concrete,i,p,y} \times 0.44 \times (C_{carbonate,post,i,y} - C_{carbonate,prior,i,y}) \quad (9)$$

Where:

$BCS_{passive}$ = Baseline carbon sink due to passive carbonation (tCO_2)

$Q_{Concrete,i,p,y}$ = Quantity of concrete products produced by the project for product MD/C *i* in year y (tonnes).

$C_{carbonate,prior,i,y}$ = Carbonate content in the concrete sample for each MD/C *i* in year y taken prior to exposure to ambient conditions (kg $CaCO_3$/kg of concrete)

$C_{carbonate,post,i,y}$ = Carbonate content in the concrete sample for each MD/C *i* in year y taken post exposure to ambient conditions (kg$CaCO_3$/kg of concrete)

Option 3: empirical factors derived from credible/reputed sources:

The project proponent must use empirical uptake factors derived from peer-reviewed scientific literature, literature published by credible/reputed sources, and industry reports related to passive carbonation of concrete. These sources must prescribe empirical factors that are demonstrably applicable to the baseline situation including the types of cements and supplementary cementitious materials, application types, exposure conditions (including weather and climatic conditions), and product geometries or be based on conservative estimates.

9.2 Project Emissions

Project emissions are calculated using the equation below and further discussed in the sections below.

$$PE_y = PE_{cement,y} + PE_{elec,y} + PE_{ffc,y} + PE_{CO2,y} + PE_{CO2,ineligible,y} \quad (10)$$

Where:

PE_y	= Emissions from the project facility in year y (tCO_2e)
$PE_{cement,y}$	= Emissions from the amount of cement used at the project facility in year y (tCO_2e)
$PE_{elec,y}$	= Emissions from the use of electricity at the project facility in year y (tCO_2e)
$PE_{ffc,y}$	= Emissions from the combustion of fossil fuels used at the project facility in year y (tCO_2e)
$PE_{CO2,y}$	= Emissions associated with the capture, compression and transport of CO_2 to the location where it will be sequestered in concrete in year y (tCO_2e)
$PE_{CO2,ineligible,y}$	= Amount of CO_2 -mineralized that comes from a non-eligible source of CO_2 or when CO_2 source is unknown in year y (tCO_2e)

9.2.1 Cement production

The project emissions from the amount of cement used at the project facility are calculated as follows:

$$PE_{cement,y} = \sum_i Q_{cement,i,p,y} \times EF_{cement} \times (1 - DF_{UD}) \quad (11)$$

Where:

$Q_{cement,i,p,y}$	= Quantity of Portland cement used in the project for concrete produced using a project MD/C *i* in year y (tonnes)
EF_{cement}	= Emissions factor for the Portland cement used in the project (tCO_2e/ tonne of cement).
DF_{UD}	= Discount factor for upstream displacement (determined using the analysis described in Appendix VIII)

9.2.2 Electricity use

The project emissions from the use of electricity at the project facility are calculated as follows:

$$PE_{elec,y} = Q_{elec,y} \times EF_{elec} \quad (12)$$

Where:

$Q_{elec,y}$ = Quantity of electricity from the grid in year y used by project activity in year y (MWh)[13,14]

Project proponents must use VT0011 Electricity System Emission Factors to determine EF_{elec}.

Refer to section 10.2 for the scope of the parameter $Q_{elec,y}$ and the detailed quantification and monitoring requirements.

9.2.3 Fossil fuel use

The project emissions from the incremental combustion of fossil fuels used to power the equipment needed to run the project activity are calculated as follows[15]:

$$PE_{ffc,y} = \sum_a \left(Q_{ff,a,y} \times FC_a \times EF_a\right) \quad (13)$$

Where:

$Q_{ff,a,y}$ = Incremental quantity of fossil fuel a used by project activity in year y (volume of liquid fuel, mass of solid fuel or cubic meters of natural gas)[16]

Refer to section 10.2 for the description of the scope of the parameter $Q_{ff,a,y}$ and the detailed quantification and monitoring requirements.

9.2.4 CO_2 processing and transport

The project emissions from the capture, compression and transport of CO_2 to the location where it will be sequestered in concrete must be calculated using the following equation:

$$PE_{CO2,y} = PE_{CO2,processing,y} + PE_{CO2,transport,y} \quad (14)$$

Where:

$PE_{CO2,processing,y}$ = Emissions associated with the capture, compression and processing of CO_2 in year y (tCO_2e)

$PE_{CO2,transport,y}$ = Project emissions associated with the transport of CO_2 to the project site in year y (tCO_2e)

The project proponents can use either of the following two options (as applicable) to determine project emissions from the capture, compression and transport of CO_2. For both options, the parameter $PE_{CO2,y}$ must be determined using equation (14) above.

[13] Please note that only electricity sourced from the grid and consumed for the operation of CO_2 injection equipment is eligible under this methodology.

[14] This includes the electricity used as a continuation of the baseline process (eg: steam curing) which occurs during the project scenario, albeit at a lower rate.

[15] Note that incremental means just the energy requirements required to inject the CO2 into the concrete – in other words, just the additional energy to carry out the project activity, which would not have taken place in the baseline scenario.

[16] This includes the fuel used as a continuation of the baseline process (e.g., steam curing) which occurs during the project scenario, albeit at a lower rate.

Option 1: Application of CCS+ Modules

Under this option:

- $PE_{CO2,processing,y}$ must be determined by applying the relevant provisions of the CO_2 capture modules eligible under the VCS methodology *VM0049*.
- $PE_{CO2,transport,y}$ must be determined by applying the relevant provisions of *VMD0057 CO_2 Transport for CCS Projects*.

  In cases where CO_2 transport distance data is not available, the project proponent must suitably justify non-availability (suitable documentation includes supply/transport contracts or written responses from transport contractors/suppliers to distance data sharing requests) and employ conservative alternative approaches—such as maximum plausible transport distances and validated proxy data—to estimate project emissions due to CO_2 transport.

Option 2: Use of default value

Project proponents may elect to use default values of 200 kWh/tonne of CO_2 processed[17,18] for CO_2 capture from the ethanol production process and Steam Methane Reforming (SMR) based hydrogen plant operating as a merchant plant (as a standalone plant). ￼other CO_2 capture sources/technologies (which include other types of hydrogen production, industrial flue gases and DAC), project proponents must use option 1 to determine $PE_{CO2,y}$
To convert kWh to GHG emissions, the project proponent must use the EF_{elec} at the facility where the CO_2 is being processed.

Note — This default value prescribed above does not include the transport of gaseous CO_2 via pipeline, which must be calculated in addition to this default value using equation 15 below.

For this option, the emissions associated with the capture, compression and processing of CO_2 are calculated using the equation below:

$$PE_{CO2,processing,y} = Q_{CO2,meter,s,y} \times 200 \frac{kWh}{tCO2} \times \frac{EF_{elec}}{1000} \qquad (15)$$

Where:

$Q_{CO2,meter,s,y}$	= Amount of CO_2 injected from source s in year y into the concrete production process, as determined by a flow meter (tCO_2) at the project activity location
EF_{elec}	= Emissions intensity of the electricity in year y (tCO_2/MWh)

The project emissions from the transport of CO_2 from the capture site to the project site are calculated as follows:

$$PE_{CO2,transport,y} = \sum_i \left(Q_{CO2,supplied,y,m} \times T_m \times EF_{CO2,m}\right) \qquad (16)$$

[17] https://www.frontiersin.org/journals/climate/articles/10.3389/fclim.2021.656108/full#B12

[18] https://ieaghg.org/publications/techno-economic-evaluation-of-smr-based-standalone-merchant-hydrogen-plant-with-ccs/

Where:

$PE_{CO2,transport,y}$ = Project emissions associated with the transport of CO_2 to the project site in year y (tCO_2e)

$Q_{CO2,supplied,y,m}$ = Amount of CO_2 procured in year y and brought to the project activity site by mode *m* (tCO_2)

T_m = km that CO_2 is transported to reach the point of use in year y by mode *m* (km)

$EF_{CO2,m}$ = CO_2 emission factor for mode *m* (barge, rail, or truck), (tCO_2/tonne-km). *See Table 3 below*

Note that the parameter $Q_{CO2,supplied,y,m}$ must be measured when Option 1 is used to determine $BE_{CO2,cap}$. Because this option employs carbon content testing (and not metering to determine the quantity of CO_2), data from the supplier is required. For projects that apply Option 2, which measures CO_2 through a meter, the parameter $Q_{CO2,supplied,y,m}$ may be substituted by $Q_{CO2,meter,s,y,}$

Modal Transport of CO_2 and other materials/inputs: CO_2 may be transported via railway, truck, etc., from the point of capture to the project activity site. The quantity of material in tonnes would be shipped a certain number of km and multiplied together to determine the number of tonne-km.

Table 2. Quantifying GHG Emissions Associated with Transport*

Transport Mode	Emissions in metric tCO_2/tonne-km[19]
Rail	0.0000372
Waterborne	0.0000708
Truck	0.0003701
Air	0.0022369

**Note: these factors may be updated by US EPA, and project proponents have the option of using updated figures. The figures above have been converted from the original EPA table to metric tonnes from short tons.*

9.2.5 Ineligible CO_2 sources

When the source of CO_2 is not known, the project proponent must assume it comes from an ineligible source, such as a geologic reservoir. The CO_2 that is mineralized, i.e., absorbed into the cement, would not be eligible for a VCU and count as a project emission. When the CO_2 sources are known and eligible, this value would be 0.

$$PE_{CO2,ineligible,y} = Q_{CO2,meter,ineligible,y} \quad (17)$$

[19] https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf

Where:

$Q_{CO2,meter,ineligible,y}$ = Amount of CO_2 injected from source ineligible or unknown in year y into the concrete production process (tCO_2)

9.3 Leakage Emissions

No sources of leakage have been identified for this project activity.

9.4 Net Reductions and Removals

Net GHG emission reductions are calculated as follows:

$$ER_y = \left[[BE_{ER,y} - (BCS_{passive} + PE_y) \left(\frac{BE_{ER,y}}{BE_{ER,y} + CR_{CO2,cap,y}} \right) \right] (1 - DF_{UNC,ER}) \quad (18)$$

Where:

ER_y = Net GHG emissions reductions in year y (tCO_2e)

$BE_{ER,y}$ = Baseline emissions in the baseline associated with reductions in year y (tCO_2e)

$BCS_{passive}$ = Baseline emissions due to passive carbonation

$CR_{CO2,cap,y}$ = Carbon dioxide removals from the capture of CO_2 (tCO_2e) in year y

PE_y = Emissions from the project facility in year y (tCO_2e)

$DF_{UNC,ER}$ = Discount factor for uncertainty of net GHG emissions reductions

Net carbon dioxide removals are calculated as follows:

$$CR_y = \left[CR_{CO2,cap,y} - (BCS_{passive} + PE_y) \left(\frac{CR_{CO2,cap,y}}{BE_{ER,y} + CR_{CO2,cap,y}} \right) \right] (1 - DF_{UNC,CR}) \quad (19)$$

Where:

CR_y = Net carbon dioxide removals in year y (tCO_2e)

$BE_{ER,y}$ = Baseline emissions in the baseline associated with reductions in year y (tCO_2e)

$BCS_{passive}$ = Baseline emissions due to passive carbonation

$CR_{CO2,cap,y}$ = Carbon dioxide removals from the capture of CO_2 (tCO_2e) in year y

PE_y = Emissions from the project facility in year y (tCO_2e)

$DF_{UNC,CR}$ = Discount factor for uncertainty of carbon dioxide removals

9.5 Uncertainty Assessment

Project proponents must identify, quantify, and conservatively address all material sources of uncertainty in the estimation of net GHG emission reductions and carbon dioxide removals in the project description. The uncertainty assessment must follow a stepwise approach described below.

Step 1: Identification of key sources of uncertainty

Project proponents must identify all material input parameters that contribute the most to the overall uncertainty. A sensitivity analysis may be used combined with the assessment of the type of data and sources. Guidance on different data types is provided as follows:

a) **Default factors uncertainty:** Variability in published default factors, like the emission factors for Portland cement production, fossil fuels or transportation, including factors sourced from IPCC, national inventories, or peer-reviewed literature. Project proponents must cite the specific version and date of each factor. When the conservative end of any published range is used, the uncertainty of the parameter may be dismissed.

b) **Measured parameters uncertainty:** Measurement error in process instrumentation such as weighing scales (like for parameters $Q_{cement,i,p,y}$ and $Q_{ff,a,y}$), electricity meters, and flow meters used during production. This data type is generally very precise but low-technology facilities with limited instrumentation must apply conservative adjustments to account for higher measurement uncertainty.

c) **Models/Laboratory analysis uncertainty:** This includes uncertainty in the models used as well as inter-laboratory and intra-test variability in the determination of parameters like baseline emissions and carbon dioxide removals from CO_2 capture ($BE_{CO2,cap}$ and $CR_{CO2,cap}$) and baseline cement quantity ($Q_{cement,i,b,y}$) respectively, which have a strong bearing on project impacts. Alternatively, the lowest credible values of such parameters may be used, consistent with the principle of conservativeness and further excluded from uncertainty propagation.

d) **Unknown uncertainties:** Residual uncertainty not captured by the above categories must be addressed using conservative, scientifically defensible parameter ranges justified with literature, expert judgment, or Verra-approved assumptions. For instance, where scientific literature proposes a range of values for the parameter $BCS_{passive}$, the lower bound must be applied.

Where conservative parameter selection is applied, this must be transparently documented and excluded in the propagation of uncertainty to avoid double counting of conservativeness.

Step 2: Estimation and propagation of uncertainty

For each material parameter, the project proponent must include in the project description the point estimate, the lower and upper limit of the 90% confidence interval (or provide the percentage relative to the point estimate), and the basis for those bounds (instrument specs, calibration records, laboratory certificates, or published literature). Combined uncertainty must then be assessed using one of the following methods:

1) Linear error propagation[20]; or
2) Monte Carlo simulation

The project proponent must justify the choice of the method employed. For the methods mentioned above, the combined uncertainty must be expressed as the half-width of the 90% confidence interval as a percentage of the point estimate of net annual GHG benefits, calculated separately for the constituents of the GHG emission reduction and carbon dioxide removal.

Step 3: Treatment and deduction

The combined uncertainty must be translated into a discount factor in the project description and applied in Equations 14 and 15, according to the following equation.

$$DF_{UNC,ER}, DF_{UNC,CR} = U \times \left(\frac{t_{\alpha\ 33\%}}{t_{\alpha\ 10\%}}\right) \quad (20)$$

Where:

U = Combined uncertainty represented as Half-width of the 90% confidence interval as a percentage of the mean estimate (%) for parameters relevant to emission reductions (ER) and carbon dioxide removals (CR) respectively.

$t_{\alpha\ 10\%}$ = t-value for the two-sided 90% confidence interval, approximately 1.6449 (absolute value; dimensionless)

$t_{\alpha\ 33\%}$ = t-value for a one-sided 66.67% confidence interval, approximately 0.4307 (absolute value; dimensionless)

The uncertainty must be determined separately for parameters contributing to emission reductions and carbon dioxide removals when claimed separately in the final credit issuance.

10 MONITORING

10.1 Data and Parameters Available at Validation

Data / Parameter	DF_{UD}
Data unit	Dimensionless
Description	Discount factor for upstream displacement
Equations	2, 11

[20] Approach 1 in 2019 Refinement to the 2006 IPCC, Vol. 1, Ch. 3. (first order Taylor series / variance method / root-sum-of-squares for independent parameters)

Source of data	*See Appendix V – Cement Displacement Market Analysis*
Value applied	0.065
Justification of choice of data or description of measurement methods and procedures applied	The default value of 6.5% for upstream displacement is applied based on the cement displacement market analysis carried out and further described in Appendix V.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	EF_{cement}
Data unit	tCO_2e/t of cement
Description	Emission factor for the production of Portland cement
Equations	2, 11, 21
Source of data	Project proponent and/or cement production facilities
Value applied	Project-specific
Justification of choice of data or description of measurement methods and procedures applied	One of the following options must be used: **Option 1. Plant-Specific Data:** Where the source of the cement used both in the baseline and project scenario is known, and the concrete production is co-located at the cement production facility (e.g., when the cement and concrete production is by the same company), plant-specific factors must be used. The information from the cement plant(s) must include total energy and fuel use (including electricity usage, on-site mobile fuel usage and regional electricity emission factors) and the project proponent must calculate the total GHG emissions per unit of cement produced. Plant-specific data on fuel use, electricity use and cement production must be provided by the cement producer, and the producer must be available to provide actual data and evidence (utility bills, etc.) directly to the validation/verification body, if requested. **Option 2. Environmental Product Declarations (EPDs):** Where Option 1 is not applicable, project proponents may use environmental product declarations (EPDs) that provide key information on GHG intensity of cement. When different cement sources are mixed together in a single truckload of concrete, a weighted average must

	be calculated based on the proportion of each cement source used. Studies indicate that raw material extraction contributes to ~11–12%[21,22] of cradle-to-gate emissions. Hence, the cement emission factor must be decreased by 11.2% when this option is used in the baseline to be conservative. **Option 3. Use of Regional Factors:** Where EPDs are not available, or where the project activity is in a country where the data needed for Options 1 and 2 are not available, the project proponent must use regional factors using the procedure described in Appendix III. The Appendix also contains the parameters needed to calculate regional factors.
Purpose of Data	Calculation of baseline and project emissions
Comments	EPDs cover the full cradle-to-gate cement life cycle, making them non-comparable with plant-specific or regional emission factors, which exclude upstream impacts.

Data / Parameter	$EF_{Clinker}$
Data unit	tCO_2e/t
Description	Emission factor for the production of clinker
Equations	21
Source of data	World Business Council for Sustainable Development's the Cement Sustainability Initiative report, *Cement Industry Energy and CO_2 Performance "Getting the Numbers Right"*.
Value applied	See Table A.1 in Appendix III.
Justification of choice of data or description of measurement methods and procedures applied	For use with Option 3 above, determining the emission factor of Portland cement using regional factors.
Purpose of Data	Calculation of baseline and project emissions, because the use of cement occurs in both the baseline and project scenarios.
Comments	N/A

[21] Improving the CO2 Performance of Cement, Part I: Utilizing Life-Cycle Assessment and Key Performance Indicators to Assess Development Within the Cement Industry", Roozbeh Feiz, et. al., Linkoping University Post Print.

[22] A Life-Cycle Assessment of Portland Cement Manufacturing: Comparing the Traditional Process with Alternative Technologies", Deborah Huntzinger, et. al. Journal of Cleaner Production, 2009.

Data / Parameter	$M_{Clinker}/M_{Cement}$
Data unit	Ratio
Description	Clinker to cement ratio
Equations	21
Source of data	World Business Council for Sustainable Development's the Cement Sustainability Initiative report, *Cement Industry Energy and CO_2 Performance: "Getting the Numbers Right"*.
Value applied	See Table A2 in Appendix III.
Justification of choice of data or description of measurement methods and procedures applied	For use with Option 3 above, determining the emission factor of cement using regional factors.
Purpose of Data	Calculation of baseline and project emissions, because the use of cement occurs in both the baseline and project scenarios.
Comments	N/A

Data / Parameter	$FC_{,a}$
Data unit	TJ
Description	Energy content per unit of fuel type *a*.
Equations	5, 13
Source of data	IPCC
Value applied	Will vary depending on fuel
Justification of choice of data or description of measurement methods and procedures applied	The *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed.
Purpose of Data	Calculation of project emissions
Comments	The latest and the most relevant version of the IPCC Guidelines must be used.

Data / Parameter	EF_a

Data unit	tCO_2e/TJ
Description	Emission factor of fuel type *a*.
Equations	5, 13
Source of data	IPCC
Value applied	Will vary depending on fuel
Justification of choice of data or description of measurement methods and procedures applied	The *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed.
Purpose of Data	Calculation of project emissions.
Comments	The latest and the most relevant version of the IPCC Guidelines must be used

Data / Parameter	$EF_{CO2,m}$
Data unit	Tonne of CO_2 per tonne-km
Description	Emission factor for mode of transport.
Equations	16
Source of data	Table in Section 8 from EPA Center for Corporate Climate Leadership (2020)
Value applied	See Table 2, will vary depending on the fuel
Justification of choice of data or description of measurement methods and procedures applied	This is an accurate and simplified default for considering the emission factors of different modes of transport.
Purpose of Data	Calculation of project emissions.
Comments	N/A

Data / Parameter	$Q_{Concrete,i,b,x}$
Data unit	tonnes concrete
Description	Quantity of concrete produced for the baseline MD/C which project MD/C i is replacing

Equations	5
Source of data	Verifiable production data, such as batch records, production logs, delivery notes, invoices, or automated plant control system data, and shall clearly link the produced concrete volumes to the specific project design mix i.
Value applied	Will vary depending on project concrete design mix
Justification of choice of data or description of measurement methods and procedures applied	Production quantities are measured using standard commercial and operational records generated as part of routine concrete production. Where, applicable, the project must apply standard procedures to weigh concrete product, which is standard industry practice for all concrete suppliers.
Purpose of Data	Calculation of baseline emissions.
Comments	Standard procedures to ensure accuracy of weighing methods, including manufacturer-recommended calibrations for measuring devices, which would be standard industry practice for all concrete suppliers. Project proponents will keep clear records of all concrete produced and used at construction sites, which can be presented to the validation/verification body. Only concrete volumes attributable to the replacement of the reference baseline mix shall be included in the assessment.

Data / Parameter	$Q_{ffSC,a,X}$
Data unit	volume of liquid fuel, mass of solid fuel or cubic meters of natural gas
Description	Quantity of fossil fuel a used for steam curing for MD/C i in year x
Equations	5
Source of data	See relevant procedures for parameter $Q_{ff,a,y}$
Value applied	Will vary depending on baseline steam curing requirements
Justification of choice of data or description of measurement methods and procedures applied	See relevant procedures for parameter $Q_{ff,a,y}$
Purpose of Data	Calculation of baseline emissions.
Comments	See relevant procedures for parameter $Q_{ff,a,y}$

Data / Parameter	$Q_{elec,x}$

Data unit	MWh
Description	Quantity of electricity used for steam curing for MD/C *i* in year x
Equations	5
Source of data	See data monitoring procedures for parameter $Q_{elec,y}$
Value applied	Will vary depending on baseline steam curing requirements
Justification of choice of data or description of measurement methods and procedures applied	See data monitoring procedures for parameter $Q_{elec,y}$
Purpose of Data	Calculation of baseline emissions.
Comments	See data monitoring procedures for parameter $Q_{elec,y}$

Note: All defaults/parameters have been reviewed and none are likely to change significantly in the future.

10.2 Data and Parameters Monitored

Data / Parameter:	$Q_{cement,i,p,y}$
Data unit:	Tonne
Description:	Quantity of Portland cement used in the project for concrete produced using a project MD/C i in year y
Equations	2, 3, 8(a), 8(b), 11
Source of data:	Project proponent
Description of measurement methods and procedures to be applied:	Use standard weighing procedures to determine mass of cement used to produce ready-mix or pre-cast concrete products over the course of year y.
Frequency of monitoring/recording:	Measured continuously, recorded at least monthly
QA/QC procedures to be applied:	Any equipment, such as scales, should be calibrated according to the manufacturer's specifications, with calibration certificates available for verification.
Purpose of data:	Calculation of baseline and project emissions.

Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$Q_{Cement,b,i,test\ n}$
Data unit:	Tonne
Description:	Quantity of Portland cement used to prepare baseline compressive strength test specimen n for concrete produced using a mix design that results in a concrete of equivalent compressive strength to project mix design *i.*
Equations	3
Source of data:	Project proponent
Description of measurement methods and procedures to be applied:	See Appendix II
Frequency of monitoring/recording:	Once per project crediting period for each mix design. If project proponents have a large number of mix designs at a given project site or across a portfolio of locations, testing can be performed on the company's mix designs that comprise at least 50% of production volume. In cases where additional mix designs or changes in existing mix designs mean that the 50% production volume threshold changes, then further testing will occur for all project instances. Any new mix designs added during the project crediting period will also be tested.
QA/QC procedures to be applied:	See Appendix II
Purpose of data:	To calculate how much cement would have been used in the absence of the project by assessing the amount of cement in baseline concrete is required to obtain the equivalent or better compressive strength as the project concrete. This is used to calculate baseline emissions.
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$Q_{Cement,p,i,test\ n}$
Data unit:	Tonne

Description:	Quantity of Portland cement used to prepare project compressive strength test specimen n for concrete produced using project mix design *i*
Equations	3
Source of data:	Project proponent
Description of measurement methods and procedures to be applied:	See Appendix II
Frequency of monitoring/recording:	Once per project crediting period for a given corporation's mix designs that comprise 50% or more of production volume. In cases where additional mix designs or changes in existing mix designs mean that the 50% production volume threshold changes, then further testing will occur for all project instances. Any new mix designs added during the project crediting period will also be tested.
QA/QC procedures to be applied:	See Appendix II
Purpose of data:	Calculation of baseline emissions by comparing the amount of cement in the project activity concrete and the amount of cement that would be required in the baseline concrete.
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$Q_{CO2,meter,s,y}$
Data unit:	Tonne
Description:	Amount of CO_2 injected from source s in year *y* to produce concrete and pre-cast products, as determined by a flow meter.
Equations	8(a), 8(b), 15
Source of data:	Measurements at project facility and information from CO_2 providers.
Description of measurement methods and procedures to be applied:	Use calibrated flow meters. The amount of CO_2 injected in concrete/concrete products and component materials must be metered before entering the production process and must be subject to standard calibration and QA/QC procedures. Note that the monitoring will take place at the point of CO_2 injection in concrete/concrete products and materials. This could be part of the concrete batching and production itself or at the process water vessel or the point where the aggregates are being produced.

	Project proponents must specify in the project description where the CO_2 injection and monitoring will take place. Project proponents must track the source of CO_2 when it goes into the concrete production process. A clear record must be provided to the VVB, such as sales records or receipts from the CO_2 supplier. For removals, the project proponent must provide clear and transparent evidence that the source is a DAC or biogenic CO_2 facility. If the process involves only, sourcing information would not be required; however a description of the process and sample testing (as per Option 1 in Component 2 as described in Section 9.1) must be provided to the VVB.
Frequency of monitoring/recording:	Data must be monitored continuously and recorded at least on a daily basis.
QA/QC procedures to be applied:	Calibration of meters must be conducted according to the equipment manufacturer's specifications. Records, sales receipts must be provided from CO_2 supplier, for example, the market CO_2 company or the DAC supplier. If a source cannot be determined precisely, it will be assumed to be ineligible.
Purpose of data:	Calculation of baseline emissions when measuring how much CO_2 was injected into the concrete and for project emissions when determining emissions from processing. The source is used determine whether CO_2 source qualifies as a carbon removal or an emission reduction under VCS guidelines
Calculation method:	N/A
Comments:	Project proponents may use a mass-flow meter to measure mass of CO_2. Proponents may also use a volumetric meter to determine cubic feet or meters of gas collected, but this number must be converted to mass by multiplying the measured volume by the density of CO_2 at normal temperature and pressure (20 degrees C at 1 atmosphere). The density of CO_2 at NTP is 1.842 kg/m^3.[23] In the project proponent's monitoring plan, each unit of quantification (e.g.: per batch or mass of concrete produced and reported) may indicate the source of CO_2 so when all units are summed together, it is clear how much CO_2 mineralized comes from a source that would qualify as a removal and how much CO_2 would be considered an emission reduction.

Data / Parameter:	$Q_{CO2,meter,ineligible,y}$
Data unit:	tCO_2

[23] www.engineeringtoolbox.com/gas-density-d_158.html

Description:	Amount of CO_2 injected from source ineligible or unknown in year y into the concrete production process
Equations	17
Source of data:	Measurements at project facility
Description of measurement methods and procedures to be applied:	If the source of CO_2 cannot be determined precisely in line with the relevant requirements of the parameter $Q_{CO2,meter,s,y}$, it will be assumed to be ineligible. The amount of CO_2 must be metered using calibrated flow meters before entering the production process and must be subject to standard calibration and QA/QC procedures. Note that the monitoring will take place at the point of CO_2 injection. Project proponents must specify in the project description where the CO_2 injection and monitoring will take place. Project proponents must track the source of CO_2 when it goes into the concrete production process and must provide a description of the process and sample testing (as per Option 1 in Component 2 as described in Section 9.1).
Frequency of monitoring/recording:	Data must be monitored continuously and recorded at least on a daily basis.
QA/QC procedures to be applied:	Calibration of meters must be conducted according to the equipment manufacturer's specifications.
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Project proponents may use a mass-flow meter to measure mass of CO_2. Proponents may also use a volumetric meter to determine cubic feet or meters of gas collected, but this number must be converted to mass by multiplying the measured volume by the density of CO_2 at normal temperature and pressure (20 degrees C at 1 atmosphere). The density of CO_2 at NTP is 1.842 kg/m^3.[24]

Data / Parameter:	$CO2_{mineralized,i,y}$
Data unit:	tCO_2/kg of concrete in the sample

[24] www.engineeringtoolbox.com/gas-density-d_158.html

Description:	Quantity of CO_2 mineralized per unit of concrete of MD/C i in year y
Equations	6a and 6b
Source of data:	Project proponent
Description of measurement methods and procedures to be applied:	The project proponent must identify all concrete mix designs produced under the project activity during the year y and must record the total quantity of concrete produced for each mix design. Hardened concrete samples representative of each mix design must be collected after curing and completion of the CO_2 mineralization process relevant to the project activity. For each concrete mix design i, the mineralized CO_2 content per unit of concrete must be determined using direct measurement methods capable of quantifying carbonate-bound CO_2. Only the net carbonate-bound CO_2 attributable to the utilization of CO_2 under the project activity must be considered mineralized CO_2 for the purposes of this methodology. One of the two measurement methods must be followed: 1. **Thermogravimetric Analysis (TGA)** TGA is an analytical technique used to quantify CO_2 chemically bound in hardened concrete by measuring mass changes in a prepared sample under controlled heating conditions. TGA must be conducted within defined temperature ranges used to identify mass loss attributable to carbonate decomposition in accordance with generally accepted thermal analysis standards, such as ASTM E1131-20 or equivalent national or international standards. 2. **Acid Digestion Methods** Acid Digestion is an analytical method used to quantify carbonate-bound CO_2 in hardened concrete by chemically dissolving specific carbonate phases via treatment with a strong acid. Acid digestion methods must involve controlled dissolution of carbonate minerals using acid and quantification of the released CO_2, consistent with established cement and concrete chemical analysis procedures, such as ASTM C114-24 or equivalent national or international standards.
Frequency of monitoring/recording:	Once per design mix. If project proponents have a large number of design mixes at a given project site or across a portfolio of locations, testing can be performed once per crediting period on a company's mix designs that comprise at least 50% of production volume.

QA/QC procedures to be applied:	Any equipment, such as scales, should be calibrated according to the manufacturer's specifications, with calibration certificates available for verification.
Purpose of data:	Calculation of baseline emissions.
Calculation method:	See Section 9.1.2
Comments:	See Section 9.1.2

Data / Parameter:	$C_{baseline\ sample,i,y}$
Data unit:	tC/kg of concrete
Description:	Carbon content of baseline concrete or pre-cast product as measured in test samples.
Equations	7a, 7b
Source of data:	Project proponent tests (see Appendix IV)
Description of measurement methods and procedures to be applied:	See Appendix IV
Frequency of monitoring/recording:	Once per design mix. If project proponents have a large number of design mixes at a given project site or across a portfolio of locations, testing can be performed once per crediting period on a company's mix designs that comprise at least 50% of production volume.
QA/QC procedures to be applied:	For all concrete/concrete products and component materials, the project proponent must conduct a minimum of three decomposition tests for the baseline products. For relevant project mix design – for both pre- and post-project concrete – the project proponent will conduct a minimum of three decomposition tests. The three tests must reveal a carbon content that is within 10% of each other, or the project proponent should continue testing the individual batch until three results within 10% of each other are obtained. The actual test result used in the calculations of baseline emissions must be the lowest of the three samples for the post-project concrete and the highest of the three results for the pre-project concrete – thus ensuring the most conservative result. All test procedures and results will be made available to the validation/verification body.
Purpose of data:	Calculation of baseline emissions.
Calculation method:	N/A

Comments:	See Appendix IV

Data / Parameter:	sample,i,y
Data unit:	tC/kg of concrete
Description:	Carbon content of project concrete or pre-cast product as measured in test samples
Equations	7a, 7b
Source of data:	Project proponent tests (see Appendix IV)
Description of measurement methods and procedures to be applied:	See Appendix IV
Frequency of monitoring/recording:	Once per design mix. If project proponents have a large number of design mixes at a given project site or across a portfolio of locations, testing can be performed once per crediting period on a company's mix designs that comprise 50% or more of production volume.
QA/QC procedures to be applied:	For all concrete/concrete products and component materials, the project proponent must conduct a minimum of three decomposition tests for the project products/materials. In the case of ready-mix and pre-cast concrete products, this testing will be done for each design mix. For relevant project mix design – for both pre- and post-project concrete – the project proponent must conduct a minimum of three decomposition tests. The three tests must reveal a carbon content that is within 10% of each other, or the project proponent should continue testing until three results within 10% of each other are obtained. The actual test result used in the calculations of baseline emissions must be the lowest of the three samples for the post-project concrete and highest of the three results for the pre-project concrete – thus ensuring the most conservative result. All test procedures and results will be made available to the validation/verification body.
Purpose of data:	Calculation of baseline emissions
Calculation method:	N/A

Comments:	See Appendix IV

Data / Parameter:	$Q_{Concrete,i,p,y}$
Data unit:	Tonne
Description:	Quantity of concrete products produced by the project for project MD/C *i* in year y.
Equations	6a, 6b, 7a, 7b, 9
Source of data:	Project proponent (see Section 9.1)
Description of measurement methods and procedures to be applied:	Standard procedures to weigh concrete product, which is standard industry practice for all concrete suppliers.
Frequency of monitoring/recording:	Measured continuously, recorded at least daily
QA/QC procedures to be applied:	Standard procedures to ensure accuracy of weighing methods, including manufacturer-recommended calibrations for measuring devices, which would be standard industry practice for all concrete suppliers. Project proponents will keep clear records of all concrete produced and used at construction sites, which can be presented to the validation/verification body.
Purpose of data:	Calculation of baseline emissions.
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$C_{carbonate,prior,i,y}$
Data unit:	kg $CaCO_3$/kg of concrete
Description:	Carbonate content in the concrete sample for each MD/C *i* in year y taken prior to exposure to ambient conditions
Equations	9
Source of data:	Project proponent
Description of measurement methods	Employ measurement techniques such as thermogravimetric analysis (TGA), acid digestion with CO_2 quantification, or X-ray diffraction (XRD) with Rietveld refinement. The chosen technique

and procedures to be applied:	must follow recognized national or international standards (ASTM, ISO, EN, or RILEM) for sample preparation, testing, calculation and reporting. The difference in carbonate content between pre- and post-exposure samples must be converted to CO_2 mass using appropriate stoichiometric factor of 0.44 ($CaCO_3$ contains 44% CO_2 by mass) and scaled to the total exposed feedstock mass.
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	Any equipment, such as scales, should be calibrated according to the manufacturer's specifications, with calibration certificates available for verification. All calculations must apply appropriate stoichiometric factors and undergo independent cross-checks. All test procedures and results will be made available to the validation/verification body.
Purpose of data:	Calculation of baseline emissions.
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$C_{carbonate,post,i,y}$
Data unit:	kg $CaCO_3$/kg of concrete
Description:	Carbonate content in the concrete sample for each MD/C *i* in year y taken post exposure to ambient conditions
Equations	9
Source of data:	Project proponent
Description of measurement methods and procedures to be applied:	Employ measurement techniques such as thermogravimetric analysis (TGA), acid digestion with CO_2 quantification, or X-ray diffraction (XRD) with Rietveld refinement. The chosen technique must follow recognized national or international standards (ASTM, ISO, EN, or RILEM) for sample preparation, testing, calculation and reporting. The difference in carbonate content between pre- and post-exposure samples must be converted to CO_2 mass using appropriate stoichiometric factor of 0.44 ($CaCO_3$ contains 44% CO_2 by mass) and scaled to the total exposed feedstock mass.

Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	Carbonate content is determined after the defined ambient exposure period, ensuring samples reflect actual field conditions. Post-exposure samples must be collected carefully to avoid loss of surface material or contamination from soil, dust, or standing water. Moisture content must be stabilized before testing, as exposure conditions may introduce variable humidity that affects analytical accuracy. Additional QA/QC steps include documenting environmental conditions during exposure (temperature, humidity, precipitation) and verifying that any observed increase in carbonate content aligns with expected carbonation kinetics. Any equipment, such as scales, should be calibrated according to the manufacturer's specifications, with calibration certificates available for verification. All calculations must apply appropriate stoichiometric factors and undergo independent cross-checks. All test procedures and results will be made available to the validation/verification body.
Purpose of data:	Calculation of baseline emissions.
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$Q_{elec,y}$
Data unit:	MWh
Description:	Quantity of electricity from the grid in year y used by project activity in year y (MWh)
Equations	12
Source of data:	Measurements at project facility or electric utility bills; and from CO_2 supplier.
Description of measurement methods and procedures to be applied:	This parameter $Q_{elec,y}$ includes electricity consumption from the following activities (inter alia), as applicable: • CO_2 injection into concrete/concrete products and operation of related equipment/infrastructure • Processing of RCA • Treatment and pumping of process water • Operation of other equipment/facilities in the project activity not covered above

	Proponents must use calibrated electricity meters for measuring this parameter. Calibration must be conducted according to the equipment manufacturer's specifications. Alternatively, utility billing data can be used.
Frequency of monitoring/recording:	Data must be monitored continuously and recorded on at least a daily basis. If utility data is used, monthly bills are acceptable.
QA/QC procedures to be applied:	The consistency of metered electricity generation should be cross-checked with receipts from electricity purchases where applicable.
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	In addition, this includes the electricity used as a continuation of steam curing (if any) which occurs during the project scenario, albeit at a lower rate. In cases where the individual piece of equipment used does not have a separate meter to calculate electricity use from just that device – and where utility bills cannot distinguish between the use of that equipment and the rest of the facility – project proponents may use sampled data. This option may be used if the electricity consumption is minor, and it is impractical to have direct measurements. A data logger or other similar method can be used to sample the energy usage (kWh, therms, etc.) over a period of time, along with the separate flow meter to determine the quantity of CO_2 introduced. This will provide an estimated level of energy used per unit of CO_2 introduced. This figure can be multiplied by the amount of CO_2 to get total energy used during a monitoring period. If a project proponent uses this approach, the PP should develop a representative sample of direct measurements of kWh per kg of CO_2 injected. A similar process would need to be done with the steam curing device. For sampling, the energy consumption and quantity of CO_2 injected must be measured during a representative time period to estimate the specific energy use per amount of CO_2 injected: • Energy consumption: measured with a data logger or other similar method • Amount of CO_2 injected: measured with a flow meter This specific energy consumption must be multiplied by the total amount of CO_2 injected during the monitoring period to obtain the total energy consumption.

	If the sampling approach is applied, project proponents must take multiple readings throughout the year at multiple facilities (relevant for grouped projects) to obtain a representative sample. If different temperatures affect power requirements, samples should be representative across time of day and season. If utilization level, age of equipment, etc. affect power requirements, samples should be representative across different equipment ages and average utilization levels. The most conservative sample (e.g., highest specific energy consumption) must be used to determine project emissions.

Data / Parameter:	EF_{elec}
Data unit:	tCO_2/MWh
Description:	Emission intensity of electricity used in year y
Equations	5, 12, 15
Source of data:	*VCS Tool VT0011 - Electricity System Emission Factors*
Description of measurement methods and procedures to be applied:	Project proponents must use the *VCS Tool VT0011 - Electricity System Emission Factors* to calculate this parameter.
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	As per the latest version of the *VCS Tool VT0011 - Electricity System Emission Factors*, if used
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$Q_{ff,a,y}$
Data unit:	Gallons (oil fuels), meters^3 (natural gas), tonnes (solid fuels)
Description:	Incremental quantity of fossil fuel *a* used by project activityin year y
Equations	13
Source of data:	Measurements at project facility.

Description of measurement methods and procedures to be applied:	This parameter includes fossil fuel consumption from the following activities (inter alia), as applicable: • CO_2 injection into concrete/concrete products and operation of related equipment/infrastructure • Project steam curing • Processing of RCA • Treatment and pumping of process water • Operation of other equipment/facilities in the project activity not covered above Proponents must use calibrated flow or gas meters for measuring this parameter, or alternatively vendor invoices/receipts. Calibration must be conducted according to the equipment manufacturer's specifications. Use calibrated scales for solid fuels.
Frequency of monitoring/recording:	Data must be monitored continuously and recorded on at least monthly basis.
QA/QC procedures to be applied:	The consistency of metered fuel use should be cross-checked with receipts from fuel suppliers where applicable.
Purpose of data:	Calculation of project emissions.
Calculation method:	N/A
Comments:	In cases where the individual piece of equipment used to inject CO_2 does not have a separate meter to calculate fossil fuel use from just that device – and where utility bills cannot distinguish between the use of that equipment and the rest of the facility – project proponents may use sampled data. This option may be used if the fossil fuel consumption is minor. For sampling, the fuel consumption and quantity of CO_2 injected must be measured during a representative time period to estimate the specific energy use per amount of CO_2 injected: • <u>Fuel consumption</u>: measured with a data logger or other similar method • <u>Amount of CO_2 injected</u>: measured with a flow meter This specific fuel consumption must be multiplied by the total amount of CO_2 injected during the monitoring period to obtain the total energy consumption. If the sampling approach is applied, project proponents must take multiple readings throughout the year at multiple facilities to obtain a representative sample. In these cases, the project proponent will take sample data from the CO_2 introduction device (or a select number of CO_2 introduction

	devices if multiple facilities are within the project boundary) or the steam curing device. Project proponents must also follow the procedures laid out in the "Comments" section of the parameter $Q_{elec,y}$ above. The most conservative sample (e.g., highest specific energy consumption) must be used to determine project emissions.

Data / Parameter:	$Q_{CO2,supplied,y,m}$
Data unit:	Tonne
Description:	Amount of CO_2 procured in year y and brought to the project activity site by mode m.
Equations	16
Source of data:	Purchase and sales records from the project proponent or from CO_2 supplier.
Description of measurement methods and procedures to be applied:	Use of sales records/receipts from CO_2 supplier
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	N/A
Purpose of data:	Determination of project emissions associated with transporting CO_2 to project site.
Calculation method:	N/A

Comments:	Note that the variable $Q_{CO2,supplied,y,m}$ is distinct from $Q_{CO2,meter,s,y}$. The CO_2 *supplied* to the site is necessary to determine the emissions associated with transporting the gas, and it is possible that CO_2 is brought by multiple transportation modes. This parameter measures that by determining the amount of CO_2 supplied by each mode m. Project proponents should keep accurate records of all CO_2 supplied by different transportation modes. It is logical to assume that all CO_2 from the supplier(s) will equal $Q_{CO2,meter,s,y}$. However, that cannot necessarily be guaranteed. If some CO_2 supplied is not actually injected, then this parameter is conservative because summing $Q_{CO2,supplied,y,m}$ for each mode will always be equal to or greater than $Q_{CO2,meter,y}$. So, if anything, this parameter will overcount project emissions. Project proponents must demonstrate that the captured CO_2 is coming from a source where the gas would – in the absence of the project activity – be emitted. The project proponent should obtain an attestation from the supplier of the CO_2 or provide other evidence that the captured CO_2 would not have otherwise been sequestered (e.g., CO_2 coming from a location supplying an Enhanced Oil Recovery project).

Data / Parameter:	T_m
Data unit:	km
Description:	km that CO_2 is transported to reach the point of use in year y by mode m
Equations	16
Source of data:	CO_2 supplier, transporter and project proponent.
Description of measurement methods and procedures to be applied:	The company supplying or transporting the CO_2 should provide data to project proponent about total number of tonnes delivered and total km driven/shipped by barge/ moved by train from the CO_2 supply point to the final destination (and which mode(s) were used – rail, truck, barge, etc.).
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Records from CO_2 supplier or transporter should be available at project verification.
Purpose of data:	Calculation of project emissions.
Calculation method:	N/A

Comments:	N/A

10.3 Description of the Monitoring Plan

The project will monitor the data parameters identified in Section 10.2, including the following:

1) Quantities of cement used for the concrete supplied both in the baseline and project scenarios (scales or screws conveyor scale can be used to measure weight of material, as well as invoices and other records to indicate product sales – all of which can generate records for validation/ verification body to review to check the integrity of the data).
2) Quantity and source of CO_2 supplied, transported and injected into the concrete (determined by meter, and meter data, along with calibration measurements can be provided to the validation/verification body).
3) Quantity of CO_2 embedded into the concrete (described earlier).
4) Quantity of electricity and fuel used as part of the concrete production process at the project facility (utility bills, invoices from fuel suppliers, flow meters and electricity meters can all provide records for verification).
5) Ensuring that the concrete products produced by the project activity have equivalent or better performance (e.g., compressive strength and code compliance) as the baseline concrete products that would have otherwise been produced and used in the absence of the project.
6) Production and sale of concrete produced by the project activity. This will be monitored through industry-standard weighing techniques. Producer attestation can also be provided to ensure the concrete is entering the market and thus displacing concrete.

Where the project uses MD/Cs, the Project Description must:

1) define the criteria for MD/Cs,
2) define a representative mix design for each MD/C, and
3) provide a volume-weighted rationale for the categorization chosen.

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions relevant for the project and baseline scenarios. Monitoring procedures must address the following:

- Types of data and information to be reported;
- Units of measurement;

- Origin of the data;
- Monitoring methodologies (e.g., estimation, modeling, measurement and calculation);
- Type of equipment used;
- Monitoring times and frequencies;
- Monitoring roles and responsibilities, including experience and training requirements;
- GHG information management systems, including the location, back up, and retention of stored data.

Where measurement and monitoring equipment is used, the project proponent must ensure the equipment is calibrated according to current good practice (e.g., relevant industry standards).

All data collected as part of monitoring must be archived electronically and kept at least for two years after the end of the last project crediting period. QA/QC procedures must include, but are not limited to:

- Data gathering, input and handling measures;
- Input data checked for typical errors, including inconsistent physical units, unit conversion errors;
- Typographical errors caused by data transcription from one document to another, and missing data for specific time periods or physical units;
- Input time series data checked for large unexpected variations (e.g., orders of magnitude) that could indicate input errors;
- All electronic files to use version control to ensure consistency;
- Physical protection of monitoring equipment;
- Physical protection of records of monitored data (e.g., hard copy and electronic records);
- Input data units checked and documented.

Where the project is implemented at a new concrete production facility, rather than an existing facility (i.e., where baseline concrete was not previously produced at the site), the Proponent must ensure that baseline MD/C samples are produced by a laboratory that is either accredited by a credible and relevant authority in the host country or region or an on-site laboratory that fulfills the following minimum competency and procedural requirements for personnel involved in testing and analysis.

All testing and analysis data (including quality control (QC) data) shall be reviewed by the Technical Services team above prior to submission for approval. The reviewed data shall then be formally assessed and approved by the Director of Technical Services and the Database Lead. To ensure data integrity and reliability, all data shall undergo a minimum of three levels of internal verification before being entered into the database.(Technical Services team):

1. Director level (minimum requirements, listed or equivalent)
    a. NRMCA Technologist Level 4
    b. ACI Certifications for Field Testing and Self-Consolidating Concrete (SCC)
2. Manager Level (minimum requirements, listed or equivalent)
    a. NRMCA Technologist Level 3
    b. ACI Certification for Field Testing
3. Technician Level (minimum requirements, listed or equivalent)
    a. NRMCA Technologist Level 2

ACI Certification for Field Testing When the project employs the use of SCMs, the project proponent must monitor and record the type, quantity, and source of all SCMs used for each monitoring period. The project proponent must also demonstrate, through credible and verifiable evidence (like supplier declarations, procurement contracts, invoices, production statistics, or other relevant documentation), that the SCMs utilized in the project are not diverted from existing applications. The evidence provided shall clearly substantiate that the SCMs are derived from materials that would otherwise remain unused, underutilized, or disposed of in the absence of the project activity.

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APPENDIX I: ACTIVITY METHOD

The concept of using greenhouse gases as a raw material for the production of useful products is only a few years old. A number of start-up companies are developing technologies that use captured GHGs to produce tangible products, with what has been termed “Carbon Capture and Utilization” (CCU). As of 2026, there is no large-scale commercial application of the technology to capture and sequester CO_2 in concrete at the global level. There is limited activity in sequestering GHGs in concrete and other similar building materials. Some of the companies include CarbonCure, Partanna and CarbiCrete.

Best estimates at the time of writing indicate that CarbonCure sequesters the most CO_2 by volume in concrete. In 2025, CarbonCure’s technology was used in 18.05 million cubic yards of ready-mix and pre-cast concrete – compared to an average of 18.3 billion cubic yards of concrete poured globally per year (approximately 0.0986% of the market by volume).[25] Other companies, such as Partanna and CarbiCrete, are in the early stages of commercialization. While this is likely to change over time, the fact that the Carbon XPrize is so focused on helping these companies is an indication of how early-stage these markets are.

In addition, it should be noted that as of the writing of this methodology, CarbonCure’s technology has been available for more than six years, demonstrating that while the project is commercially available at a modest scale, its growth has been limited – indicating barriers to penetration in the wider market. Some of these barriers include:

- Regulatory: Engineering approval of concrete mixes is required for commercial buildings on a case-by-case basis. This limits the volume that producers can create using innovative types of concrete and requires interaction with major engineers/architects within each geographic region to remove barriers to implementation. There are limited region-specific policies that promote the use of CO_2-mineralization on a large scale, and no state level or federal level regulation or legislation that requires its use. In short, producers can view CO_2-containing concrete as a 'nice to have' rather than a 'need to have'.
- Time Burden: Quality control processes require up to six months to 'normalize' addition of CO_2-mineralization equipment to the manufacturing process (for new plants). This represents additional costs that many producers – particularly smaller ones – will most likely not want to incur.
- Market Fragmentation/Current Practice: The concrete manufacturing industry is extremely fragmented. This represents additional barriers to implementation as each company must be engaged with on an individual basis. An IBISWorld Report outlines that even the largest producers rarely control more than 10% of the overall market. Many producers own one or two plants.

[25] https://gccassociation.org/concretefuture/cement-concrete-around-the-world

Positive List

This methodology uses Option A: Activity Penetration (AP) to determine additionality. Under this option, a methodology must demonstrate that the project activity has achieved a low level of penetration relative to its maximum adoption potential (MAP). AP is determined by dividing the observed adoption (OA) of the project activity by the project activity's MAP.

MAP is defined as "the total adoption of a project activity that could currently be achieved given current resource availability, technological capability, level of service, implementation potential, total demand, market access and other relevant factors within the methodology's applicable geographically defined market." In this case, the MAP is defined as all sales and use of concrete globally. In order to qualify as additional, the project AP can be no higher than 5%. In this case, the project activity has not reached true commercial scale. To determine the total market size, the best metric would be the volume of global ready-mix and pre-cast concrete production. As referenced above, CarbonCure's technology penetration, which accounts for a majority of market penetration for CO_2 sequestration in concrete, accounts for approximately 0.0986% of market penetration by volume.

Therefore, the activity penetration level of the project activity covered by this methodology is clearly below the five percent threshold, and the project activity may be deemed additional.

Where relevant, similar activity penetration calculations can be completed for Pre-cast, Process water and Recycled Aggregate technologies of which there are no or limited adaptations of technologies to date.

APPENDIX II: TESTING PROCEDURES TO DETERMINE BASELINE CEMENT QUANTITY

1. Project proponents must perform a cement test to determine the quantities of cement in both the baseline and project.
2. Project proponents must conduct a sufficient number of cement tests so that:
   a) MD/Cs representing at least 50% of the concrete volume in the project crediting period are tested, and
   b) Each baseline MD/C that correspond to a tested project MD/Cs, is tested.
3. Each cement test must include:
   a) a specimen from a minimum of three different batches of the same MD/C, and
   b) statistically equivalent number of specimens in the baseline MD/C as is tested for the corresponding project MD/C.
4. For grouped projects, a cement test result may represent MD/Cs produced from multiple facilities.

Test procedure requirements:

1. Test specimen volumes for each MD/C in the baseline must equal those used for each project MD/C test specimen.
2. The measurement of the volume of cement and preparation, curing, and testing of the test specimen must:
   a. meet the requirements of *ASTM C39 – Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*, or an equivalent justified as such by the project proponent, and
   b. be the same for each corresponding MD/C in the baseline and project.
3. Each concrete test must have a specified design strength interval (e.g., 28-day compressive strength) that is the same for all test specimens, including from the project and baseline.

Concrete tests must be conducted by a laboratory that is accredited by ISO/IEC 17025 and ASTM or equivalent or an on-site laboratory that complies with the minimum competency requirements prescribed in section 10.3.

Test result requirements:

1. For a concrete test to be valid:

a. the average compressive strength of the project MD/C test specimens must be equivalent or better to the compressive strength of the corresponding baseline MD/C test specimen. The compressive strength of each project test specimen in a concrete test should fall within 10% of each other, and be within "good" classification of variation for standards of concrete control in *ACI 214R-11 Guide to Evaluation of Strength Test Results of Concrete* to determine equivalency. and

b. the compressive strength of each project test specimen in a concrete test should fall within 10% of each other, or be a "good" classification of variation for standards of concrete control in *ACI 214R-11 Guide to Evaluation of Strength Test Results of Concrete*.

2. The project proponent must measure and report the test results, which at a minimum must include:

   a. the average mass of cement in the test specimens for a project MD/C 'i' ($Q_{Cement,p,i,test\ n}$),

   b. the standard deviation of the mass of cement in the specimens tested.

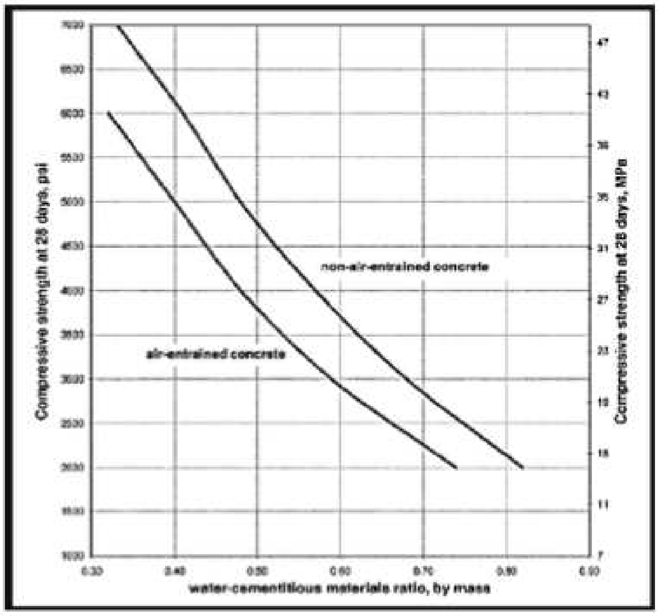
Carbon Tests

1. The project proponent must determine the carbon content of at least three specimens from each MD/C in the baseline and project on an annual basis.
2. The carbon content must be determined using a carbon analyzer.
3. Each test must reveal a carbon content that is within 10% of the other two tests, or the project proponent should continue testing until three results within 10% of each other are obtained. If the project is installed in a new concrete facility, as opposed to an existing facility, where baseline concrete was not previously produced, then the concrete manufacturer would produce samples NOT using the project equipment and develop samples with the same compressive strength as the post-project concrete.
4. The quantity of CO_2 stored must be calculated using the most conservative test results, defined as the lowest value from the project concrete samples and the highest value from the baseline concrete samples, with all test procedures and results made available to the validation and verification body. The test result is then extrapolated to all of the concrete produced for that project design mix in year y as shown in Equations 4a and 4b. The baseline concrete test results are reflected in the variable $C_{baseline\ sample,i,y}$. The project concrete test results are reflected in the variable $C_{project\ sample,i,y}$.
5. Concrete samples should be collected as early as practicable once carbonation is complete and before setting; if the sample is fully representative, results may be expressed as carbon or CO_2 per unit of concrete and compared against the carbon content of equivalent baseline concrete produced without CO_2.
6. Sampling may be conducted either on fresh concrete, by separating mortar from aggregates, or on hardened concrete, by crushing the sample without crushing coarse aggregates. The testing procedure, results, and scaling calculations used to derive carbon content must be clearly documented and made available to the verifier, and project proponents may optionally provide video documentation to support verification.

Three Point Curves

Three Point Curves are common with concrete producers. A three-point curve is a simple way, to obtain a relationship between one factor that is varied to 3 different levels and a measured result using the least number of experiments. All other factors are kept constant. For concrete mixtures the three-point curve is used to establish mixture proportions for selected project requirements.15 A concrete mix is generally not static over the course of a year in most climates, so the cement content will be adjusted up and down depending on the season and the weather on certain days. The mixes may vary slightly on a humid day compared to a dry day, for example. Concrete producers thus complete a three-point curve in their lab with the same mix design at three different water/cement (w/c) ratios, creating a linear line that decreases as the w/c increases (strength goes down as w/c goes up). Such testing can be allowed under this methodology for project mixes, which can then be compared to the appropriate baseline design mix. Without the ability to use three-point curves, depending on when the baseline is established, the CO2 mix may have more cement than the baseline but less than the equivalent mix at that time of year. The figure below provides an illustration of this concept; in this instance, the three points on the non-air-entrained concrete line are those at 7120 psi, 4200 psi, and 2250 psi along the line.

The figure below provides an illustration of this concept, in this instance the three points on the non-air entrained concrete line are those at 7120 psi, 4200 psi and 2250 psi along the line.



APPENDIX III: EMISSIONS FACTOR OF CEMENT USING REGIONAL FACTORS

The following formula must be used to determine the emission factor for cement (EF_{cement}) where no local data or EPDs are available, as per Section 10.1:

$$EF_{cement} = \frac{M_{clinker}}{M_{cement}} \times EF_{clinker} \tag{21}$$

Where:

EF_{cement} = Emission factor for Portland cement production (tCO_2e/tonne of cement)
$M_{Clinker}/M_{Cement}$ = Clinker to cement ratio (unitless).
$EF_{Clinker}$ = Emission factor of clinker (tCO_2e/tonne of clinker).

The factors in Table A1 include emissions from the chemical process of calcination and emissions from fuel combustion, and consider those facilities that combust a wide range of carbon intensive and biogenic fuel sources. Table A2 shows the typical ratio of clinker-to-cement on a regional basis throughout the world. These tables were sourced from VM0031 and derived from the Cement Sustainability Initiative report, *Cement Industry Energy and CO_2 Performance "Getting the Numbers Right"* (World Business Council for Sustainable Development).

Table A1: CO_2 emissions per tonne of clinker per kiln type (global average)

Kiln Type	$EF_{Clinker}$ (kg CO_2/t clinker)
Dry with preheater and precalciner	842
Dry with preheater and without precalciner	861
Dry without preheater	955
Semi wet/Semi dry	896
Wet	1043

Table A2: Ratio of Clinker to Cement on a Regional Basis

Region	Clinker to Cement Ratio (%)
Africa and Middle East	79
Asia excluding China, India, CIS and Japan	84
China and India	74
CIS	80
Europe	76
Japan, Australia and New Zealand	83

Latin America	74
North America	84
World (any areas of the world not including the locations listed above).	78

APPENDIX IV: ADDITIONAL INFORMATION ON TESTING AMOUNT OF CO_2 STORED IN CONCRETE

Concrete is generically comprised of coarse aggregate (stone), fine aggregate (sand), cement, and water. The injected CO_2 will be mineralized through a chemical reaction with the cement or cement replacement. To quantify the mineralized CO_2, project proponents must use carbon analyzers that are currently available and common in the industry.

The operating principle behind a carbon analyzer (often the device is used also to detect sulfur in solid materials) involves heating of a sample in oxygen rich environment to oxidize carbon and sulfur content of sample material to generate carbon monoxide, carbon dioxide and sulfur dioxide respectively. These gases are then passed through detection cells to measure content of carbon and sulfur. The measured data are compared with the mass of sample to identify content of respective elements in sample. The residual gas is finally discharged out. The results can be compared to the mass of the sample in order to determine a mass percentage of carbon and sulphur. Different companies supply these advanced analyzers with an infrared detection system for analyzing the percentage of carbon and sulphur in combustion gases.

For each mix design– for both the baseline and the project concrete – the project proponent must conduct a minimum of three analyzer tests. Each test must reveal a carbon content that is within 10% of the other two tests, or the project proponent should continue testing until three results within 10% of each other are obtained. If the project is installed in a new concrete facility, as opposed to an existing facility, where baseline concrete was not previously produced, then the concrete manufacturer would produce samples NOT using the project equipment and develop samples with the equivalent or better compressive strength and any other relevant functional equivalence metrics as the post-project concrete.

The actual test result used in the calculations of quantity of CO_2 stored must be the lowest of the three samples for the project concrete and highest of the three results for the baseline concrete – thus ensuring the most conservative result. All test procedures and results will be made available to the validation/verification body. The test result is then extrapolated to all of the concrete produced for that project design mix in year y as shown in Equations 4a and 4b. The baseline concrete test results are reflected in the variable $C_{baseline\ sample,i,y}$. The project concrete test results are reflected in the variable $C_{project\ sample,i,y}$.

It is recommended that concrete samples should be acquired at the earliest time upon which the carbonate reaction is expected to be complete, before the sample sets. If the input sample is fully representative of the complete concrete composition, the result can be expressed in a straightforward manner as an amount of carbon or CO_2 per unit of concrete. The results are compared to a baseline carbon content of an equivalent concrete that has not been produced using carbon dioxide.

For example, a concrete sample that is analyzed to have a net increase in carbon of 0.05% by mass concrete translates to one cubic meter (m^3) of concrete (typically about 2400 kg) contains 1.2 kg of carbon. A conversion from carbon to CO_2 by multiplying by the ratio of their molar masses (44 for CO_2, 12 for C) would result in a conclusion of 4.4 kg of CO_2 per m^3 of concrete.

If the mineralized CO_2 is in low abundance (1% or less by weight of cement) with respect to the concrete then project proponents have the option of minimizing the analysis of the components that are not reacting with CO_2. The sample can be processed to increase the fraction of the cement paste fraction by, for example, removing coarse aggregates. Then the same test can be performed on the baseline and post-project materials (in this case without the aggregates that would not react with CO_2 in the project scenario).

One percent by weight of cement is around 0.1% by weight of concrete (assuming the concrete is 10% by mass cement). Thus, if one starts with concrete then it would be hard to measure the CO_2. But if one can process the concrete to have a sample that is mostly cement (removing aggregate) then the denominator changes and the abundance of what is measured goes up – thus making it easier to quantify.

Sampling in this manner can be done in two states: 1) on fresh concrete, where the mortar (cement and sand) is separated from the aggregates; and 2) when the concrete has hardened where a sample can be crushed -- as long as the coarse aggregates are not crushed. The testing procedure should be clearly spelled out for the verifier with results made available. Project proponents may want to consider videoing a sample test to make it easier for a verifier to understand the procedure. The project proponent should also clearly describe and show calculations for how the test results in terms of carbon content of the sample are scaled up to account for this processing step.

APPENDIX V: CEMENT DISPLACEMENT MARKET ANALYSIS

The objective of this analysis is to determine the cement displacement due to CarbonCure technology and to estimate a discount factor for upstream displacement of cement. The study followed a 5-step approach:

1. Conduct a scan of peer-reviewed academic literature to gather insights on cement supply and demand.
2. Collect publicly available market data and CarbonCure data and estimate the price responsiveness of cement due to CarbonCure technology through an econometric analysis using the collected data.
3. Conduct interviews with CarbonCure customers to understand the impact of CarbonCure technology on cement pricing, supply and demand.
4. With the results from the econometric modelling, estimate the impact of supply price adjustment on volume of cement production using a computable general equilibrium (CGE) model.
5. Estimate the cement discount factor by comparing the increase in the volume of cement produced in the market to the cement avoided due to CarbonCure technology.

A jurisdictional scan and review of peer-reviewed academic literature as well as government and industry sources was conducted to assess cement market dynamics, with a focus on demand and supply drivers, price elasticity, and the substitutability of low-carbon concrete products. The review did not identify published cement displacement discount factors applicable to CarbonCure technology.

The modeling framework combined econometric estimation and CGE modeling to assess how cement prices and quantity respond to CarbonCure technology. Econometric analysis was used to assess a change in price by conventional cement producers when the demand for cement is reduced due to CarbonCure technology. An Instrumental Variables (IV) econometric model was developed using quarterly U.S. data on cement prices, cement volume of production, capacity utilization, GDP, housing starts, and electricity price over 1981-2025.[26] It was estimated that CarbonCure technology decreased the price of conventional cement by approximately 0.17%, which reflects the small market share of CarbonCure as well as the inelastic price responsiveness of cement supply price to reduced cement demand.

The price changes estimated using the econometric analysis were then introduced into the CGE model to estimate changes in cement production volumes as reduction in prices due to CarbonCure technology can partially counteract its impact on cement production. The model is a large-scale, dynamic, multi-region, multi-commodity model that employs the GTAP database produced by Purdue University and covers almost all countries in the world. This enabled modelling of price and quantity changes across key CarbonCure markets. Based on the CGE modelling, it was estimated that the

[26] The IV approach was used to address the potential simultaneity bias as price and quantity are jointly determined in the market. Instruments were chosen for their correlation with quantity and their exogeneity with respect to the price. The instruments included demand shifters (housing starts and GDP) as well as lagged production of cement.

volume of cement production increased by 8.2 thousand tonnes globally as a result of the cement price adjustment, partially offsetting the decrease in the cement demand due to CarbonCure technology.

Finally, the discount factor was calculated as an average of CarbonCure top markets and the rest of the world. The estimation involved the following steps:

1. Calculation of the cement avoided as a result of CarbonCure technology compared to the total demand of cement across CarbonCure markets (rows 1 and 2 in the table).
2. Estimation of the reduction in the average market price of cement (row 4), calculated by multiplying the market share (row 2) by the supply price elasticity (row 3).
3. Increase in quantity demanded based on the shock of the CGE model (rows 5 and 6).
4. The discount factor was determined by dividing the increased quantity demanded (row 6) by the cement avoided due to CarbonCure technology (row 1).

Based on this methodology, the global average cement displacement discount factor was estimated at 4.9% for CarbonCure. However, when considering uncertainty, it was determined that the discount factor estimate falls within a range of **3.3%** to **6.5%.** This range represents the 95% confidence interval based on the estimated supply price elasticity, capturing the uncertainty regarding how cement suppliers adjust prices of conventional cement in response to decreased demand resulting from the adoption of CarbonCure technology. Thus, for the sake of conservativeness, **the methodology prescribes a cement displacement discount factor value of 6.5%**.

In addition, interviews with concrete producers who are CarbonCure customers indicate that concrete produced using CarbonCure technology is not sold at a premium, and that customers have not experienced impacts of CarbonCure technology on cement prices.[27]

A number of factors may affect the value of the discount factor over time: increased adoption of CarbonCure technology; greater reduction in cement prices which may stimulate demand for conventional cement; increased competition in the cement market (including the entry of substitutes) which may raise supply price elasticity; greater price sensitivity of cement users; and changes in CarbonCure's geographic composition of portfolio. The analysis in the study accounts for the current levels of these factors, as reflected in the historical CarbonCure data, as well as in the data used for the econometric and CGE modelling. It is recommended that the analysis be updated periodically to ensure that any changes in these factors are reflected in the estimated discount factor. It is recommended to update the analysis every two years, as this provides enough new quarterly observations to allow for parameter updates.

[27] In total, five interviews with US-based CarbonCure customers were conducted. While customers indicated that they did not experience cement price changes due to CarbonCure technology this might be due to a small impact of CarbonCure technology that in reality may be hardly distinguished from other drivers of prices, including macroeconomic factors. Therefore, economic modelling was still required to assess the impact of CarbonCure.

Limitations of the analysis include the following:

- The econometric analysis is based on the U.S. data due to limited data availability for other countries. However, an application of an elasticity estimated for selected jurisdictions to other jurisdictions is frequently done in economic modelling due to data limitations.
- Point estimates derived from econometric analysis are subject to statistical uncertainty, which is reflected in the associated confidence interval.
- The CGE model used in the analysis does not include financial markets and monetary policy. However, given that changes in prices due to CarbonCure technology are small, this unlikely represents a material limitation.

Table: Estimation of Cement Displacement Discount Factor: Key Parameters

(1)	Cement avoided due to CarbonCure technology, world, 2024, metric tonnes (thousands)	167.5
(2)	Cement avoided due to CarbonCure technology, average across markets	0.41%
(3)	Supply price elasticity (% change in price as a result of 1% change in quantity)	0.40%
(4)	Change in market price of cement, based on estimated supply price elasticity, average across markets	-0.17%
(5)	Increase in quantity produced, average across markets	0.02%
(6)	Increase in quantity produced, metric tonnes (thousands)	8.2
(7)	Global average discount factor (row 6 / row 1)	4.9%
(8)	Conservative bound of the global average discount factor (considering uncertainty)	**6.5%**

Note to reader:
The estimates presented within this document have been provided by Deloitte LLP ("Deloitte") to CarbonCure Technologies Inc. ("CarbonCure") for the purpose of determining the cement displacement that might occur due to CarbonCure's technology or similar technology by another project developer to estimate a discount factor for upstream displacement of cement. The modelling methodology used in this study is applicable to similar technologies used by other project developers.
Deloitte does not assume any responsibility or liability for losses incurred by any party as a result of the circulation, publication, reproduction or use of this initial analysis contrary to its intended purpose.
The analysis is provided as of July 10th, 2025 and we disclaim any undertaking or obligation to advise any person of any change in any fact or matter affecting this analysis, which may come or be brought to our attention after the date hereof. Without limiting the foregoing, in the event that there is any material change in any fact or matter affecting the analysis after the date hereof, we reserve the right to change or modify the analysis but are under no obligation to do so. Observations are made on the basis of economic, industrial, competitive, and general business conditions prevailing as at the date hereof. In the analysis, we may have made assumptions with respect to industry performance, general enterprise information, and economic conditions and other matters, many of which are beyond our control, including government and industry regulation.

No opinion, counsel, or interpretation is intended in matters that require legal or other appropriate professional advice. It is assumed that such opinion, counsel, or interpretations have been, or will be, obtained from the appropriate professional sources. To the extent that there are legal issues relating to compliance with applicable laws, regulations, and policies, we assume no responsibility therefore.
We believe that our analysis must be considered as a whole and that selecting portions of the analysis or the factors considered by it, without considering all factors and analyses together, could create a misleading view of the issues related to the report. Amendment of any of the assumptions identified throughout this report could have a material impact on our analysis contained herein. Should any of the major assumptions not be accurate or should any of the information provided to us not be factual or correct, our analysis, as expressed in this report, could be significantly different.

APPENDIX VI: ALIGNMENT WITH A NET ZERO FUTURE

Purpose and Scope

This appendix provides an assessment of the risk that project activities implemented under this methodology may lead to carbon lock-in. Carbon lock-in refers to the reinforcement or prolongation of technologies, infrastructure systems, or practices that result in continued or increased greenhouse gas (GHG) emissions relative to feasible lower-emission alternatives.

The assessment evaluates whether project activities:

- Delay or displace the adoption of lower-emission technologies or practices;
- Entrench consumer behavior or business models dependent on unabated fossil fuel use;
- Result in long-lived physical infrastructure that may constrain future decarbonization pathways.

This appendix applies to all project activities eligible under VM0043 involving CO_2 utilization in concrete production and optional activities listed in section 4.

Identification of Relevant Lower-Emission Alternatives

The following categories of alternative technologies or practices are considered when assessing carbon lock-in risk:

(a) Low- and Zero-Cement Alternatives

- Use of supplementary cementitious materials (SCMs) or alternative cementitious materials (ACMs) to partially or fully replace Portland cement;
- Novel binder systems with significantly lower process emissions.

(b) Material Efficiency and Design Optimization

- Reduction of cement intensity through structural or mix design optimization;
- Increased use of recycled aggregates or alternative materials.

(c) Electrification and Fuel Switching in Cement Production

- Use of low-carbon energy sources in clinker production;
- Electrification or alternative fuels replacing fossil fuel combustion.

(d) Demand-Side Substitution

- Substitution of concrete with lower-emission construction materials (e.g., timber, low-carbon composites) where technically feasible.

Assessment of Lock-In Channels

The risk of carbon lock-in is evaluated across three dimensions:

Physical Infrastructure Lock-In

Projects may involve installation of equipment for CO_2 capture, transport, storage, and injection into concrete. The risk of lock-in is assessed based on:

- Whether such infrastructure is dependent on continued operation of emission sources (e.g., fossil fuel-based CO_2 supply);
- The extent to which infrastructure is modular, reversible, or compatible with future low- or zero-carbon systems;
- Typical operational lifetimes of concrete production facilities and associated equipment (often extending over multiple decades).

Assessment:
VM0043 project activities primarily involve retrofitting or incremental modifications to existing production facilities rather than construction of new high-emission assets. Where CO_2 emission sources transition to low-carbon or biogenic sources over time, the infrastructure remains compatible with decarbonization pathways. Accordingly, the risk of long-term physical lock-in is considered minimal, provided that dependence on fossil-based CO_2 sources is not structurally reinforced.

Technological and Investment Lock-In

Projects may influence capital allocation and technology trajectories by:

- Incentivizing continued use of cement-based construction systems;
- Reducing incentives for breakthrough low-carbon materials if marginal abatement options are favored.

Assessment:
CO_2 utilization in concrete does not inherently prevent the adoption of SCMs, ACMs, or alternative binders; rather, it promotes their use leading to a reduction in cement demand intensity within existing systems. However, there is a small risk that incremental improvements could delay deployment of more transformative low-emission materials if such alternatives are commercially viable during the project lifetime.

This risk is moderated by:

- The continued applicability of SCMs and ACMs within the methodology scope;
- Market-driven adoption of lower-cost or lower-emission alternatives;
- The absence of explicit requirements mandating continued use of high-clinker cement.

Behavioral and Market Lock-In

Projects may influence market and behavioral dynamics by:

- Reinforcing the dominance of conventional concrete in construction markets;

- Creating perceptions that incremental improvements are sufficient substitutes for deeper decarbonization.

Assessment:
The methodology operates within an existing high-demand market for concrete and does not directly regulate material choice at the system level. While project activities may marginally reinforce continued reliance on concrete, they also:

- Reduce emissions intensity per unit of concrete;
- Enable transition pathways compatible with progressive decarbonization of cement and construction sectors.

The risk of behavioral lock-in is therefore considered minimal but context-dependent, particularly in markets where viable substitutes exist but are not adopted due to cost or regulatory barriers.

<u>Consideration of Project Lifetimes</u>

Concrete production assets and associated infrastructure typically have operational lifetimes spanning multiple decades, which may overlap with expected timelines for deep decarbonization of the construction sector.

In assessing lock-in risk:

- Short- to medium-term emission reductions achieved by project activities are weighed against potential long-term constraints;
- The flexibility of infrastructure to adapt to lower-emission inputs (e.g., low-carbon CO_2 sources, alternative materials) is considered critical.

Projects that rely on long-term supply contracts for fossil-derived CO_2 without flexibility for transition may present a higher lock-in risk.

<u>Overall Assessment and Conclusion</u>

Overall, project activities under VM0043 are **not expected to significantly increase or prolong unabated fossil fuel consumption**, provided that:

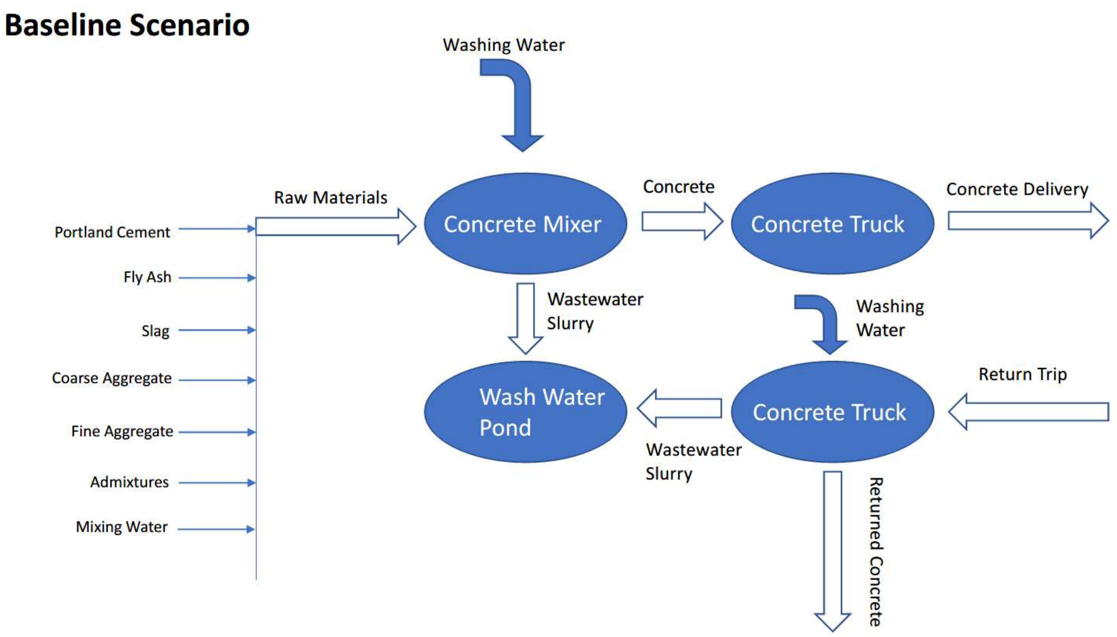
1. CO_2 sourcing does not structurally depend on long-term operation of high-emission facilities;
2. Project implementation does not preclude or discourage adoption of lower-emission alternatives;
3. Market and regulatory developments continue to support transition toward low-carbon construction systems.

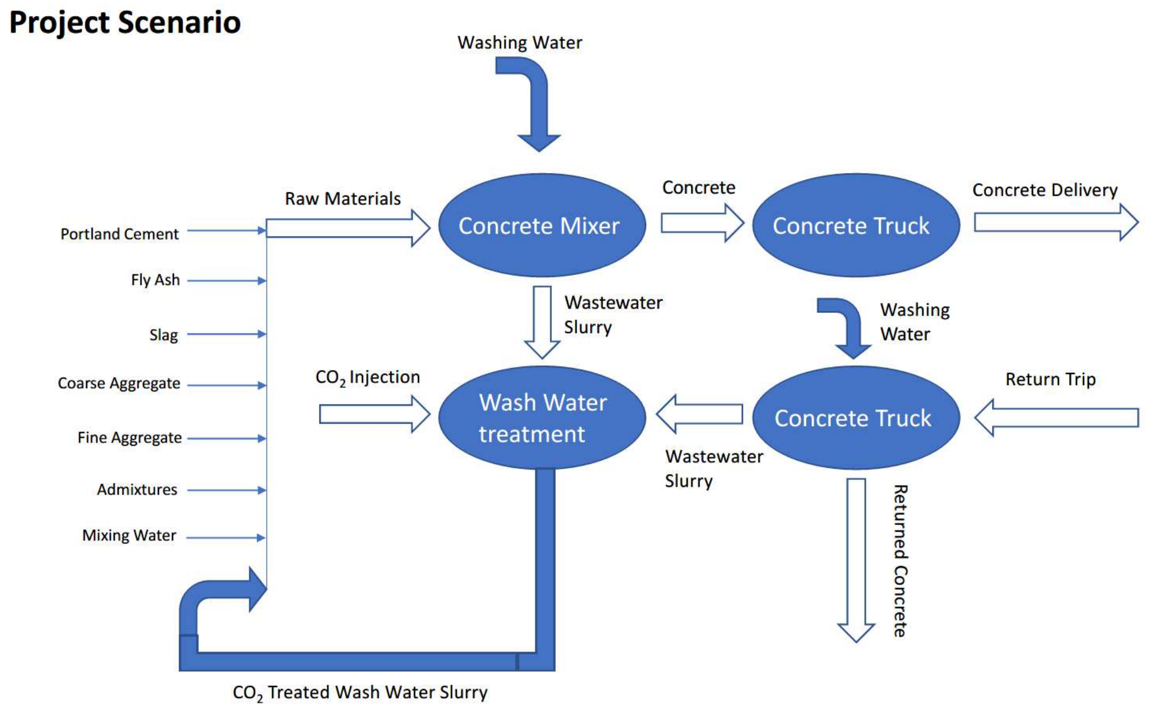
APPENDIX VIII: GUIDANCE ON PROCESS WATERAND RECYCLED CONCRETE AGGREGATES

Process water/CO_2 Introduction:

A significant amount of process water is generated during concrete production and must be managed, typically through ponds, pits or tanks located at the concrete production facilities. The process water is a slurry where the suspended solids comprise cementitious materials and other fines (such as fine sand) that can be used as a replacement for virgin cement in new concrete, for example, reducing cement input by another 4-5%. CO_2 introduction technology can be used to input CO_2, which can then become mineralized into these cementitious fines. The proportion of the benefit attributable to mineralization can be significantly higher. This activity can have numerous other co-benefits, including improved water quality in and around the concrete plant and lower or eliminated haulage costs associated with reclaimer fine sludges / filter cakes and waste concrete. Although it should be noted that not all of the sequestered CO2 in the process water may be part of an input into a final concrete product.

Another way to illustrate the process is provided below. These diagrams illustrate that in the baseline scenario, process water accumulates and is left in ponds, pits or agitated tanks. In the project scenario, CO_2 is introduced into the process water treatment process (the waste slurry coming both from the concrete mixer and the returning concrete truck) and this CO_2-treated process water slurry is then returned to the main production process, which along with cement, aggregates, water, etc. is then used as an input into newly produced concrete.





To be more precise, the following pathways are generally what happens with process water:

1. Separation of solids and liquid (through gravity), disposal of solids (landfill), and neutralization and discharge of water
2. Disposal of solids (landfill), re-use of water at plant to wash the equipment (ends up back in the pond)
3. Disposal of solids (landfill), re-use of water as mix water in new concrete
4. Re-use of solids and re-use of water as mix-water in concrete through dilution (addition of clean water). Note that this re-use of solids in this baseline scenario may not have an associated cement replacement/reduction.

As noted in the above pathways, while it is most likely the solids will be disposed of and not used in new concrete, this can happen, and is more frequently the case in certain markets. Thus, the re-use of cementitious materials in the process water can happen as part of the baseline scenario. In these cases where the baseline scenario includes the re-use of cementitious materials from the process water, the CO_2 introduction is still beneficial as it serves to stabilize the hydrating cement, allowing greater flexibility and consistency when reusing the process water solids and additional stabilized solids made available by CO_2 treatment in a concrete mix, which can result in the ability to improve the performance and thus allow for the displacement of virgin cement. Given these benefits, even in the cases where the baseline is re-using recovered cementitious materials from process water, this activity would still be eligible. The reason is that the baseline design mix would reflect the use of cementitious materials from theprocess water prior to the project activity. That would translate into lowering the amount of virgin cement input in the baseline case (as compared if no process water materials were reclaimed). The project design mix would reflect any increase in the use of material from the process water that is part of the project activity. Thus, the project design mix would reflect the delta between the use of process water in the baseline and project cases and the resulting decrease in virgin cement input from the baseline mix.

In addition, projects using this technology must have a process for determining the carbon content of the post-introduction material, in order to assess how much CO_2 has been sequestered if the default mineralization option is not selected. This measurement can be done using a batch quantification approach via ultimate analysis of elemental carbon present in an agitated vessel or tank containing a process water slurry. Project proponents can collect a representative sample of dried process water solids from the agitated vessel before and after CO_2 introduction (The Evaluation Period). Project proponents must collect three representative samples at least annually per installation.

The project proponents can measure the change in elemental carbon (wt%) of the dried process water solids. In an appropriately controlled environment (eg: no disturbance to the contents of the process water vessel as a function of material inflows or outflows), the efficiency of the mineralization process can be measured by attributing the increase in elemental carbon in the process water solids to mineralized carbon dioxide, and then quantifying the efficiency using the measurement of CO_2 introduced into the mineralization system over the course of the Evaluation Period.

As a hypothetical example, there is a process water pond at a concrete facility where a reclaimer with CO2 introduction device is installed. Before the equipment is activated, the project proponent takes three samples of the slurry (the sample must contain at least some solids). The material is dried and is found to be 5% by weight carbon. Then the CO2 introduction begins. After the Evaluation Period, the CO2 introduction is stopped and three more samples are taken. It is found that, once dried, the solid contains 10% by weight carbon. This is measured in kgC per kg of solid recovered from the slurry. That delta of 5% by weight represents the higher carbon content caused by the mineralization of CO2. For the sake of simplicity, the baseline sample has 5kg of carbon per 100s kg of recovered solid. After the evaluation period, the samples read around 10 kg of carbon per 100 kgs of recovered solid. That would mean 5 kg of C per 100 kg were mineralized, which required 18.3 kg of CO2 introduction (5 kg x 44/12). If over the course of one year, 800,000 kg of recovered solids were then put into new concrete, it can be assumed that 800,000 * 18.3/100 = 146,400 kg of CO2 were mineralized.

It is important to note that only the amount of solid materials that is used for new concrete production can be used for counting carbon offsets. In the above example, if only 500,000 of the 800,000 kgs were actually used as a component into new concrete, credit can only be given for the 500,000 kgs. These "evaluation period" tests must be performed annually, prior to the verification. The percentage of carbon mineralization is assumed to be constant for each reclaimer device for at least one year. Annual testing is necessary to account for any losses in efficiency, equipment degradation, etc., and test results should be made available to the VVB. Finally, while the basis of determining CO_2 mineralized will be based on the quantity of waste material actually weighed and inserted into new concrete mixes, this can be crossed checked by the CO_2 flow meter that will accompany the reclaimer equipment. The flow meter results should be expected to be higher than what would be calculated by quantifying the amount of recovered solids because not all CO_2 that flows through the meter will be mineralized. The key monitoring parameters, specifically the weighing of the recovered solids with CO_2 mineralization, will be the same as other requirements in this methodology as it relates to measurement devices for weighing materials. Finally, the impact of the use of recovered solids in lowering the amount of virgin cement content can be measured according to the rest of the methodology (determining virgin cement content pre-and-post project).

Recycled Concrete Aggregates (RCA):

RCA is produced by crushing concrete reclaimed from demolished highways, buildings and other structures, as well as fresh unused concrete that is hardened. This RCA has the capacity to absorb and permanently mineralize CO_2 at an accelerated rate to natural carbonation. RCA in this case can refer to materials that are not virgin concrete. For example, fresh concrete may be returned to the producer because it is not actually used in the intended application (for example, rejected at the job site or a surplus to the required quantity). Instead of being wasted, this concrete can be left to harden, crushed and graded – and can also be treated with CO_2, then used as aggregate in a batch of new concrete or used as road base under asphalt or concrete pavements. Old concrete that is crushed and graded can be made to react with CO_2, and the resulting material can then be used as aggregates. This adds further clarification to Applicability Condition #7, because this is not recycled concrete per se but unused concrete that is converted to aggregate material. Thus, this application would also be eligible under the revised methodology.

The treatment of RCA with CO_2 can either be in a dry process, under ambient or partial pressure, or it can be done in an aqueous environment. Both processes are analogous to accelerated weathering, akin to what is observed in the field. The optimal process will depend on the source of the RCA being treated, water availability, RCA end use etc. The dry process treatment requires a treatment container or vessel equipped for CO_2 introduction in gas or solid form. The CO_2 gas will react with the paste content of the RCA particles and mineralize in the aggregate pores or on the particle surface. This can lead to densification and strengthening of the material. The aqueous process requires the CO_2 to be dissolved in the water used for the treatment. The CO_2 will then react with the ions dissolved from the RCA paste, resulting in mineralization of the CO_2 occurring in the water. Some mineralization can also happen in the RCA particles that would lead to densification and strengthening. The water used in aqueous treatments can be recycled for multiple batches of RCA treatments but would require to be replenished as some will be removed with the RCA after treatment. In both processes CO_2 reacts with calcium oxides and is permanently stored as a calcium carbonate ($CaCO_3$).

RCA may be sold as a commercial concrete product, although some of the sequestered CO_2 in the calcium carbonate may not be part of the final product that is sold as RCA (as the CO_2 may react with ions dissolved from the RCA paste in the case of an aqueous process). Regardless of whether the mineralized CO_2 is sold as part of the final product that is sold as RCA, the sequestered CO_2 will be used in applications that do not decompose or release the CO_2 and will be an eligible project activity.

DOCUMENT HISTORY

Version	Date	Comment
v1.0	05 Apr 2021	Initial version
v1.1	23 Dec 2024	Minor revision to VM0043, which encompasses: • Inclusion of a discount factor for upstream displacement • Separation of removals and reductions • Expansion of the applicability to include pre-cast concrete products • Correction to Equation 5 • Inclusion of procedure in case the electricity consumption for CO_2 injection is not available or cannot be measured separately • Inclusion of requirements related to the source of CO_2 • Revisions to the definitions of "Precast concrete" and "Supplementary Cementitious Material (SCM)" and the addition of a definition of "Cement replacement" • Update to the cement production and market penetration values in Appendix-I • Update the approach to define, categorize and test individual mix designs • Update the testing procedure to determine baseline cement quantity • Methodology renamed to *VM0043 CO_2 Utilization in Concrete Production*
v2.0 (draft)	10 July 2026	• Inclusion of passive carbonation in the ERR calculations, i.e., CO_2 that would have sequestered naturally in the baseline and project scenarios without project intervention • Introduction of requirements to conduct project-based calculations, and update the approach involving static (default) numbers, like the default mineralization efficiency of 60% • Inclusion of the following eligible optional project activities in the methodology scope and the corresponding quantification and monitoring requirements: ○ use of supplementary cementitious materials not diverted from existing uses ○ use of process water with dissolved CO_2 ○ reduction of process-related CO_2 emissions from steam curing ○ mineralization of CO_2 into recycled concrete aggregate feedstocks • Inclusion of a new cement displacement factor of 6.5%, which replaces the default factor of 30% • Inserting relevant provisions from the CCS+ capture module for quantifying parameter $PE_{CO2,processing,y}$ and making relevant updates to the default values procedure, as necessary • Promoting alignment with the CCS+ modules, where applicable. • Restricting the eligibility of ongoing capture facilities in line with paragraphs 1b and c, section 4 of VMD0059. • Inclusion of Section 5 – General Implementation • Inclusion of uncertainty assessment and the related discount • Inclusion of Appendix Vi: Alignment with a Net Zero Future

		• Making editorial improvements and aligning with the current methodology template/requirements.