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Low-Carbon Cement

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Abbreviations and Acronyms

ACM	Alternative cementitious material
ASTM	ASTM International (previously American Society for Testing and Materials)
$CaCO_3$	Calcium carbonate
Caltrans	California Department of Transportation
CaO	Calcium oxide
CARB	California Air Resources Board
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CRT	Climate Reserve Tonne
EF	Emission factor
EPA	U.S. Environmental Protection Agency
EPD	Environmental Product Declaration
GCCA	Global Cement and Concrete Association
GGBFS	Ground granulated blast furnace slag
GHG	Greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
kWh	Kilowatt hour
LCA	Lifecycle assessment
LEED	U.S. Green Building Council's Leadership in Energy and Environmental Design
NOV	Notices of Violations
PLC	Portland Limestone Cement
PC	PPortland Cement

QA/QC	Quality assurance/quality control
SCM	Supplementary cementitious material
SSRs	Sources, sinks, and reservoirs
t	Tonne (or metric ton)
tCO_2e	tonnes of carbon dioxide equivalent

1. Introduction

The Climate Action Reserve (the Reserve) Low-Carbon Cement Protocol provides guidance to account for, report, and verify greenhouse gas (GHG) emission reductions associated with the production and processing of supplementary cementitious materials (SCM/ACM s) or alternative cementitious materials (ACMs) that can partially or fully replace portland Cement(PC) during the production of concrete and reduce GHG emissions generated during PC production. This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification and verification of GHG emission reductions associated with a low-carbon cement project.[1]

The Reserve is an offset registry serving the California cap-and-trade program and the voluntary carbon market. The Reserve encourages actions to reduce GHG emissions and works to ensure environmental benefit, integrity, and transparency in market-based solutions to address global climate change. It operates the largest accredited registry for the California compliance market and has played an integral role in the development and administration of the state's cap-and-trade program. For the voluntary market, the Reserve establishes high quality standards for carbon offset projects, oversees independent third-party verification bodies, and issues and tracks the transaction of carbon credits (Climate Reserve Tonnes, or CRTs) generated from such projects in a transparent, publicly accessible system. The Climate Action Reserve is a private 501(c)(3) non-profit organization based in Los Angeles, California.

Project developers that initiate low-carbon cement projects use this document to quantify and register GHG reductions with the Reserve. The protocol provides eligibility rules, methods to calculate reductions, performance-monitoring instructions, and procedures for reporting project information to the Reserve. Additionally, all project reports receive independent verification by ISO-accredited and Reserve-approved verification bodies. Guidance for verification bodies to verify reductions is provided in the Reserve Verification Program Manual[2] and Section 8 of this protocol.

[1] See the WRI/WBCSD GHG Protocol for Project Accounting (Part I, Chapter 4) for a description of GHG accounting principles.
[2] Available online at: https://www.climateactionreserve.org/how/program-resources/program-manual/.

2 The GHG Reduction Project

2.1 Background

Cement is a key binding agent in concrete, the most widely used building material in the world. Cement production is one of the largest sources of GHG emissions in the industrial sector and contributes approximately 7% of all global carbon dioxide (CO2) emissions.[3] Over half of GHG emissions from producing the most common type of cement, known as portland portland Cement(PC), are attributable to a chemical reaction caused by a high-temperature process ("calcination") used to produce portland portland cement clinker (PC clinker), the primary intermediate component for PC. The remainder of the emissions from typical cement production result the mining and transportation of the materials used during the production process.

PC is manufactured by mixing calcium-containing minerals, such as limestone, with silica-alumina minerals such as sand, shale, or clay. This mixture is then formed into PC clinker by drying, grinding, and heating the raw materials in a rotary kiln. When the mixed raw materials are placed in the rotary kiln and subjected to extreme heat (nearly 2,700 degrees Fahrenheit), a chemical process occurs that transforms the calcium carbonate ($CaCO_3$) into calcium oxide (CaO) and CO_2 gas, which is emitted into the atmosphere (Figure 2.1). Next, the PC clinker is combined with gypsum and other materials and finally ground into PC, which is then sold as a powder to make concrete.

$$CaCO_3 + heat \rightarrow CaO + CO_2$$

Figure 2.1. Chemical Reaction for Calcination during traditional PC Production

ASTM International, formerly known as the American Society for Testing and Materials, establishes procedures and standards for testing cements and concretes. To be ASTM-certified as PC, the product must include 90% to 95% PC clinker and is defined by the ASTM as a hydraulic cement produced by pulverizing clinker, consisting essentially of crystalline hydraulic calcium silicates, and usually containing one or more of the following: water, calcium sulfate, up to 5 % limestone, and processing additions. The clinker-to-cement ratio, or the proportion of PC clinker integrated in each batch of cement, is a critical component in determining the emissions intensity of cement. In 2019, U.S. cement plants emitted roughly 67,000,000 tonnes of carbon dioxide equivalent (tCO_2e).[4]

PC makes up only a small portion of the concrete mix by mass (approximately 10%); however, it comprises roughly 80% to 90% of concrete's total GHG emissions.[5] Thus, one of the most

[3] "Global Energy Review 2021," International Energy Association, April, 2021, https://www.iea.org/reports/global-energy-review-2021/co2-emissions.

[4] Environmental Protection Agency, "U.S. Cement Industry Carbon Intensities (2019)," *Environmental Protection Agency*, October 2021, 2.

[5] Alex Johnson, "California Enacts Legislation to Slash Cement Emissions," NRDC, September 23, 2021, https://www.nrdc.org/experts/alex-jackson/california-enacts-legislation-slash-cement-emissions.

effective strategies to reduce GHG emissions associated with concrete production is to replace some or all of the PC with materials called supplementary cementitious materials (SCM/ACM s) or alternative cementitious materials (ACMs). SCMs are defined by ASTM International as inorganic material that contributes to the properties of a cementitious mixture through hydraulic or pozzolanic activity, or both[6]. ACMs are manufactured clinkered, calcined, or non-clinkered materials that can fully replace PC clinker in cement[7]. SCM/ACM can both be used to reduce GHG emissions by replacing PC clinker at the cement processing plant and/or replacing the amount of PC used at the ready mix concrete plant or in concrete products. In addition to reducing GHG emissions through PC replacement, some SCMs/ACMs can also improve the performance of concrete[8].

Most SCM/ACM s used today are byproducts of other industrial processes or natural materials that display cementitious and pozzolanic properties in concrete mixtures. The two most well-known groups of SCMs used in cement and concrete production are fly ash and ground granulated blast furnace slag (GGBFS), which are byproducts of the declining coal and pig iron industries respectively. In 2020, the U.S. concrete industry utilized about 11,000,000 tonnes of fly ash and approximately 2,600,000 tonnes of GGBFS.[9, 10] Other materials that are byproducts of industrial processes include silica fume and non-ferrous slags, however these are only occasionally used in specialty concretes. Finally, natural pozzolans including diatomaceous earths, volcanic ash, pumicites , and some calcined clays and shales can also be used as an SCM.

Traditionally, ACMs have been used by industry for infrastructure repairs as these formulations offer rapid set, shrinkage compensation effects, and rapid early strength development. However, with a lower emission profile and other structural benefits, ACMs are not only being used for infrastructure repairs but also during new builds as a full replacement for PC.

Despite the potential for SCM/ACM to significantly reduce concrete's GHG footprint, there are a number of factors that impede the widespread SCM/ACM adoption by the cement and concrete industry including (1) regional and seasonal supply constraints for certain SCMs/ACMs (such as fly ash and GGBFS) that materially limit their accessibility in significant quantities, (2) the inability to use many SCMs/ACMs beyond a certain replacement rate before negatively impacting the performance of concrete,[11] (3) diminishing supply of SCMs as a result of declining coal and changes with steel production processes (fresh fly ash and GGBFS), and (4) a general lack of market acceptance. Appendix A includes further information on SCM/ACM legal requirements and Appendix B includes information on SCM/ACM uses and limitations.

Despite regional SCM/ACM shortages, SCM/ACM some SCMs/ACMs including natural

[6] ASTM International. "C125: Standard Terminology Relating to Concrete and Concrete Aggregates," ASTM International, October 4, 2021.
[7] US Department of Transportation, "Alternative Cementious Materials: An Evolution or Revolution?" Kurtis, 2019, https://highways.dot.gov/public-roads/autumn-2019/alternative-cementitious-materials-evolution-or.
[8]Design of Steel-Concrete Composite Structures Using High-strength Materials, "Standard Terminology Relating to Concrete and Concrete Aggregates," Liew, 2021, https://www.sciencedirect.com/topics/engineering/supplementary-cementitious-material
[9] American Coal Ash Association, "Production and Use Survey"
[10] Geological Survey, "Iron and Steel Slag Statistics and Information," https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-slag-statistics-and-information.
[11] Barbara Pacewska and Iwona Wilińska, "Usage of Supplementary Cementitious Materials: Advantages and Limitations," *Journal of Thermal Analysis and Calorimetry* 142, no. 1 (October 1, 2020): 371–93, https://doi.org/10.1007/s10973-020-09907-1.

pozzolans and harvested coal ash are becoming more available, but they are not ready to be deployed at scale due to significant economic hurdles, and their current supply is insufficient to meet growing demand. The concrete, cement, and SCM/ACM industry will require innovative yet costly technological advancements to bring new SCMs/ACMs to market and fill the growing gap between supply and demand. These innovative advancements could bring SCMs/ACMs novel to market but they will required new or updated quality standards to meet concrete-grade specifications and support market acceptance. SCM/ACM

2.2 Project Definition

For the purpose of this protocol, the GHG reduction project is defined as the manufacturing of SCMs or ACMs that can partially or fully replace PC. The project results in the avoidance of GHG emissions from PC production.

SCM/ACM SCM/ACM
SCM/ACM SCMs or ACMs can be processed to display cementitious properties to replace some or all PC in concrete production and/or concrete products. Eligible projects must meet applicable ASTM standards (Section 3.6). A single project may consist of a single eligible SCM/ACM or more than one type of eligible SCM/ACM.
SCM/ACM SCM/ACM SCM/ACM
Project crediting shall occur at an SCM/ACM manufacturing site or group of SCM/ACM manufacturing sites. A SCM/ACM manufacturing site is defined as a site that processes or manufacturers upgraded and/or novel SCM/ACMs. The protocol is applicable to eligible SCMs/ACMs that are sold domestically within the project country. As discussed further in Section 3.4, eligible SCMs/ACMs must also exceed the Legal Requirement Test and meet the Performance Standard Test. The baseline scenario for all projects is the production/supply of PC in the project region.

Multiple eligible SCMs/ACMs may be produced at a single manufacturing site. If additional eligible SCMs/ACMs are produced at an existing qualifying manufacturing site, this is considered a project expansion. If the project developer chooses to define an additional activity as a project expansion, the project start date and crediting period remain the same as the original project, and a single project verification will cover all activities. If the project developer defines the additional activity as a new project, the project will require a new start date and crediting period, and the new project will require separate verification.

The Reserve has identified SCM/ACM products that are ineligible under the protocol. This version of the protocol does not apply to the production of:

- Portland Limestone Cement (PLC)
- Traditional fresh fly ash
- Traditional GGBFS
- Silica fume

Appendices A and B include further information on project eligibility.

SCM/ACM

SCM/ACM SCM/ACM

The following is a positive list of potentially eligible SCM/ACM under the protocol. This list is non-inclusive with an aim to remain technology agnostic and encourage the development and use of other potential novel SCMs/ACMs. For a SCM/ACM to be considered eligible under the protocol, the SCM/ACM must be additional and meet quality standards (Sections 3.4 and 3.6).

- Beneficiated ash (upgraded and/or harvested fly or bottom ash)
- Raw natural pozzolans (i.e. volcanic ash)
- Ground glass pozzolans
- Calcined clays/shale and/or metakaolin
- Limestone calcined clay cements (LC3)
- CO_2 / Biochar
- Other artificial pozzolans or treated calcined materials (including rice husk ash)
- Other waste by-products (including Bauxite residue (Red Mud), lime kiln dust, or cement kiln dust)
- Novel ACMs (including clinkered, calcined, and non-clinkered materials)
- Hydroxide products (including portland ite ($Ca(OH)_2$) and brucite ($Mg(OH)_2$))
- Other novel SCM/ACM s (including biogenic limestone, etc)
- Blends including one or more of the SCM/ACM listed above

SCM/ACM SCM/ACM SCM/ACM SCM/ACM SCM/ACM

SCM/ACM SCM/ACM SCM/ACM

SCMs or ACMs that make up the project must be defined by the project developer at the time of project submittal. The SCM/ACM or mix of SCMs/ACMs must either partially or fully replace PC during cement production or at the ready-mix concrete facility. The monitoring requirements are further discussed in Section 6.

SCM/ACM SCM/ACM SCM/ACM SCM/ACM

2.3 The Project Developer

The "project developer" is an entity that has an active account on the Reserve, submits a project for listing and registration with the Reserve, and is ultimately responsible for all project reporting and verification. Project developers may be SCM/ACM suppliers and manufacturers, low-carbon cement technology suppliers, or entities that specialize in project development. The project developer must have clear ownership of the project's GHG reductions. Ownership of the GHG reductions must be established by clear and explicit title, and the project developer must attest to such ownership by signing the Reserve's Attestation of Title form.[13] The default project developer is the SCM/ACM producer r, unless the rights to the emissions reductions have been transferred to another entity.

2.4 Project Aggregation

[13] Attestation of Title form available at https://www.climateactionreserve.org/wp-content/uploads/2019/12/Attestation-Title-12-16-19.docx

Eligible projects may be aggregated to improve cost-effectiveness while maintaining rigor in overall carbon inventory accounting. Individual projects at the same or multiple locations can benefit through participation in an aggregate by grouping a number of the same SCM/ACM projects to align with typical sales structures within the cement and concrete industry. Similarly, verification of aggregated projects is considered across the broader population, which reduces the verification costs to individual projects participating in an aggregate. An aggregate consists of two or more individual Low-Carbon Cement projects that would not be financially viable without the potential for aggregation (i.e. less than X tonnes of SCM/ACM production). For more information, please refer to the Guidelines for Aggregating Low-Carbon Cement Projects.

3 Eligibility Rules

Projects that meet the definition of a GHG reduction project in Section 2.2 must fully satisfy the following eligibility rules to register with the Reserve.

Eligibility Rule I:	Location	⟶	*U.S. and its tribal lands and territories*
Eligibility Rule II:	Project Start Date	⟶	*No more than 12 months prior to project submission*
Eligibility Rule III:	Project Crediting Period	⟶	*Emission reductions may only be reported during the crediting period; the crediting period may be renewed one time*
Eligibility Rule IV:	Additionality	⟶	*Exceed legal requirements*
		⟶	*Meet performance standard*
Eligibility Rule V:	Regulatory Compliance	⟶	*Compliance with all applicable laws*
Eligibility Rule VI:	Quality	⟶	*Meet appliable standards*

3.1 Location

Under this protocol, only projects located in the United States, U.S. tribal lands and territories are eligible to register with the Reserve.[14] All phases of sourcing, production, and end use of the SCM/ACM must occur in the United States, U.S. tribal lands and territories. Project activities may occur in locations where activities from other carbon project types are occurring, as long as such projects are in good standing with the program in which they were or are enrolled. However, such project stacking is subject to prior approval from the Reserve and guidance for any adjustments that may be required of the Low-Carbon Cement project to ensure additionality and to prevent double-counting of credits.

3.2 Project Start Date

[14] The Reserve anticipates that this protocol could be applied throughout some regions internationally. To expand its applicability, data and analysis supporting the appropriate performance standard for other countries would have to be conducted accordingly. Refer to Appendices A and B for information on the performance standard analysis supporting application of this protocol.

The project start date is defined as the date on which production commences of eligible SCM/ACM as defined in Section 2.2. This protocol is applicable to projects that generate eligible SCM/ACM at greenfield SCM/ACM manufacturing sites or in existing SCM/ACM manufacturing sites that increase capacity, install new technology, or enhance existing technology that results in the production of new types of eligible SCM/ACMs.

To be eligible, the project must be submitted to the Reserve no later than 12 months after the project start date.[15] The start date is defined in relation to the commencement of SCM/ACM production, not other activities that may be associated with project initiation or research and development. Any project comprised of multiple SCM/ACM manufacturing sites must select a single project start date, which shall be within the initial 12-month start-up period for the first manufacturing site in the project. Additional project activities may be implemented at the same manufacturing site in the same project at any time; however, project developers must submit a revised listing form covering these additional eligible SCMs/ACMs by the end of each additional SCM/ACM 12-month initial start-up period, to indicate that the SCM/ACM manufacturer will begin reporting with the project by the end of that start-up period.

Projects may always be submitted for listing by the Reserve prior to their start date. For projects that are transferring to the Reserve from other offset registries, start date guidance can be found in the Reserve Offset Program Manual.[16]

3.3 Project Crediting Period

The crediting period for projects under this protocol is ten years. At the end of a project's first crediting period, project developers may apply for eligibility under a second crediting period. However, the Reserve will cease to issue CRTs for GHG reductions if, at any point in the future, the production of eligible SCM/ACM or the inclusion of eligible SCM/ACM sin concrete becomes legally required, as defined by the terms of the legal requirement test (see Section 3.4.1). Thus, the Reserve will issue CRTs for GHG reductions quantified and verified according to this protocol for a maximum of two ten-year crediting periods after the project start date, or until the project activity is required by law, including under an emissions cap or other emissions trading scheme (ETS).

The project crediting period begins at the project start date regardless of whether sufficient monitoring data is available to verify GHG reductions. However, the project will not start generating credits until monitoring data is available which must begin within 12 months after the start date of the project (see Section 6.3). Projects will be eligible to apply for a second crediting period, provided the project meets the eligibility requirements of the most current version of the protocol at the time of such application. If a project developer wishes to apply for eligibility under a second ten-year crediting period, they must do so no sooner than six months before the end date of the initial crediting period.

A project may be eligible for a second crediting period even if the project has failed to maintain continuous reporting up to the time of applying for a second crediting period, provided the project developer elects to take a zero-credit reporting period for any period for which

[15] Projects are considered submitted when the project developer has fully completed and filed the appropriate Project Submittal Form, available at: http://www.climateactionreserve.org/how/program-resources/documents.
[16] Please refer to the most current version of the Reserve Offset Program Manual, available at: http://www.climateactionreserve.org/how/program/program-manual/.

continuous reporting was not maintained.[17] The second crediting period shall begin on the day following the end date of the initial crediting period.

3.4 Additionality

The Reserve strives to register only projects that yield surplus GHG reductions that are additional to what would have occurred in the absence of a carbon offset market.

Projects must satisfy the following tests to be considered additional:

1. The Performance Standard Test
2. The Legal Requirement Test

3.4.1 The Performance Standard Test

For this protocol, the Reserve uses a technology-specific threshold, sometimes referred to as a practice-based threshold. The Performance Standard Test employed by this protocol is based on a national assessment of “common practice” for use of SCM/ACM to replace PC and reduce emissions. The performance standard defines the SCMs/ACMs that the Reserve has determined will exceed common practice and therefore generate additional GHG reductions. A summary of the study and analysis used to establish the Performance Standard Test is provided in Appendix B.

The Performance Standard Test is applied at the time a project applies for registration with the Reserve. Once a project is registered, it does not need to be evaluated against future versions of the protocol or the Performance Standard Test for the duration of its first crediting period.

If a project developer wishes to apply for a second crediting period, the project must meet the requirements of the most current version of this protocol, including any updates to the Performance Standard Test. A summary of the Reserve’s research on the Performance Standard Test is provided in Appendix B.

3.4.2 The Legal Requirement Test

All projects are subject to a Legal Requirement Test to ensure that the GHG reductions achieved by a project would not otherwise have occurred due to federal, state, or local regulations, or other legally binding mandates. A project passes the Legal Requirement Test when there are no laws, statutes, regulations, court orders, environmental mitigation agreements, permitting conditions, or other legally binding mandates (e.g., cap-and-trade programs, emissions trading schemes) requiring the production of a SCM/ACM at the project site or use of a SCM/ACM as a cementitious material.

The legal requirement test is applicable to all three phases of a project as follows:

1. The production of a SCM/ACM, including under the circumstances relevant to the project, must not be legally required;
2. The use of SCM/ACM in those ways it is being applied under the project is not legally mandated; and

[17] See zero-credit reporting period guidance and requirements in the Reserve Offset Program Manual, http://www.climateactionreserve.org/how/program-resources/program-manual.

3. Emissions from SCM/ACM manufacturing sites are not included under an emissions cap.

To satisfy the Legal Requirement Test, project developers must submit a signed Attestation of Voluntary Implementation form[18] prior to the commencement of verification activities each time the project is verified (see Section 8). In addition, the project's Monitoring Plan (Section 6) must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the Legal Requirement Test.

The Reserve did not identify any existing federal regulations that obligate the production or use of SCM/ACMs. However, some states have legal requirements which would deem the project ineligible based on the legal requirement test. A summary of the Reserve's research on legal requirements is provided in Appendix A.

If an eligible project begins operation at a SCM/ACM manufacturing site that later becomes subject to a regulation that calls for the production of eligible SCM/ACM or use of an eligible SCM/ACM in concrete, emission reductions may be reported to the Reserve up until the date that eligible SCM/ACMs are legally required to be produced or used. If the manufacturing site's emissions are included under an emissions cap, emission reductions may likewise be reported to the Reserve until the date that the emission cap takes effect.

3.5 Regulatory Compliance

As a final eligibility requirement, project developers must attest that project activities do not cause material violations of applicable laws (e.g., air, water quality, safety, etc.). To satisfy this requirement, project developers must submit a signed Attestation of Regulatory Compliance form[20] prior to the commencement of verification activities each time the project is verified. Project developers are also required to disclose in writing to the verifier any and all instances of legal violations – material or otherwise – caused by the project activities.

A violation should be considered to be "caused" by project activities if it can be reasonably argued that the violation would not have occurred in the absence of the project activities. If there is any question of causality, the project developer shall disclose the violation to the verifier.

If the verifier finds that project activities have caused a material violation, then CRTs will not be issued for GHG reductions that occurred during the period(s) when the violation occurred. Individual violations due to administrative or reporting issues, or due to "acts of nature," are not considered material and will not affect CRT crediting. However, recurrent administrative violations directly related to project activities may affect crediting. Verifiers must determine if recurrent violations rise to the level of materiality. If the verifier is unable to assess the materiality of the violation, then the verifier shall consult with the Reserve.

3.6 Quality Standards

[18] Attestation of Voluntary Implementation form available at https://www.climateactionreserve.org/wp-content/uploads/2019/12/Attestation-Voluntary-Implementation-12-16-2019.docx
[20] Attestation of Regulatory Compliance form available at https://www.climateactionreserve.org/wp-content/uploads/2019/12/Attestation-Regulatory-Compliance-12-16-19.docx

3.6.1 Applicable ASTM International Standards

Eligible SCM/ACM must meet applicable quality standards to ensure the product is competitive in the market and able to displace PC. ASTM International establishes procedures and standards for certifying specific cement and concrete products. The Reserve requires that for a project to be eligible, the SCM/ACM must meet any applicable ASTM standard which are summarized and referenced below. To meet this requirement, project developers must provide a copy of their ASTM report. If the SCM/ACM product does not have a specific ASTM standard, the Attestation of SCM/ACM Use form must support that the quality of the product meets end-use requirements and will be used to displace PC.

Table 3.1 ASTM Standards for Eligible SCM/ACM

Eligible SCM/ACM /ACM	**ASTM Standard Specifications**
Beneficiated ash	C618-23ε1: Standard Specification for Coal Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
Natural pozzolans	C618-23ε1: Standard Specification for Coal Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
Ground glass pozzolans	C1866/C1866M – 22: Standard Specification for Ground-Glass Pozzolan for Use in Concrete
Calcined clays/shale and/or metakaolin	C618-23ε1: Standard Specification for Coal Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
Limestone calcined clay cements (LC3)	C595/C595M – 21: Standard Specification for Blended Hydraulic Cements (or C1157/C1157M)
CO_2 / Biochar	Standard Specification for Cement that Hardens by Carbonation (in development)
Blends (including an eligible SCM/ACM)	C595/C595M – 21: Standard Specification for Blended Hydraulic Cements (or C1157/C1157M)
Manufactured ACMs	C989: Standard Specification for Slag Cement for Use in Concrete and Mortars*
Other artificial pozzolans or treated calcined materials (including rice husk ash)	**
Other waste by-products (including Bauxite residue (Red Mud), lime kiln dust, or cement kiln dust)	**
Hydroxide products (including portland ite ($Ca(OH)_2$) and brucite ($Mg(OH)_2$))	**
Other novel SCM/ACMs (biogenic limestone, etc)	**

*C989 is an example ASTM standard for manufactured ACMs. Other ASTM standards could be used instead if applicable for the product.
**These products do not currently have a specific ASTM standard. The protocol will be revised to include future ASTM standards for other SCM products which are currently under development.

3.6.2 Eligibility of Beneficiated Ash

Fresh fly ash is currently the most commonly used SCM in the U.S. for cement and concrete production. Based on market penetration rates at this time, fresh ash has been categorized as an ineligible project activity under the protocol. However, there is a significant amount of coal ash that is currently in a landfill or is being sent to a landfill because it does not meet the ASTM specifications and it is too costly to improve the product for use in the market. Based on the lack of beneficiated coal ash in the cement market today and significant capital and operational costs associated with its improvement, the protocol considers beneficiated coal ash to be an eligible project activity. This section of the protocol aims to explain what constitutes as beneficiated ash with respect to the ASTM C618-23ε1: Standard Specification for Coal Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. To meet eligibility requirements, the unprocessed product must be insufficient according to the referenced ASTM standard. To demonstrate the ash product has been beneficiated for the purposes of the protocol, the product must be tested before and after any beneficiation processes to show that the product was improved in at least one of the following chemical or physical requirement categories. For example, if the moisture content is above 3% and is processed to lower the moisture content below 3% the product would be considered beneficiated and eligible for the purposes of this protocol.

Table 3.2 Chemical Requirements under ASTM Standard C618-23ε1

Chemical Requirement	**Before Processing**	**After Processing**
Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3)	<50.0%	>50.0%
Sulfur trioxide (SO_3)	>5.0%	<5.0%
Moisture content	>3.0%	<3.0%
Loss on ignition	>6.0%	<6.0%

Table 3.3 Physical Requirements under ASTM Standard C618-23ε1

Physical Requirement	**Before Processing**	**After Processing**
Fineness (wet-sieved, retained on 45-μm (No. 325) sieve)	>34%	<34%
(retained on 150-μm (No. 100) sieve). Only applies to harvested coal ash or coal ash containing bottom ash.	> 10%	< 10%
Strength activity index	<75% of control at both 7 and 28 days	> 75% at either 7 or 28 days
Water requirement, max,	>105%	<105%

percent of control		
Uniformity Requirements - Density, max variation from average - Percent retained on 45-μm (No. 325)	>5%	<5%

4 The GHG Assessment Boundary

The GHG Assessment Boundary delineates the GHG sources, sinks, and reservoirs (SSRs) that shall be assessed by project developers in order to determine the total net change in GHG emissions caused by a low carbon cement project.

Figure 4.1 below provides a general illustration of the GHG Assessment Boundary, indicating which SSRs are included or excluded from the boundary. All SSRs within the dashed line are accounted for under this protocol.

Table 4.1 provides greater detail on each SSR and provides justification for the inclusion or exclusion of SSRs from the GHG Assessment Boundary.

Figure 4.1. General illustration of the GHG Assessment Boundary

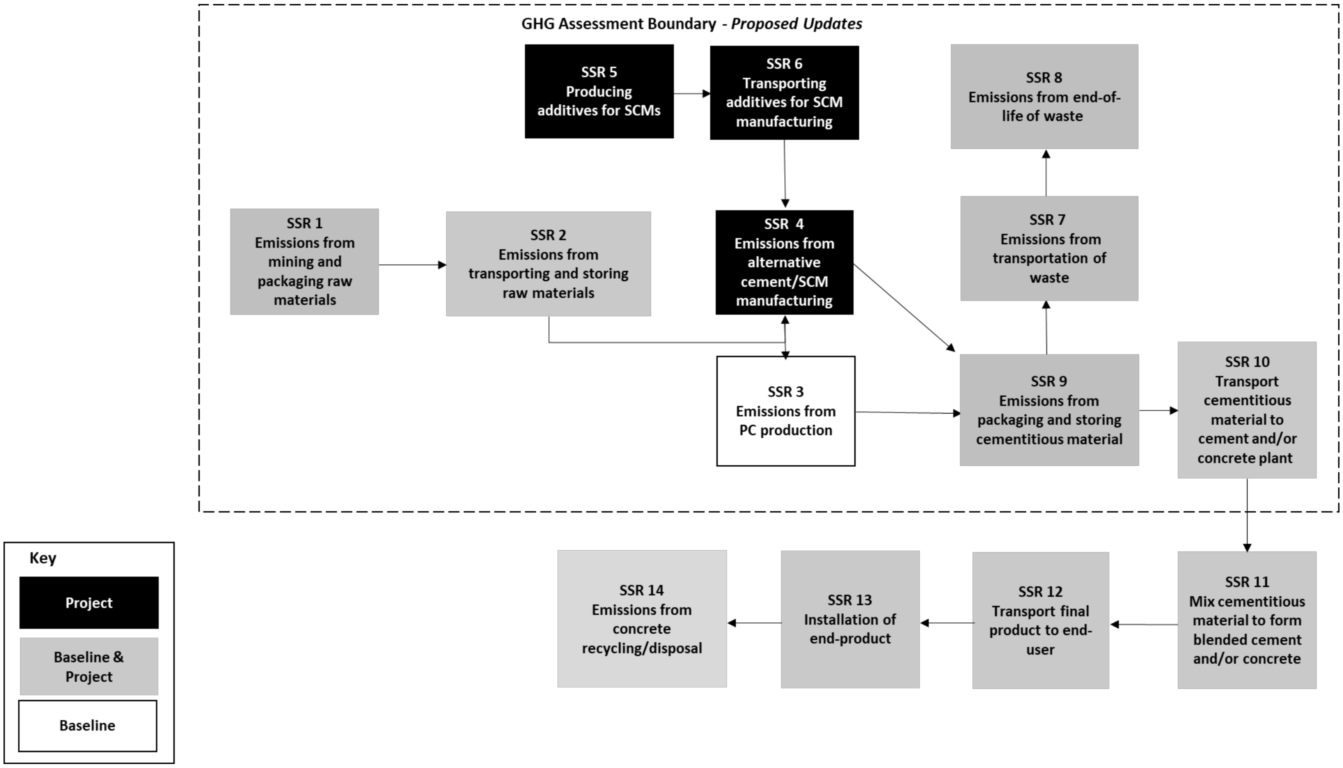


Table 4.1. Summary of identified sources, sinks, and reservoirs for low-carbon cement projects

SSR	Source Description	Gas	Included (I) or Excluded I	Baseline (B) or Project (P)	Quantification Method	Justification/ Explanation
1	Emissions from mining raw material	CO_2	I	B, P	N/A	A GHG project will directly impact these emissions. Calculated in reference to mining emissions.
		CH_4	E	B, P	N/A	Excluded, as project activity is unlikely to impact emission relative to baseline activity
		N_2O	E	B, P	N/A	Excluded, as project activity is unlikely to impact emission relative to baseline activity
2	Emissions from transportation and storage of raw materials	CO_2	I	B, P	GHG emissions based on distance and emission factor for mode of transportation.	A GHG project will directly impact these emissions. Calculated in reference to transportation emissions.
		CH_4	E	B, P	N/A	Excluded, as this emission source is considered negligible.
		N_2O	E	B, P	N/A	Excluded, as this

						emission source is considered negligible.
3	Emissions from PC production	CO_2	I	B	GHG emissions based on electricity, fuel consumption, and calcination.	Energy consumption and calcination are primary sources of emissions for PC production. Calculated in reference to PC production. A GHG project will directly impact these emissions.
		CH_4	E	B	N/A	Excluded, as this emission source is considered negligible.
		N_2O	E	B	N/A	Excluded, as this emission source is considered negligible.

SSR	Source Description	Gas	Included (I) or Excludl(E)	Baseline (B) or Project (P)	Quantification Method	Justification/ Explanation
4	Emissions from SCM/ACM manufacturing	CO_2	I	P	GHG emissions based on electricity and fuel consumption.	Energy consumption is a primary source of emissions for SCM/ACM manufacturing. A GHG project will directly impact these emissions.
		CH_4	E	P	N/A	Excluded, as this emission source is considered negligible.
		N_2O	E	P	N/A	Excluded, as this emission source is considered negligible.
5	Emissions from transportation of waste	CO_2	I	B, P	GHG emissions based on distance and emission factor for mode of transportation.	A GHG project will directly impact these emissions. Calculated in reference to transportation emissions.
		CH_4	E	B, P	N/A	Excluded, as this emission source is considered negligible.
		N_2O	E	B, P	N/A	Excluded, as this emission source is considered negligible.
6	Emissions from production of additives	CO_2	I	P	GHG emissions based on electricity and fuel consumption.	A GHG project will directly impact these emissions if additives make up a significant portion of the final product. The source is considered negligible if additives make up 5% or less of the final SCM/ACM by weight. If additives make up greater than 5%

						of the final SCM/ACM product by weight, the emissions associated with the primary additive(s) must be calculated in reference to additive production, however, secondary additives may be excluded from the calculation up to 5% of the total SCM/ACM product by weight.
		CH_4	E	P	N/A	Excluded, as this emission source is considered negligible.
		N_2O	E	P	N/A	Excluded, as this emission source is considered negligible.

SSR	Source Description	Gas	Included (I) or Excled (E)	Baseline (B) or Project (P)	Quantification Method	Justification/ Explanation
7	Emissions from transportation of additives	CO_2	I	P	GHG emissions based on distance and emission factor for mode of transportation.	A GHG project will directly impact these emissions if additives make up a significant portion of the final product. The emission source is considered negligible if additives make up 5% or less of the final SCM/ACM product by weight. If additives make up greater than 5% of the final SCM/ACM product by weight, the transportation emissions associated with the primary additive(s) must be calculated in reference to transportation emissions. However, the transportation of secondary additives may be excluded from the calculation up to 5% of the total SCM/ACM product by weight.
		CH_4	E	P	N/A	Excluded, as this emission source is considered negligible.
		N_2O	E	P	N/A	Excluded, as this emission source is considered negligible.
8	Emissions from End-of-Life Waste	CO_2	I	B, P	N/A	A GHG project will directly impact these emissions. Calculated in reference to landfill, incineration, or recycling.
9	Emissions	CO_2	I	B, P	GHG emissions	Calculated in reference to

	from packaging and storing cement				based on electricity and fuel consumption.	energy consumption.
		CH_4	E	B, P	N/A	Excluded, as this emission source is considered negligible.
		N_2O	E	B, P	N/A	Excluded, as this emission source is considered negligible
10	Emissions from transportation of cement	CO_2	I	B, P	N/A	A GHG project will directly impact these emissions. Calculated in reference to transportation emissions.
		CH_4	E			Excluded, as this emission source is considered negligible.
		N_2O	E			Excluded, as this emission source is considered negligible
11	Emissions from concrete production	CO_2	E	B,P	N/A	Energy consumption is a primary source of emissions for SCM/ACM manufacturing. A GHG project will directly impact these emissions.
		CH_4	E			Excluded, as this emission source is considered negligible.
		N_2O	E			Excluded, as this emission source is considered negligible.
SSR	**Source Description**	**Gas**	**Included (I) or Iluded (E)**	**Baseline (B) or Project (P)**	**Quantification Method**	**Justification/ Explanation**
12	Emissions from concrete transportation and installation	CO_2 CH_4 N_2O	E	B,P	N/A	Excluded, as project activity is unlikely to impact emission relative to baseline activity
13	Emissions from concrete recycling or disposal	CO_2 CH_4 N_2O	E	B,P	N/A	Excluded, as project activity is unlikely to impact emission relative to baseline activity
14	Emissions from installation of end-product	CO_2 CH_4 N_2O	E	B,P	N/A	Excluded, as project activity is unlikely to impact emission relative to baseline activity
15	Emissions from concrete recycling/di	CO_2	E	B,P	N/A	Excluded, as project activity

	sposal					is unlikely to impact emission relative to baseline activity

5 Quantifying GHG Emission Reductions

GHG emission reductions from a low-carbon cement project are quantified by comparing actual project emissions to baseline emissions at a PC production site. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary (see Section 4) that would have occurred in the absence of the low-carbon cement project. Project emissions are actual GHG emissions that occur at sources within the GHG Assessment Boundary when implementing the low-carbon project. Project emissions must be subtracted from the baseline emissions to quantify the project's total net GHG emission reductions (Equation 5.1).

Equation 5.1. Calculating GHG Emission Reductions

$$ER = BE - PE$$

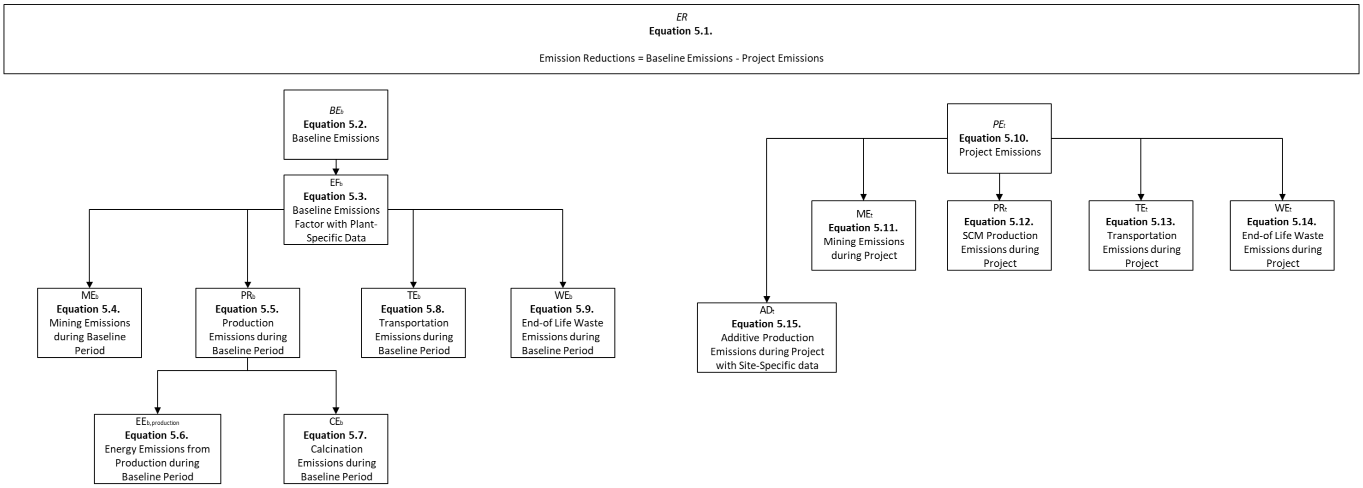
Where,

			Units
ER	=	Total emission reductions for reporting period.	tCO_2e
BE	=	Total baseline emissions from all SSRs in the GHG Assessment Boundary, see Equation 5.2.	tCO_2e
PE	=	Total project emissions from all SSRs in the GHG Assessment Boundary, see Equation 5.9.	tCO_2e

GHG emission reductions must be quantified and reported on at least an annual basis. Such reports must be verified on a schedule in accordance with the requirements of Section 7.3. Project developers may choose to quantify and verify GHG emission reductions on a more frequent basis if they desire. The length of time over which GHG emission reductions are quantified and reported is called the "reporting period".

Project developers shall use the calculation methods provided in this protocol to determine baseline and project GHG emissions in order to quantify GHG emissions reductions. Figure 5.1 illustrates the relationships between the various equations used in this section.

Figure 5.1. Organizational Chart of Equations for Low-Carbon Cement Projects



5.3 Quantifying Baseline Emissions

Baseline emissions represent the GHG emissions within the GHG Assessment Boundary that would have occurred in the absence of the low-carbon cement project. Total baseline emissions for the reporting period are estimated by calculating and summing the emissions from all relevant baseline SSRs that are included in the GHG Assessment Boundary (as indicated in Figure 4.1 and Table 4.1). The calculation of baseline emissions in Equation 5.2 requires inputs related to PC production, the appropriate weight adjustment factor, and the appropriate emission factor.

Equation 5.2. Quantifying Total Baseline GHG Emissions

$$BE = (Q_b \times R_b \times EF_b)$$

Where,			Units
BE	=	Total baseline emissions for the reporting period, from all SSRs in the GHG Assessment Boundary.	tCO_2e
Q_b	=	Total quantity of PC that would have been produced during the reporting period.	tonnes
R_b	=	PC to SCM/ACM weight adjustment factor in percent during the reporting period.	percent
EF_b	=	CO_2 emission factor for PC production during the reporting period.	tCO_2e/tonne of PC

Records that may satisfy a verifier as to quantity of PC that would have been produced may include invoices, sales records, receipts, or sales contracts for SCM/ACM production and sale during the reporting period. This list is not exhaustive and is meant to provide a few examples of evidence that may satisfy a verifier.

The weight adjustment factor refers to the amount of SCM/ACM required to replace one tonne of PC. For example, if one tonne of PC could be replaced by one tonne of aSCM/ACM , the weight adjustment factor would be 1:1. However, if two tonnes of PC could be replaced with one tonne of a SCM/ACM , the weight adjustment factor would be 2:1 (PC:SCM/ACM). The weight adjustment factor can be determined through secondary materials including concrete mix designs, ASTM standards, scientific studies, laboratory tests, or similar documentation that would be acceptable to a verifier. Section 6 further discusses appropriate materials for monitoring. The weight adjustment factor must be reported once at validation.

5.1.1 Hierarchical Approaches for Determining Baseline PC Emission Factor

The determination of the emission factor for PC production is carried out using one of the following three hierarchical approaches:

5.1.1.1 Historical PC production records using plant-specific data
5.1.1.2 Regional emission factor using PC Environmental Product Declaration (EPD)

5.1.1.1 Quantifying PC Emission Factor from Plant-Specific Data (Approach 1)

If the facility location and source of PC (baseline) emissions are known, project developers must use Approach 1 with plant-specific data if historical production records or data to support historical production are available. Approach 1 would ensure site specificity and the closest depiction of the historical PC production practices at the site. Three years' worth of data from the baseline look-back period is required to set an average mining emission factor, transport emission factor, and production emission factor (Equation 5.3). Records that may satisfy a verifier as to historical PC production may include energy bills, fuel use receipts, invoices or receipts for clinker. This list is not exhaustive and is meant to provide a few examples of evidence that may satisfy a verifier. Written records of some or all of the above will be necessary.

Project developers are encouraged to seek guidance from the Reserve to ensure the reports they intend to provide are sufficient. If insufficient data exists for Approach 1, then project developers may use either Approach 2 or Approach 3.

For equations with emission factors, project developers must use the cited Environmental Protection Agency (EPA) eGRID subregion emission factors for electricity and emission factors from the EPA's Emissions Factor Hub for fuel consumption. If project developers would like to use alternative emission factors, there must be reasonable justification (i.e. that an emission factor from a local utility is a better representation than the subregional emission factor from eGRID) to support that these values are more accurate than the EPA emission factor values.

Equation 5.3. Quantifying Baseline Emission Factor from Plant-Specific Data

$$EF_b = \frac{(ME_b + PR_b + TE_b + WE_b)}{Q}$$

Where,			Units
EF_b	=	CO_2 emission factor for PC production during the look-back period.	tCO_2e/tonne of PC
ME_b	=	Mining emissions for PC production during the look-back period.	tCO_2e
PR_b	=	Production emissions for PC production during the look-back period.	tCO_2e
TE_b	=	Transport emissions for PC production during the look-back period.	tCO_2e
WE_b	=	End-of-life waste emissions for PC production during the look-back period.	tCO_2e
Q	=	Quantity of PC produced during the look-back period.	Tonnes

Equation 5.4. Quantifying Mining Emissions for PC Production from Plant-Specific Data

$$ME_b = (EL_{b,mining,grid} \times EF_{b,mining,grid}) + (FC_{b,mining} \times EF_{b,mining,fuel})$$

Where,			Units
ME_b	=	Mining emissions for PC production during the look-back period.	tCO_2e
$EL_{b,mining,grid}$	=	Grid electricity consumption for PC mining during the look-back period.	kWh
$EF_{b,mining,grid}$	=	CO_2 emission factor for grid electricity consumed from the most recent U.S. Environmental Protection Agency (EPA) eGRID emission factor publication.[21] Projects shall use the most recent total output emission rates for thesubregion where the project is located.	tCO_2/kWh
$FC_{b,mining}$	=	Fuel consumption for PC mining during the look-back period.	Tonnes of fuel
$EF_{b,mining,fuel}$	=	CO_2 emission factor for fuel consumed from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[22] Projects shall use the CO_2 factor for the appropriate fuel type.	tCO_2e/ tonne of fuel

[21] Available online at: https://www.epa.gov/egrid
[22] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

Equation 5.5. Quantifying Production Emissions for PC Production from Plant-Specific Data

$$PR_b = EE_b + CE_b$$

Where,

			Units
PR_b	=	Production emissions for PC production during the look-back period.	tCO_2e
EE_b	=	Energy emissions for PC production during the look-back period (calculated in Equation 5.6.).	tCO_2e
CE_b	=	Calcination emissions for PC production during the look-back period (calculated in Equation 5.7.).	tCO_2e

Equation 5.6. Quantifying Energy Emissions for PC Production from Plant-Specific Data

$$EE_b = (EL_{b,production,grid} \times EF_{b,production,grid}) + (FC_{b,production} \times EF_{b,production,fuel})$$

Where,

			Units
EE_b	=	Energy emissions for PC production during the look-back period.	tCO_2e
$EL_{b,production, grid}$	=	Grid electricity consumption for PC production during the look-back period.	kWh
$EF_{b,production,grid}$	=	CO_2 emission factor for grid electricity consumed from the most recent EPA eGRID emission factor publication.[23] Projects shall use the most recent annual total output emission rates for the subregion where the project is located.	tCO_2/kWh
$FC_{b,production}$	=	Fuel consumption for PC production during the look-back period.	Tonnes of fuel
$EF_{b,production,fuel}$	=	CO_2 emission factor for fuel consumed from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[24] Projects shall use the CO_2 factor for the appropriate fuel type.	tCO_2e/ tonne of fuel

Equation 5.7. Quantifying Calcination Emissions for PC Production from Plant-Specific Data

$$CE_b = R_{b,clinker} \times EF_{b,clinker}$$

[23] Available online at: https://www.epa.gov/egrid
[24] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

Where,			Units
CE_b	=	Calcination emissions for PC production during the look-back period.	tCO_2e
$R_{b,clinker}$	=	Clinker to cement ratio for PC production during the look-back period.	Percent
$EF_{b,clinker}$	=	CO_2 emission factor forclinker during the reporting period from the most recent national emissions data (see below information).[25]	tCO_2e/ tonne of clinker

PC, by ASTM definition, is required to be 90-95% clinker. As clinker production emissions are proportional to the lim content in the clinker, which does not vary across time or between cement faiclities, a conservative IPCC default emission factor (0.510 tCO2e/t clinker) can be employed.[26]
Project developers must use this default emission factor for clinker unless they have verifiable evidence to support use of a different emission factor for a higher or lower clinker ratio in the baseline PC project.

Equation 5.8. Quantifying Transport Emissions for PC Production with Plant-Specific Data

$$TE_b = \sum d_b \times EF_{b,transport}$$

Where,			Units
TE_b	=	Transport emissions for PC production during the look-back period.	tCO_2e
d_b	=	Fuel quantity or distance traveled for PC production during the look-back period.	Gallons hours miles
$EF_{b,29ransport}$	=	CO_2 emission factor for mode of transport from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[27] Projects shall use the CO_2 factor for the appropriate transportation mode.	tCO_2e/ unit

Equation 5.9. Quantifying End-of-Life Waste Emissions from PC Production with Plant-Specific Data

$$WE_b = \sum_s qw_{b,s} \times EF_{b,s,waste}$$

Where,			Units
WE_b	=	End-of-life waste emissions generated during PC manufacturing	tCO_2e
qw_b	=	Quantity of waste generated during PC manufacturing.	tonnes
$EF_{b,transport}$	=	CO_2 emission factor for end-of-life of waste from the most recent ecoinvent[28]. Projects shall use the CO_2 factor for the appropriate disposal method (landfill, incineration, recycling.	tCO_2/ t

[25] For example, the Global Cement and Concrete Association's Getting the Numbers Right (GNR) Database publishes worldwide data for OPC production. This database was previously managed by the World Business Council for Sustainable Development's Cement Sustainability Initiative. The GNR database can be found here: https://www.cement-co2-protocol.org/en/Content/Internet_Manual/linebyline-calculatedonly.htm#kanchor996
[26] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cement-co2-protocol.org/en/Content/Resources/Downloads/WBCSD_CO2_Protocol_En.pdf
[27] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[28] https://ecoinvent.org/the-ecoinvent-database/

5.1.1.2 Quantifying a Regional PC Emission Factor (Approach 2)

Where the source of PC (baseline) is not known and Approach 1 is not applicable, project developers must use Approach 2 which was developed by the Reserve to quantify a regional PC emission factor through use of the industry-wide type III environmental product declarations (EPDs) for PC and regional emission factors for fuel mixes and grid electricity. See Appendix C for more information.Project developers who wish to utilize Approach 2 should use the LLCQuant Tool to determine the baseline emissions for their project according to the below equations.

Equation 5.10. Quantifying Regional Baseline Emission Factor

$$EF_{b,r} = PME_{b,r} + TE_{b,a} + WE_{b,a}$$

Where,			Units
$EF_{b,r}$	=	Regional average CO_2 emission factor for PC production during the look-back period.	tCO_2e/tonne of PC
$PME_{b,r}$	=	Regional average production and mining emission factor for PC production during the look-back period (calculated with Equations 5.12 .and 5.13.). $EE_{b,r}$ below includes both energy consumption for PC production and mining of raw materials.	tCO_2e /tonne of PC
$TE_{b,a}$	=	Average transport emission factor for PC production during the look-back period (0.01 tCO_2e /tonne of PC).	tCO_2e /tonne of PC
$WE_{b,a}$	=	Average end-of-life waste emission factor for PC production during the look-back period (0 tCO_2e /tonne of PC).	tCO_2e /tonne of PC

Equation 5.12. Quantifying Regional Production Emissions for PC Production (PR_b)

$$PR_{b,r} = EE_{b,r} + CE_{b,a}$$

Where,			Units
$PME_{b,r}$	=	Regional production emission factor for PC production and mining during the look-back period.	tCO_2e /tonne of PC
$EE_{b,r}$	=	Regional energy emissions for PC production and mining during the look-back period (calculated with Equation 5.13.).	tCO_2e /tonne of PC
$CE_{b,a}$	=	Average calcination emissions for PC production during the look-back period (0.48 tCO_2e /tonne of PC.).	tCO_2e /tonne of PC

Equation 5.13. Quantifying Regional Energy Emissions for PC Production

$$EE_{b,r} = (EL_{b,a,production,mining,,grid} \times EF_{b,production,mining,grid}) + (FC_{b,a,production,mining} \times EF_{b,r,production,mining,fuel})$$

Where,			Units
$EE_{b,r}$	=	Reginal energy emission factor for PC production and mining during the look-back period.	tCO_2e/tonne of PC
$EL_{b,a,production, grid}$	=	Average grid electricity consumption for PC production and mining = 0.152.	MWh/tonne of PC
$EF_{b,production,grid}$	=	CO_2 emission factor for grid electricity consumed from the most recent EPA eGRID emission factor publication.[29] Projects shall use the most recent annual total output emission rates for the subregion where the project is located (see Table 5.1.).	tCO_2e/kWh
$FC_{b,a,production}$	=	Fuel consumption for PC production = 3.8.[30]	mmBTU/tonne of PC
$EF_{b,r,production,fuel}$	=	CO_2 emission factor for fuel consumed. Projects shall use the emission factors provided for the subregion where the project is located (see Table 5.2.).	tCO_2e/ mmBTU

[29] Available online at: https://www.epa.gov/egrid

[30] The average amount of fuel consumed for PC mining and production processes was determined by subtracting the amount of average grid electricity consumed for PC mining and production (0.52 mmBTU) from the total energy consumption found within the PCA's Labor Energy Survey at 4.282 mmBTU/tonne of PC. Available online at: www.cement.org/docs/default-source/market-economics-pdfs/more-reports/labor-energy-sample-2.pdf?sfvrsn=6&sfvrsn=6

Table 5.1 Regional Emission Factors for Grid Electricity Consumed from the Most recent EPA eGRID emission factor publication.

eGRID subregion acronym	eGRID subregion name	CO2e (t/MWh)
AKGD	ASCC Alaska Grid	0.54
AKMS	ASCC Miscellaneous	0.24
AZNM	WECC Southwest	0.41
CAMX	WECC California	0.27
ERCT	ERCOT All	0.41
FRCC	FRCC All	0.42
HIMS	HICC Miscellaneous	0.57
HIOA	HICC Oahu	0.82
MROE	MRO East	0.80
MROW	MRO West	0.50
NEWE	NPCC New England	0.27
NWPP	WECC Northwest	0.32
NYCW	NPCC NYC/Westchester	0.41
NYLI	NPCC Long Island	0.61
NYUP	NPCC Upstate NY	0.12
PRMS	Puerto Rico Miscellaneous	0.78
RFCE	RFC East	0.34
RFCM	RFC Michigan	0.61
RFCW	RFC West	0.53
RMPA	WECC Rockies	0.58
SPNO	SPP North	0.50
SPSO	SPP South	0.52
SRMV	SERC Mississippi Valley	0.39
SRMW	SERC Midwest	0.78
SRSO	SERC South	0.45
SRTV	SERC Tennessee Valley	0.47
SRVC	SERC Virginia/Carolina	0.32
U.S.		0.43

Table 5.2. Estimated Regional Emission Factors for Fuel Consumption by Fuel Mix and Production Volumes.

State	Region	State EF (kg CO2/mmBtu)	Regional EF (tCO2/mmBtu)
Illinois	MW		
Indiana	MW		
Iowa	MW		
Kansas	MW		
Michigan	MW		
Missouri	MW		
Nebraska	MW		
Ohio	MW		
South Dakota	MW		
Maine	NE		
New York	NE		
Pennsylvania	NE		
Alabama	S		
Arkansas	S		
Florida	S		
Georgia	S		
Kentucky	S		
Maryland	S		
Oklahoma	S		
South Carolina	S		
Tennessee	S		
Texas	S		
Virginia	S		
West Virginia	S		
Arizona	W		
California	W		
Colorado	W		
Montana	W		
Nevada	W		

New Mexico	W		
Oregon	W		
Utah	W		
Washington	W		
Wyoming	W		

5.4 Quantifying Project Emissions

Project emissions are actual GHG emissions that occur within the GHG Assessment Boundary as a result of the project activity. Project emissions must be quantified every reporting period on an *ex post* basis.

As shown in equation 5.10, project emissions equal:

- Emissions from mining, plus
- Emissions from transportation of mined inputs from mine processing plant to processing facility, plus
- Emissions from the production of SCMs/ACMs, plus
- Emissions from the transportation of SCMs/ACMs to storage (if applicable) and transportation of waste (if applicable), plus
- Emissions from the production and transportation of additives (additives may include chemical activators, minerals, or other additional materials that are added in the low-carbon cement replacement for PC) if additives make up more than 5% of the final SCM/ACM by weight. If additives make up greater than 5% of the final SCM/ACM product by weight, the emissions associated with the primary additive(s) must be calculated in reference to additive production, however, secondary additives may be excluded from the calculation up to 5% of the total SCM/ACM product by weight. If total additives make up 5% or less of the final SCM/ACM product by weight, these emissions are considered negligible. See Section 5.2.1 for additional information on additives.
- Emissions from the transportation of SCMs/ACMs to the ready-mix concrete facility.

For equations with emission factors, project developers must use the cited Environmental Protection Agency (EPA) eGRID subregion emission factors for electricity and emission factors from the EPA's Emissions Factor Hub for fuel consumption. If project developers would like to use alternative emission factors, there must be reasonable justification (i.e. that an emission factor from a local utility is more representative than the broader subregion value from eGRID) to support that these values are more accurate than the EPA emission factor values.

Equation 5.10. Quantifying Project Emissions for SCM/ACM Manufacturing

$$PE = \sum_s ME_{t,s} + PR_{t,s} + TE_{t,s} + WE_{t,s} + AD_{t,s}$$

Where,			Units
PE	=	Project emissions for SCM/ACM manufacturing during the reporting period.	tCO_2e
$ME_{t,s}$	=	Mining emissions for SCM/ACM manufacturing during the reporting period for all eligible SCM/ACM "s".	tCO_2e
$PR_{t,s}$	=	Production emissions for SCM/ACM manufacturing during the reporting period for all eligible SCM/ACM "s".	tCO_2e
$TE_{t,s}$	=	Transport emissions for SCM/ACM inputs to manufacturing, storage, additives, delivery, and waste during the reporting period for all eligible SCM/ACM "s".	tCO_2e
$WE_{t,s}$		End-of-life of waste emissions generated during SCM/ACM manufacturing	tCO_2e
$AD_{t,s}$	=	Additive production emissions for SCM/ACM manufacturing during the reporting period.	tCO_2e

Equation 5.11. Quantifying Mining Emissions for SCM/ACM Manufacturing

$$ME_t = (EL_{t,mining,grid} \times EF_{t,mining,grid}) + (FC_{t,mining} \times EF_{t,mining,fuel})$$

Where,			Units
ME_t	=	Mining emissions for inputs to SCM/ACM manufacturing during the reporting period.	tCO_2e
$EL_{t,mining,grid}$	=	Grid electricity consumption for SCM/ACM mining during the reporting period.	kWh
$EF_{t,mining,grid}$	=	CO_2 emission factor for grid electricity consumed during mining in the reporting period from the most recent EPA eGRID emission factor publication.[32] Projects shall use the annual total output emission rates for the subregion where the project is located.	tCO_2/kWh
$FC_{t,mining}$	=	Fuel consumption for SCM/ACM mining during the reporting period.	tonnes of fuel
$EF_{t,mining,fuel}$	=	CO_2 emission factor for fuel consumed during the reporting period from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[33] Projects shall	tCO_2/ tonne

[32] Available online at: https://www.epa.gov/egrid
[33] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

		use the CO_2 factor for the appropriate fuel type.	of fuel

Equation 5.12. Quantifying Production Emissions for SCM/ACM Manufacturing

$$PR_{t,s} = (EL_{t,production,grid} \times EF_{t,production,grid}) + (FC_{t,production} \times EF_{t,production,fuel})$$

Where,			Units
$PR_{t,s}$	=	Production emissions for SCM/ACM manufacturing during the reporting period.	tCO_2e
$EL_{t,production, grid}$	=	Grid electricity consumption for SCM/ACM manufacturing during the reporting period.	kWh
$EF_{t,production,grid}$	=	CO_2 emission factor for grid electricity consumed during the reporting period from the most recent EPA eGRID emission factor publication.[34] Projects shall use the annual total output emission rates for the subregion where the project is located.	tCO_2/kWh
$FC_{t,production}$	=	Fuel consumption for SCM/ACM production during the reporting period.	tonnes of fuel
$EF_{t,production,fuel}$	=	CO_2 emission factor for fuel consumed during the reporting period from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[35] Projects shall use the CO_2 factor for the appropriate fuel type.	tCO_2/ tonne of fuel

Transportation emissions include emissions involved with transporting raw input materials to the manufacturing site, transporting primary additives (if applicable), transportation involved with packaging and storing, and transporting waste to a disposal facility. Waste can be defined as any byproduct material generated at the SCM/ACM manufacturing facility that is sent to a landfill.

Equation 5.X. Quantifying End-of-Life Waste Emissions from SCM/ACM Manufacturing

$$WE_{t,s} = \sum_{s} qw_{t,s} \times EF_{t,s,waste}$$

Where,			Units
$WE_{t,s}$	=	End-of-life waste emissions generated during SCM/ACM manufacturing	tCO_2e
$qw_{t,s}$	=	Quantity of waste generated during SCM/ACM manufacturing.	t
$EF_{t,s,transport}$	=	CO_2 emission factor for end-of-life of waste from the most recent ecoinvest[36]. Projects shall use the CO_2 factor for the appropriate disposal method (landfill, incineration, recycling.	tCO_2/ t

Equation 5.13. Quantifying Transportation Emissions for SCM/ACM Manufacturing and Delivery

$$TE_{t,s} = \sum_{s} d_{t,s} \times EF_{t,s,transport}$$

[34] Available online at: https://www.epa.gov/egrid
[35] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[36] Available online at: https://ecoinvent.org/the-ecoinvent-database/

Where,			Units
$TE_{t,s}$	=	Transport emissions for SCM/ACM inputs to manufacturing, storage, additives, delivery and waste during the reporting period for all eligible SCMs/ACMs "s".	tCO_2e
$d_{t,s}$	=	Distance traveled for SCM/ACM manufacturing and delivery during the reporting period.	gallons miles hours
$EF_{t,s,transport}$	=	CO_2 emission factor for mode of transport during the reporting period from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[37] Projects shall use the CO_2 factor for the appropriate transportation mode.	tCO_2/ unit

5.4.1 Hierarchical Approaches for Determining Additive Production Emissions

If additives make up greater than 5% of the final SCM/ACM product by weight, the emissions associated with the primary additive(s) must be calculated. Secondary additives making up 5% or less of the total SCM/ACM product by weight may be excluded from the calculation. For example, if a product is made up of 4.5% gypsum, 2% lime, and 1.5% other activators for a total of 8% additives, the project proponent would be required to quantify emissions from the production of the primary additive (gypsum). Since the secondary additives (lime and other activators) make up less than 5% of the weight of the final SCM/ACM product, their emissions may be excluded from the calculation as they would be considered negligible.

If primary and secondary additives make up 5% or less of the final SCM/ACM by weight, their production emissions are considered negligible and the GHG emissions calculated in Equation 5.13 may be considered zero. For example, if a product is made up of 3% gypsum and 1% other activators for a total of 4% additives, the emissions from additive production could be excluded from the calculation. The determination of the emission factor for additive production is carried out using one of the following two hierarchical approaches:

1. Estimated emission factor using EPDs
2. Published emission factor using regional data

5.4.1.1 Quantifying Additive Emissions from Regional EPD (Approach 1)

For Approach 1, project developers must use a regional type III EPD that provides an emission factor for additive production. A type III EPD provides transparent data on a product's GHG emissions based on a LCA report, which is verified by a third party and compliant with ISO 14025. The EPD must account for cradle-to-gate GHG emissions from additive production through transportation.[38] The emission factor reported in the most recent EPD may be applied in Equation 5.13.

Project developers pursuing Approach 1 for the SCM/ACM project should seek guidance from the Reserve to ensure the EPD they intend to use is sufficient.

Equation 5.14. Quantifying Additive Production Emissions for SCM/ACM process, if additives make up more than 5% of the weight of the final product

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

[38] For reference, the Portland Portland Cement Association publishes a type III EPD to report the environmental and GHG emission impacts of OPC production in the United States. At the time of writing this protocol, the most recent EPD quantified an emission factor of 0.922 tCO_2e per one tonne of OPC can be found here: https://www.cement.org/docs/default-source/default-document-library/pca_epds_2021_rev01312022.pdf?sfvrsn=d26ffbf_2

$$AD_{t,s} = \sum_{s} Q_{t,ad} \times EF_{t,ad}$$

Where,			Units
$AD_{t,s}$	=	Emissions for additive production during the reporting period for all eligible SCMs/ACMs.	tCO_2e
$Q_{t,ad}$	=	Quantity of additives used during the reporting period.	tonnes
$EF_{t,a}$	=	CO_2 emission factor for additive production during the reporting period.	tCO_2/tonne of additive

5.4.1.2 Quantifying Additive Emission Factor from National Data (Approach 2)

If an EPD for an additive (Approach 1) is unavailable or insufficient for the given region, project developers may use Approach 2 with published national or regional data for the additive emission factor. Project developers using Approach 3 must use a publicly available and peer-reviewed emission factor for additive production which may be applied in Equation 5.13.

5.5. Secondary Effects

Secondary effects, i.e., leakage, may occur if a low-carbon cement project begins to produce more SCMs/ACMs than it otherwise would because the value of the carbon offset creates an incentive to shift production to the respective SCM/ACM facility to maintain and/or increase production at levels above market conditions. Since SCM/ACM production has not yet met market demands and is the key activity being incentivized under the protocol, this was not found to be an area of concern. The Reserve found that the most significant risk would be if a SCM/ACM does not successfully displace PC in the market which could encourage the maintained and/or increased production of PC at other cement facilities to meet market demands. If leakage were to occur, a portion of the CRTs would not be representative of real GHG emission reductions.

To mitigate potential leakage, the Project Developer must complete the Attestation of SCM/ACM Use form which includes questions that provide reasonable assurances the SCM/ACM is being purchased instead of PC and that the SCM/ACM meets the necessary quality standards to reach its end-use in the market.

5.6. Reconciliation with Stacked Projects

As previously described, Low-Carbon Protocol projects have the opportunity to be implemented in such a way that project activities overlap with the project activities attributable to another project type. If such project stacking is approved by the Reserve, guidance may be required to be provided by Reserve staff to reconcile the quantification of the biochar with the quantification of the stacked project(s) to ensure no double-counting/-crediting of GHG impacts occurs. The Reserve maintains the right to determine if any reconciliation between a Low-Carbon Cement project and another project with which it is stacked is necessary and what the requirements for such reconciliation may be.

6 Project Monitoring

The Reserve requires a Monitoring Plan to be established for all monitoring and reporting activities associated with the project. The Monitoring Plan will serve as the basis for verifiers to confirm that the monitoring and reporting requirements in this section and

Section 7 have been and will continue to be met, and that consistent, rigorous monitoring and record keeping is ongoing at the project site. The Monitoring Plan must cover all aspects of monitoring and reporting contained in this protocol and must specify how data for all relevant parameters in Table 6.2 will be collected and recorded.

At a minimum, the Monitoring Plan shall include the frequency of data acquisition; a record keeping plan (see Section 7.2 for minimum record keeping requirements); the frequency of quality assurance/quality control (QA/QC) activities; the role of individuals performing each specific monitoring activity; and a detailed project diagram. The Monitoring Plan must include QA/QC provisions to ensure that data acquisition is carried out consistently and with precision.

Finally, the Monitoring Plan must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the legal requirement test (Section 3.4.1).

Project developers are responsible for monitoring the performance of the project and ensuring that the operation of all SCM/ACM manufacturing plants and other project-related equipment is consistent with the manufacturer's recommendations for each component of the system.

6.1 Monitoring Requirements for Energy Consumption

The consumption of energy or fuel must be monitored and measured by the project developer. Methods of measuring solid, liquid, or gaseous fuels are discussed further below.

In the case of liquid or gaseous fuels or electricity, permissible measured methods are as follows:

- The project may use electricity meters.
- The project may use a combination of secondary documented records such as fuel invoices and calculations of fuel inventories to demonstrate fuel consumption.
- In the case electricity consumption, electricity consumption can be demonstrated through the use of invoices and other evidence deemed acceptable to a verifier.

In the case of solid fuels, permissible measurement methods are as follows:

- The project may measure consumption via secondary means such as truck scales, stocks calculations, delivery receipts etc. For secondary measurements of fuels, stock calculations must be performed at least annually.

6.2 Monitoring Requirements for Quantity & Quality Analysis

In the case that Project Developers are using plant-specific data (Approach 1) to quantify baseline emissions, permissible measurement methods are as follows:

- Quantity of PC produced during the look-back period. The project may use a combination of scales, invoices, contracts, and other sales evidence deemed acceptable to a verifier.

In the case that Project Developers are using secondary data (Approach 2 or Approach 3) to quantify baseline emissions, permissible measurement methods are as follows:

- Emission factors from a product-specific type III EPD that conforms to ISO Standards and is approved by a third party deemed acceptable by a verifier.
- Regional factors that are peer-reviewed and/or approved by a third party deemed acceptable to a verifier.
- The quantity of PC is based on the amount of SCM/ACM produced and/or sold during the reporting period. The project may use a combination of scales, invoices, contracts, and other sales evidence deemed acceptable to a verifier.

The quantity and quality of SCMs/ACMs produced during the reporting period must be monitored and measured by the project developer, permissible measurement methods are as follows:

- To monitor the quantity of SCM/ACM produced for the project, the project may use a combination of scales, invoices, contracts, and other sales evidence deemed acceptable to a verifier.
- To monitor the quality and weight replacement of SCM/ACM produced for the project, the project may use a combination of performance tests, laboratory tests, ASTM standards, ready mix designs, and other documentation evidence deemed acceptable to a verifier.
- To monitor the quantity of additives used for the project, the project may use a combination of scales, invoices, contracts, and others sales evidence deemed acceptable to a verifier.
- To monitor the quantity of waste generated from the project, the project may use a combination of scales, invoices, contracts, and other sales evidence deemed acceptable to a verifier.

6.3 Missing Data Substitution

If for any reason the SCM/ACM monitoring data is unavailable or unsuitable, then no emission reductions can be credited for the period of inaccessibility.

6.4 Monitoring Parameters

Prescribed monitoring parameters necessary to calculate baseline and project emissions are provided in Table 6.1.

Table 6.1. Low-Carbon Cement Project Monitoring Parameters

Eq. #	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
N/A	Regulations	Project developer attestation of compliance with regulatory requirements relating to the project	N/A	Environmental regulations	Each verification cycle	
5.1	ER	Total emission reductions for the reporting period	tCO_2e	c	Each reporting period	
5.1, 5.2	BE	Total baseline emissions for the reporting period, from all SSRs in the GHG Assessment Boundary	tCO_2e	c	Each reporting period	
5.1, 5.9	PE	Total project emissions for the reporting period, from all SSRs in the GHG Assessment Boundary	tCO_2e	c	Each reporting period	
5,10, 5.X	W	End-of-life of waste emissions generated during SCM/ACM manufacturing	tCO_2e	c	Each reporting period	
5.2	Q_b	Total quantity of PC that would have been produced during the reporting period	Tonnes	o	Monthly	Based off the amount of SCM/ACM produced during the reporting period
5.2	R_b	SCM/ACM to PC weight adjustment factor in period during the reporting period	Percent	o	Each reporting period	

5.2, 5.3	EF_b	CO_2 emission factor for PC production during the reporting period	tCO_2/tonne of PC	r,c	Each reporting period (if referenced) or once at validation (if calculated)	Approach 1: Plant-Specific data, Approach 2: Environmental Product Declaration, Approach 3: Regional data
Eq. #	**Parameter**	**Description**	**Data Unit**	**Calculated(c) Measured (m) Reference(r) Operating Records (o)**	**Measurement Frequency**	**Comment**
5.3, 5.4	ME_b	Mining emissions for PC production during the look-back period	tCO_2e	c	Once at validation	If using Approach 1: Plant-Specific data
5.3, 5.5	PR_b	Production emissions for PC production during the look-back period	tCO_2e	c	Once at validation	If using Approach 1: Plant-Specific data
5.3, 5.8	TE_b	Transport emissions for PC production during the look-back period	tCO_2e	c	Once at validation	If using Approach 1: Plant-Specific data
5.3	Q	Quantity of PC produced during the look-back period	tonnes	m	Once at validation	If using Approach 1: Plant-Specific data
5.4	$EL_{b,mining,grid}$	Grid electricity consumption for PC mining during the look-back period	kWh	m	Monthly	If using Approach 1: Plant-Specific data
5.4	$EF_{b,mining,grid}$	CO_2 emission factor for grid electricity consumed during the look-back period	tCO_2/kWh	r	Each reporting period	If using Approach 1: Plant-Specific data, from the most recent EPA eGRID emission factor publication.[39] Projects shall use the annual total output emission rates for the subregion where the project is located.
5.4	$FC_{b,mining}$	Fuel consumption for PC mining during the look-back period	tonnes of fuel	m	Monthly	If using Approach 1: Plant-Specific data
5.4	$EF_{b,mining,fuel}$	CO_2 emission factor for fuel consumed during the look-back period	tCO_2/tonne of fuel	r	Each reporting period	If using Approach 1: Plant-Specific data, from the most recent EPA Emission Factors for Greenhouse Gas

[39] Available online at: https://www.epa.gov/egrid

						Inventories.[40] Projects shall use the CO_2 factor for the appropriate fuel type.
Eq. #	**Parameter**	**Description**	**Data Unit**	**Calculated(c) Measured (m) Reference(r) Operating Records (o)**	**Measurement Frequency**	**Comment**
5.5, 5.6	EE_b	Energy emissions for PC production during the look-back period	tCO_2e	c	Each reporting period	If using Approach 1: Plant-Specific data
5.5, 5.7	CE_b	Calcination emissions for PC production during the look-back period	tCO_2e	c	Monthly	If using Approach 1: Plant-Specific data
5.6	$EL_{b,production,grid}$	Grid electricity consumption for PC production during the look-back period	kWh	m	Monthly	If using Approach 1: Plant-Specific data
5.6	$EF_{b,production,grid}$	CO_2 emission factor for grid electricity consumed during the look-back period	tCO_2/kWh	r	Each reporting period	If using Approach 1: Plant-Specific data, from the most recent EPA eGRID emission factor publication.[41] Projects shall use the annual total output emission rates for the subregion where the project is located.
5.6	$FC_{b,production}$	Fuel consumption for PC production during the look-back period.	tonnes of fuel	m	Monthly	If using Approach 1: Plant-Specific data
5.6	$EF_{b,production,fuel}$	CO_2 emission factor for fuel consumed during the look-back period	tCO_2/ tonne of fuel	r	Each reporting period	If using Approach 1: Plant-Specific data, from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[42] Projects shall use the CO_2 factor for the appropriate fuel type.
5.7	$R_{b,clinker}$	Clinker to cement ratio for PC production during the look-back period	Percent	o	Each reporting period	If using Approach 1: Plant-Specific data

[40] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[41] Available online at: https://www.epa.gov/egrid
[42] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

5.7	$EF_{b,clinker}$	CO_2 emission factor for clinker during the reporting period from the most recent data.	tCO_2/ tonne of clinker	r	Each reporting period	If using Approach 1: Plant-Specific data
Eq. #	**Parameter**	**Description**	**Data Unit**	**Calculated(c) Measured (m) Reference(r) Operating Records (o)**	**Measurement Frequency**	**Comment**
5.8	d_b	Distance traveled for PC production during the look-back period	miles	m	Monthly	If using Approach 1: Plant-Specific data
5.8	$EF_{b,transport}$	CO_2 emission factor for mode of transport during the look-back period from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[43] Projects shall use the CO_2 factor for the appropriate transportation mode.	tCO_2/ mile	r	Each reporting period	If using Approach 1: Plant-Specific data
5.10, 5.11	$ME_{t,s}$	Mining emissions for SCM/ACM manufacturing during the reporting period for all eligible SCMs/ACMs "s"	tCO_2e	c	Each reporting period	
5.10, 5.12	$PR_{t,s}$	Production emissions for SCM/ACM manufacturing during the reporting period for all eligible SCM/ACM s "s"	tCO_2e	c	Each reporting period	
5.10, 5.13	$TE_{t,s}$	Transport emissions for SCM/ACM inputs to manufacturing, storage, additives, and waste during the reporting period for all eligible SCM/ACM s "s"	tCO_2e	c	Each reporting period	

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

5.10, 5.14	$AD_{t,s}$	Additive production and transportation emissions for SCM/ACM manufacturing during the reporting period	tCO_2e	c	Each reporting period	
Eq. #	**Parameter**	**Description**	**Data Unit**	**Calculated(c) Measured (m) Reference(r) Operating Records (o)**	**Measurement Frequency**	**Comment**
5.11	$EL_{t,mining,\ grid}$	Grid electricity consumption for SCM/ACM mining during the reporting period	kWh	m	Monthly	
5.11	$EF_{t,mining,grid}$	CO_2 emission factor for grid electricity consumed during the reporting period	tCO_2/kWh	r	Each reporting period	From the most recent EPA eGRID emission factor publication.[44] Projects shall use the annual total output emission rates for the subregion where the project is located.
5.11	$FC_{t,mining}$	Fuel consumption for SCM/ACM mining during the reporting period.	tonnes of fuel	m	Monthly	
5.11	$EF_{t,mining,fuel}$	CO_2 emission factor for fuel consumed during the reporting period	tCO_2/ tonne of fuel	r	Each reporting period	from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[45] Projects shall use the CO_2 factor for the appropriate fuel type.
5.12	$EL_{t,production,\ grid}$	Grid electricity consumption for SCM/ACM manufacturing during the reporting period	kWh	m	Monthly	
5.12	$EF_{t,production,grid}$	CO_2 emission factor for grid electricity consumed during the reporting period	tCO_2/kWh	r	Each reporting period	from the most recent EPA eGRID emission factor publication.[46] Projects shall use the annual total output

[44] Available online at: https://www.epa.gov/egrid
[45] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[46] Available online at: https://www.epa.gov/egrid

						emission rates for the subregion where the project is located.
5.12	$FC_{t,production}$	Fuel consumption for SCM/ACM production during the reporting period.	tonnes of fuel	m	Monthly	
Eq. #	**Parameter**	**Description**	**Data Unit**	**Calculated(c) Measured (m) Reference(r) Operating Records (o)**	**Measurement Frequency**	**Comment**
5.12	$EF_{t,production,fuel}$	CO_2 emission factor for fuel consumed during the reporting period	tCO_2/ tonne of fuel	r	Each reporting period	from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[47] Projects shall use the CO_2 factor for the appropriate fuel type.
5.13	$d_{t,s}$	Distance traveled for SCM/ACM manufacturing during the reporting period	miles	m	Monthly	
5.13	$EF_{t,s,transport}$	CO_2 emission factor for mode of transport during the reporting period	tCO_2/ mile	r	Each reporting period	from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[48] Projects shall use the CO_2 factor for the appropriate transportation mode.
5.14	$Q_{t,ad}$	Quantity of additives used during the reporting period	tonnes	m	Quarterly	
5.14	$EF_{t,a}$	CO_2 emission factor for additive production during the reporting period	tCO_2/tonne of additive	r	Each reporting period	from the most recent EPD (Approach 1) or from a published regional factor (Approach 2).

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

7 Reporting Parameters

This section provides requirements and guidance on reporting rules and procedures. A priority of the Reserve is to facilitate consistent and transparent information disclosure among project developers. Project developers must submit verified emission reduction reports to the Reserve for every reporting period.

7.1 Project Submittal Documentation

Project developers must provide the following documentation to the Reserve in order to register a low carbon cement project:

- Project Submittal form
- Signed Attestation of Title form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Regulatory Compliance form
- Verification Report
- Verification Statement

Project developers must provide the following documentation each reporting period in order for the Reserve to issue CRTs for quantified GHG reductions:

- Verification Report
- Verification Statement
- Signed Attestation of Title form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Regulatory Compliance form
- Signed Attestation of SCM/ACM Use

At a minimum, the above project documentation (except for the project diagram) will be available to the public via the Reserve's online registry. Further disclosure and other documentation may be made available on a voluntary basis through the Reserve. Project submittal forms can be found at http://www.climateactionreserve.org/how/program/documents/.

7.2 Joint Project Verification

Since the protocol allows for multiple projects at a several SCM/ACM production facilities, project developers have the option to hire a single verification body to verify multiple projects at a number of facilities through a "joint project verification." This may provide economies of scale for the project verifications and improve the efficiency of the verification process. Under joint project verification, each project, as defined by the protocol, is submitted for listing, listed, and registered separately in the Reserve system. Furthermore, each project requires its own separate verification process and Verification Statement (i.e., each project is assessed by the verification body separately as if it were the only project at the facility). However, all projects (with the same or similar SCM/ACM product types) may be verified together by a single site visit to the facility. Furthermore, a single Verification Report may be filed with the Reserve that summarizes the findings from multiple project verifications. Regardless of whether the project developer chooses to verify multiple projects through a joint project verification or pursue verification of each project separately, the documents and records for each project must be retained according to this section.

7.3 Record Keeping

For purposes of independent verification and historical documentation, project developers are required to keep all information outlined in this protocol for a period of 10 years after the information is generated or 7 years after the last verification. This information will not be publicly available, but may be requested by the verifier or the Reserve.

System information the project developer must retain includes:

- All data inputs for the calculation of the project emission reductions
- Documentation for the quality and quantity of eligible SCMs/ACMs
- Documentation for the quantity of additives
- Copies of all solid waste, air, water, and land use permits, Notices of Violations (NOVs),and any administrative or legal consent orders dating back at least five years prior to the project start date, and for each subsequent year of project operation
- Executed Attestation of Title, Attestation of Regulatory Compliance, and Attestation of Voluntary Implementation form

7.4 Reporting Period and Verification Cycle

Project developers must report GHG reductions resulting from project activities during each reporting period. A reporting period must represent a full production cycle, defined as the full length of producing an SCM/ACM. A reporting period may exceed 12 months in length when a single campaign exceeds 12 months, in which case the reporting period may match the length of the campaign. One site visit is required per verification or per year, whichever is less frequent. Reporting period must be contiguous; there must be no time gaps in reporting during the crediting period of a project once the initial reporting period has commenced. Occasionally, certain types of maintenance activities may be required at the manufacturing site that may interrupt project activities. Such maintenance periods, defined as a period during which no SCMs/ACMs are produced, are permissible with the following caveats to ensure continuous reporting for the project:

- Maintenance periods must be included within the dates of a reporting period to ensure continuous reporting.
- The data generated during the maintenance period shall be excluded when performing the calculations in Section 5.
- Monitoring equipment may be removed during these maintenance periods, as necessary.
- Once production commences following a maintenance period, the monitoring requirements of Section 6 must resume in a timely manner.

7.4.1 Reporting Periods

The reporting period is the length of time over which GHG emission reductions from project activities are quantified. Project developers must report GHG reductions resulting from project activities during each reporting period. A reporting period may not exceed 12 months in length, except for the initial reporting period, which may cover up to 24 months. The Reserve accepts verified emission reduction reports on a sub-annual basis, should the project developer choose to have a sub-annual reporting period and verification schedule (e.g., monthly, quarterly, or semi-annually). Reporting periods must be contiguous; there must be no gaps in reporting during the crediting period of a project once the first reporting period has commenced.

7.4.2 Verification Periods

The verification period is the length of time over which GHG emission reductions from project activities are verified. The initial verification period for a low-carbon cement project is limited to one reporting period of up to 24 months of data. Subsequent verification periods may cover up to two reporting periods, with a maximum of 24 months of data (i.e., 12 months of data per reporting period). CRTs will not be issued for reporting periods that have not been verified. For any reporting period that ends prior to the end of the verification period (i.e., year 1 of a 2-year verification period), an interim monitoring report must be submitted to the Reserve no later than six months following the end of the relevant reporting period. The interim monitoring report shall contain a summary of emission reductions, description of QA/QC activities, and description of any potential nonconformances, data errors, metering issues, or material changes to the project. All mandatory sections of interim monitoring reports must be verified in the subsequent verification. To meet the verification deadline, the project developer must have the required verification documentation (see Section 7.1) submitted within 12 months of the end of the verification period. The end date of any verification period must correspond to the end date of a reporting period.

7.4.3 Verification Site Visit Schedule

A site visit at the SCM/ACM production facility, mining facility (if separate than the SCM/ACM production facility) and the PC facility (if Approach 1 is used to quantify baseline emissions) must occur during the initial verification, and at least once every two reporting periods thereafter. A reporting period may be verified without a new site visit if the following requirements are met:

1. A new site visit occurred in conjunction with the verification of the previous reporting period;
2. The current verification is being conducted by the same verification body that conducted the site visit for the previous verification;
3. The project is part of a joint verification; and
4. There have been no significant changes in data management systems, equipment, or personnel since the previous site visit.

The above requirements apply regardless of whether the verification period contains one or two reporting periods. The Reserve maintains the discretion to require a new site visit for a reporting period despite satisfaction of the above requirements. For example, the approval of a significant variance during the reporting period could be considered grounds for denial of the option to forego a site visit for the verification.

8 Verification Guidance

This section provides verification bodies with guidance on verifying GHG emission reductions associated with the project activity. This verification guidance supplements the Reserve's Verification Program Manual and describes verification activities in the context of reducing GHG emissions through low carbon cement projects.

Verification bodies trained to verify low-carbon cement projects must be familiar with the following documents:

- Reserve Offset Program Manual
- Climate Action Reserve Verification Program Manual
- Climate Action Reserve Low Carbon Cement Protocol (this document)

The Reserve Offset Program Manual, Verification Program Manual, and protocols are designed to be compatible with each other and are available on the Reserve's website at http://www.climateactionreserve.org.

Only ISO-accredited verification bodies trained by the Reserve for this project type are eligible to verify low carbon cement project reports. Information about verification body accreditation and Reserve project verification training can be found on the Reserve website at http://www.climateactionreserve.org/how/verification/.

8.1 Standard of Verification

The Reserve's standard of verification for low carbon cement projects is the Low-Carbon Cement Protocol (this document), the Reserve Offset Program Manual, and the Verification Program Manual. To verify a low-carbon cement project report, verification bodies apply the guidance in the Verification Program Manual and this section of the protocol to the standards described in Sections 2 through 7 of this protocol. Sections 2 through 7 provide eligibility rules, methods to calculate emission reductions, performance monitoring instructions and requirements, and procedures for reporting project information to the Reserve. Project developers may choose to have a verification body conduct multiple project verifications at a single facility under a join project verification.

8.2 Monitoring Plan

The Monitoring Plan serves as the basis for verification bodies to confirm that the monitoring and reporting requirements in Section 6 and Section 7 have been met, and that consistent, rigorous monitoring and record keeping is ongoing at the project site. Verification bodies shall confirm that the Monitoring Plan covers all aspects of monitoring and reporting contained in thisprotocol and specifies how data for all relevant parameters in Table 6.2 are collected and recorded.

8.3 Verifying Project Eligibility

Verification bodies must affirm a low carbon cement project's eligibility according to the rules describedin this protocol. The table below outlines the eligibility criteria for low-carbon cement projects. This table does not present all criteria for determining eligibility comprehensively; verification bodies must also look to Section 3 and the verification items list in Table 8.1.

Table 8.1. Summary of Eligibility Criteria for a Low-Carbon Cement Project

Eligibility Rule	Eligibility Criteria	Frequency of Rule Application
Start Date	Projects must be submitted for listing within 12 months of the project start date	Once during first verification
Location	United States and U.S. territories and tribal areas	Once during first verification
Project Crediting period	Ensure the project is within its first, second, or third crediting period	Once during first verification
Performance Standard	Production of SCMs/ACMs that can fully or partially replace PC •	Every verification
Legal Requirement Test	Signed Attestation of Voluntary Implementation form and monitoring procedures for ascertaining and demonstrating that the project passes the legal requirement test	Every verification
Regulatory Compliance Test	Signed Attestation of Regulatory Compliance form and disclosure of all non-compliance events to verifier; project must be in material compliance with all applicable laws	Every verification

8.4 Core Verification Activities

The Low-Carbon Cement Protocol provides explicit requirements and guidance for quantifying GHG reductions associated with manufacturing upgraded and/or novel SCMs/ACMs that can replace PC. The Verification Program Manual describes the core verification activities that shall be performed by verification bodies for all project verifications. They are summarized below in the context of an SCM/ACM production project, but verification bodies shall also follow the general guidance in the Verification Program Manual.

Verification is a risk assessment and data sampling effort designed to ensure that the risk of reporting error is assessed and addressed through appropriate sampling, testing, and review. The three core verification activities are:

1. Identifying emission sources, sinks, and reservoirs
2. Reviewing GHG management systems and estimation methodologies
3. Verifying emission reduction estimates

Identifying emission sources, sinks, and reservoirs
The verification body reviews for completeness the sources, sinks, and reservoirs identified for a project.

Reviewing GHG management systems and estimation methodologies
The verification body reviews and assesses the appropriateness of the methodologies and management systems that the facility operator uses to gather data on manufacturing site operations and CO_2 emissions and to calculate baseline and project emissions.

Verifying emission reduction estimates
The verification body further investigates areas that have the greatest potential for material misstatements and then confirms whether or not material misstatements have occurred. This involves site visits to the project to ensure the systems on the group correspond to and are consistent with data provided to the verification body. In addition, the verification body recalculates a representative sample of the performance or emissions data for comparison with data reported by the project developer in order to double-check the calculations of GHG emission reductions.

8.5 Low-Carbon Cement Production Verification Items

The following tables provide lists of items that a verification body needs to address while verifying a low carbon cement project. The tables include references to the section in the protocol where requirements are further specified. The table also identifies items for which a verificationbody is expected to apply professional judgment during the verification process. Verification bodies are expected to use their professional judgment to confirm that protocol requirements have been met in instances where the protocol does not provide (sufficiently) prescriptive guidance. For more information on the Reserve's verification process and professional judgment, please see the Verification Program Manual.

Note: These tables shall not be viewed as a comprehensive list or plan for verification activities, but rather guidance on areas specific to low carbon cement projects that must be addressed during verification.

Table 8.2. Eligibility Verification Items

Protocol Section	Eligibility Qualification Item	Apply Professional Judgment?
2.1 – 2.3	Verify that the project meets the definition of an SCM/ACM project	No
2.1	Verify when the SCM/ACM manufacturing site is existing, upgraded, relocated or restarted	No
2.2	Verify ownership of the reductions by reviewing the Attestation of Title	No
3.1	Verify that the project only consists of activities at a SCM/ACM manufacturing site operating within the U.S. or its territories	No
3.2	Verify eligibility of project start date	No
3.2	Verify accuracy of project start date based on operational records	Yes
3.3	Verify that project is within its 10-year crediting period	No
3.4.1	Verify that the project meets the appropriate Performance Standard Test for the project type	No
3.4.2	Confirm executing of the Attestation of Voluntary Implementation form to demonstrate eligibility under the Legal Requirement Test	No
3.4.2	Verify the Monitoring Plan contains procedures for ascertaining and demonstrating that the project passes the Legal Requirement Test at all times	Yes

3.5	Verify that the project activities comply with applicable laws by reviewing any instances of non-compliance provided by the project developer and performing a risk-based assessment to confirm the statements made by the project developer in the Attestation of Regulatory Compliance form	Yes
3.6	Verify that the SCM/ACM meets any applicable ASTM International Standard and confirm execution of the Attestation of SCM/ACM Use form.	Yes
6	Verify that monitoring meets the requirements of the protocol. If it does not, verify that a variance has been approved for monitoring variations.	No
n/a	If any variances were granted, verify that variance requirements were met and properly applied	Yes

8.5.1 Project Eligibility and CRT Issuance

Table 8.2 lists the criteria for reasonable assurance with respect to eligibility and CRT issuancefor low carbon cement projects. These requirements determine if a project is eligible to register with the Reserve and/or have CRTs issued for the reporting period. If any requirement is not met, either the project may be determined ineligible or the GHG reductions from the reporting period (or subset of the reporting period) may be ineligible for issuance of CRTs, as specified in Sections 2, 3, and 6.

8.5.2 Quantification

Table 8.3 lists the items that verification bodies shall include in their risk assessment and recalculation of the project GHG emission reductions. These quantification items inform any determination as to whether there are material and/or immaterial misstatements in the project GHG emission reduction calculations. If there are material misstatements, the calculations must be revised before CRTs are issued.

Table 8.3. Quantification Verification Items

Protocol Section	Qualification Item	Apply Professional Judgment?
4	Verify that SSRs included in the GHG Assessment Boundary correspond to those required by the protocol and those represented in the project diagram for the reporting period	No
5	Verify that all SSRs in the GHG Assessment Boundary are accounted for	No
5	Verify that the baseline emissions are properly aggregated	No
5	Verify that the project developer received Reserve approval for using Approach 2 or Approach 3 in the baseline, if applicable	No
5	Verify that the project developer correctly calculated the PC weight adjustment factor	No
5	Verify that the baseline emissions were calculated according to the protocol with the appropriate data	No
5	Verify that the project emissions were calculated according to the protocol with the appropriate data	No

5	Verify that the project developer correctly monitored, quantified, and aggregated electricity use, if applicable	Yes
5	Verify that the project developer correctly monitored, quantified, and aggregated fossil fuel use, if applicable	Yes
5	Verify that the project developer applied the correct emission factors for fossil fuel combustion and grid-delivered electricity, if applicable	No
5	If default emission factors are not used, verify that project-specific emission factors are based on official audited emissions data	No
5	Verify that the appropriate calculations were performed by the project developer and quantification and equation processes were followed	No
5	Verify the additive emission were appropriately calculated and quantified, if applicable	No
5	Verify SCM/ACM displaced PC at cement facility or ready-mix concrete plant though review of sales receipts and the Attestation of SCM/ACM Use form	Yes

8.5.3 Risk Assessment

Verification bodies will review the following items in Table 8.4 to guide and prioritize their assessment of data used in determining eligibility and quantifying GHG emission reductions.

Table 8.4. Risk Assessment Verification Items

Protocol Section	Item that Informs Risk Assessment	Apply Professional Judgment
6	Verify that the project Monitoring Plan is sufficiently rigorous to support the requirements of the protocol and proper operation of the project	Yes
6	Verify that the individual or team responsible for managing and reporting project activities are qualified to perform this function	Yes
6	Verify that appropriate monitoring equipment is in place to meet the requirements of the protocol	Yes
6	Verify that appropriate training was provided to personnel assigned to GHG reporting duties	Yes
6	Verify that all contractors are qualified for managing and reporting GHG emissions if relied upon by the project developer. Verify that there is internal oversight to assure the quality of the contractor's work	Yes
6, 7	Verify that all required records have been retained by the project developer	No

8.5.4 Completing Verification

The Verification Program Manual provides detailed information and instructions for verification bodies to finalize the verification process. It describes completing a Verification Report, preparing a Verification Statement, submitting the necessary documents to the Reserve, and notifying the Reserve of the project's verified status.

As stated in Section 8.1, project developers may choose to have a verification body conduct multiple project verifications at a single facility under a join project verification. The verification body must verify the emission reductions entered into the Reserve system for each project and upload a unique Verification Statement for each project with the joint verification. The verification body can prepare a single Verification Report that contains information on all of the projects, but this must also be uploaded to every project under the joint verification.

9 Glossary of Terms

Accredited verifier	A verification firm approved by the Climate Action Reserve to provide verification services for Project Owners.
Additionality	Project activities that are above and beyond "business as usual" operation, exceed the baseline characterization, and are not mandated by regulation.
Alternative cementitious material (ACM)	
Blended cement	A mix of portland cement and at least one supplementary cementitious material or limestone that is developed at the cement plant or blending plant and meets specific ASTM standards.
Carbon dioxide (CO_2)	The most common of the six primary greenhouse gases,

	consisting of a single carbon atom and two oxygen atoms.
CO_2 equivalent (CO_2e)	The quantity of a given GHG multiplied by its total global warming potential. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.
Cementitious Material	The binding ingredient of concrete.
Clinker	A mixture of raw materials (e.g., limestone, shale, sand, clay) that is produced in a kiln with high heat during the production of ordinary portland cement.
Concrete	A building material that is composed of cementitious materials, mineral aggregates, and water.
Direct emissions	GHG emissions from sources that are owned or controlled by the reporting entity.
Effective date	The date of adoption of this protocol by the Reserve board: XXXX XX, 2022.
Emission factor (EF)	A unique value for determining an amount of a GHG emitted for a given quantity of activity data (e.g., tonnes of carbon dioxide emitted per barrel of fossil fuel burned).
Fossil fuel	A fuel, such as coal, oil, and natural gas produced by the decomposition of ancient (fossilized) plants and animals.
Traditional fly ash	A by-product of coal-fired power generation that is beneficially used directly from the power plant without further processing.
Greenhouse gas (GHG)	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), or perfluorocarbons (PFCs)
GHG Reservoir	A physical unit or component of the biosphere, geosphere, or hydrosphere with the capability to store or accumulate a GHG that has been removed from the atmosphere by a GHG sink or a GHG captured from a GHG source.
GHG sink	A physical unit or process that removes GHG from the atmosphere.

GHG source	A physical unit or process that releases GHG into the atmosphere.
Ground Granulated Blast Furnace Slag (GGBFS)	Material recovered as a by-product during crude iron production that can be utilized in concrete production.
Indirect emissions	Reductions in GHG emissions that occur at a location other than where the reduction activity is implemented, and/or at sources not owned or controlled by project participants.
Metric ton (t, tonne)	A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1 short tons.
MMBtu	One million British thermal units.
Transport emissions	Emissions from the transportation of materials, products, and waste resulting from the combustion of fuels in company owned or controlled mobile combustion sources (e.g., cars, trucks, tractors, dozers, etc.).
Pozzolan	Material that chemically reacts with moisture and calcium hydroxide to display cementitious properties.
portland portland Portland Cement(PC)	The most common type of cement that is manufactured by grinding clinker and mixing it with other minor raw materials.
Project baseline	A "business as usual" GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.
Project developer	An entity that undertakes a GHG project, as identified in Section 2.2 of this protocol.
SCM/ACM concrete	Concrete that has one or more supplementary cementitious materials combined with portland portland Portland Cementand other materials at a ready mix concrete batch plant.
Supplementary cementitious materials (SCM)	Siliceous or siliceous aluminous materials that can be processed to display cementitious properties and can be blended with or replace portland portland Portland Cementin concrete production.

Verification	The process used to ensure that a given participant's GHG emissions or emission reductions have met the minimum quality standard and complied with the Reserve's procedures and protocols for calculating and reporting GHG emissions and emission reductions.
Verification body	A Reserve-approved firm that is able to render a verification opinion and provide verification services for operators subject to reporting under this protocol.
Weight Adjustment Factor	Ratio for the amount of SCM/ACM s required to replace one tonne of PC, as identified in Section 5.

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Appendix A Development of the Legal Requirement Test

A.1 Developing a Legal Requirement Test

Under the U.S. EPA Greenhouse Gas Reporting Program (GHGRP), cement plant operators within the United States and U.S. territories are required to estimate and report their production process GHG emissions along with their cement and clinker production each year.[49] Moreover, the 2010 National Emissions Standards for Hazardous Air Pollutants, promulgated by U.S. EPA under the federal Clean Air Act, implemented stationary source standards for hazardous air pollutants, which compelled numerous plants to install equipment to reduce air toxics emitted during kiln clinker production.[50] Cement producers and suppliers of their raw materials must also adhere to National Ambient Air Quality Standards, regulations for coal combustion residuals, and regulations around alternative fuels.[51,52]

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[49] Environmental Protection Agency, "Cement Production Subpart H, Greenhouse Gas Reporting Program" (Environmental Protection Agency, February 2018), https://www.epa.gov/sites/default/files/2018-02/documents/h_infosheet_2018_2.pdf.
[50] Environmental Protection Agency, "National Emission Standards for Hazardous Air Pollutants Compliance Monitoring," Overviews and Factsheets, Environmental Protection Agency, January 7, 2021, https://www.epa.gov/compliance/national-emission-standards-hazardous-air-pollutants-compliance-monitoring.
[51] Baer, Louis, "Energy & Environment Regulatory Priorities," Portland Portland Cement Association, 2019, https://www.cement.org/issues-advocacy/regulatory-priorities/energy-environment-regulatory-priorities.
[52] OLEM Environmental Protection Agency, "Disposal of Coal Combustion Residuals from Electric Utilities Rulemakings," Other Policies and Guidance, EPA, 2014, https://www.epa.gov/coalash/coal-ash-rule.

The U.S. currently has no federal regulation, such as a cap-and-trade program or carbon tax, that requires GHG emission reductions in the cement industry. Nor are there any national laws that require the production of SCMs/ACMs, blended cement, or SCM/ACM concrete.

Despite a lack of federal regulations to reduce GHG emissions from cement production, there has been momentum at the state level to decarbonize the cement sector. In 2021, California enacted Senate Bill 596, which mandates the California Air Resources Board (CARB) to create and implement a plan to reach net-zero GHG emissions in the cement sector by at least 2045, including an interim goal of reducing emissions by at least 40% by mid-2035 (compared to 2019 levels).[53] California's GHG cap-and-trade program also applies to cement plants; however, cement imported into California is not covered by the program.[54] Therefore, PC facilities in California have been identified as an ineligible path for purchase of SCM/ACMs which is verified with through the Attestation of SCM/ACM Use form.

Additionally,, the California Department of Transportation (Caltrans) already sets minimum amounts of required SCM in state pavement and structure applications. These minimum requirements include 20% to 25% natural pozzolan or fly ash, 12% silica fume or metakaolin, or 50% GGBFS.[55] However, Caltrans has reported concerns around how the worsening shortage of suitable SCMs could impact current and future state construction projects.[56]

In 2021, New York legislators passed Senate Bill S542A, the Low Embodied Carbon Concrete Leadership Act, which directs the Office of General Services to set guidelines for utilizing low-carbon concrete in state projects.[57] In 2021, the New Jersey Legislature enacted a concrete mandate (S3091/A4933) that incentivizes lower carbon concrete for state projects by offering a tax credit for builders.[58] Colorado legislators also enacted a similar bill (HB21-1303) in 2021 that requires the office of the state architect and the department of transportation to create policies to reduce the global warming potential for specific public projects, including cement and concrete mixtures.[59] In the past, members of the Washington House of Representatives introduced, but failed to pass, the Buy Clean Buy Fair Washington Act (HB 2412-2017-18), which would have required state agencies to require Environmental Product Declarations (EPD) for construction projects.[60]
The U.S. EPA also has Comprehensive Procurement Guidelines to encourage the use of recovered materials from municipal solid waste. The procurement guidelines direct agencies to

[53] Johnson, "California Enacts Legislation to Slash Cement Emissions."
[54] "AB 32 Global Warming Solutions Act of 2006 | California Air Resources Board," accessed March 15, 2022, https://ww2.arb.ca.gov/resources/fact-sheets/ab-32-global-warming-solutions-act-2006.
[55] Caltrans, "Revised Standards Specifications," October 15, 2021.
[56] Concrete Task Group of the Caltrans Rock Products Committee and Industry, "Fly Ash Current and Future Supply," *Caltrans Office of Structural Materials*, 2020, 25.
[57] Addabbo Jr, Joseph et al., "NY State Senate Bill S542A," Pub. L. No. S542A (2021), https://www.nysenate.gov/legislation/bills/2021/s542/amendment/a.
[58] Addiego, Dawn Marie et al., Pub. L. No. S3091 ScaScaSa (3R), accessed January 27, 2022, https://www.njleg.state.nj.us/bill-search/2020/A4933.
[59] Chris Hansen, Barbara McLachlan, and Tracey Bernett, "Global Warming Potential For Public Project Materials," Pub. L. No. HB21-1303 (2021).
[60] DeBolt, Doglio and Ormsby, Macri, "Creating the Buy Clean Washington Act," Pub. L. No. HB 2412-2017-18, accessed February 2, 2022, https://app.leg.wa.gov/billsummary?BillNumber=2412&Year=2017#documentSection.

permit the use of fly ash, GGBFS, and silica fume in cement and concrete projects; however, the use of these SCM/ACM s is not required nor even specifically recommended. The EPA's CPG guidelines state that SCM/ACM replacement rates are up to 20% to 30% for fly ash, 70% for GGBFS, and 5% to 10% for silica fume. Builders may also be incentivized to use SCMs/ACMs due to their lower GHG emissions; for example, the use of SCMs/ACMs in any cement used in construction can lead to a higher score under the U.S. Green Building Council's voluntary Leadership in Energy and Environmental Design (LEED) certification. However, these are not required.

At a state level, the North Carolina Coal Ash Management Act created a legal requirement that the "installation and operation" of three "ash beneficiation projects, each capable of annually processing 300,000 tons of ash to specifications appropriate for cementitious products". [61]

As stated in Section 3.4.1 of the protocol, the legal requirement test is applicable to both the production of SCMs/ACMs and use of SCMs/ACMs in concrete. According to the Reserve's understanding of existing requirements in the U.S., there are currently no federal regulations that require the production or use of the eligible SCMs/ACMs.. If any state agencies specifically require the production of SCMs/ACMs or the replacement of PC with SCMs/ACM, projects that fall under the legislation in these regions may be ineligible for crediting. Currently, two examples of state level legislation that would deem a project ineligible for crediting include the North Carolina Coal Ash Management Act and Caltrans minimum requirement to include 20% to 25% natural pozzolan or fly ash in state pavement and structure applications. Note, use of SCMs/ACMs above and beyond that minimum requirement could be eligible for crediting under the protocol.

Appendix B Development of the Performance Standard Threshold

The initial Performance Standard analysis for the Low Carbon Cement Protocol Version 1.0 was adopted in 2022. The protocol will only be applicable to project activities that bring innovative

[61] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://files.nc.gov/ncdeq/Coal+Ash/CoalAshDAQ-Handout-090418.pdf

SCM/ACM s to market. SCM/ACM SCM/ACM SCM/ACM were identified by our research as innovative categories SCM/ACM that have the potential to bolster the regional supply of SCMs/ACMs in the United States. Through this protocol, carbon financing will incentivize the market to identify and recover these SCM/ACM sources to help fill the nation's supply void. As traditional fly ash and traditional GGBFS are already being used at appreciable volumes today, production of these SCM/ACM s would not constitute eligible projects under the protocol. SCM/ACM

B.1 Developing a Performance Standard Test

To inform the Performance Standard Test, the Reserve typically undertakes an assessment of prevailing practice in the specific industry and jurisdiction in question, which includes assessing drivers of adoption for a given practice or technology, as well as what the barriers to adoption might be. The Reserve seeks to develop a performance standard that represents a practice or technology that goes beyond what is common practice in the industry today.

The purpose of the performance standard in this protocol is to establish a technology threshold applicable to all projects. Projects that meet or exceed this technology-based performance threshold are eligible under this protocol, having demonstrated that they go beyond common practice and are therefore "additional."

B.2 Current Industry Practice for SCM/ACM Use in the United States

Using regional benchmarks conducted by NRMCA, the national average of cement used in the United States is approximately 81%, Portland cement, 14% fly ash cement and 4% slag cement.[62] Since silica fume is a niche product, it does not have a significant presence in the United States market. However, it is found to be readily available across the United States and common practice in specific situations.[63] Based on the current market penetration rate, these products were found to be ineligible under this protocol.

The Project Developer must demonstrate that the usage rate of the novel SCM/ACM in concrete is either near zero (first-of-its kind) and thus has insufficient data to calculate a penetration rate or provide evidence that production of the SCM/ACM product is less than 5% of the cementitious materials market in the United States[64].

The production of SCM/ACM are an emerging industry that is not commonly used in the U.S. today. Annually, there are millions of tonnes of fly ash produced that end up in the landfill instead of being beneficially used because they are either produced too far away from demand or their quality does not meet concrete grade specifications.[65] Currently, landfilled fly ash is an untapped resource that is hindered by significant and expensive processing and comingling challenges. There are only a handful of projects in existence today that harvest, or reclaim, disposed of fly ash because the technology is prohibitively expensive and has not been

[62] www.nrmca.org/wp-content/uploads/2020/02/NRMCA_REGIONAL_BENCHMARK_Nov2019.pdf
[63] Other?
[64] https://www.usgs.gov/centers/national-minerals-information-center/cement-statistics-and-information
[65] American Coal Ash Association, "The Future of Fly Ash" (Iowa Better Concrete Conference, November 10, 2021), https://intrans.iastate.edu/app/uploads/sites/7/2021/11/A1B-Ward-Fly-Ash.pdf.

deployed at scale.[66,67] The industry also lacks sufficient testing and research on the performance of harvested fly ash, which faces additional hurdles due to varying quality, weathering, and contamination.

There are similarly only a handful of natural pozzolan producers in the U.S. as pozzolans are expensive to produce and have varying chemical properties that make them less attractive than traditional SCMs/ACMs. The Natural Pozzolan Association website currently lists four raw natural pozzolan producers that are in operation along with a few emerging companies.[68] There are some emerging companies that produce manufactured products; however, these companies are also in the early stages of testing or production and have not deployed at scale.[69] Upgraded and novel SCMs/ACMs are currently uncommon in the cement and concrete industry as they face multiple barriers as discussed in Section B.3.

B.3 Barriers to Adopting SCMs/ACMs in the United States

The amount of SCM/ACM s used in cement have remained largely stagnant in the U.S. While significant drivers exist to utilize SCM/ACM s, the industry faces challenges in overcoming supply constraints. Increasing the use of SCM/ACM s faces several barriers that can be alleviated through carbon finance. These barriers can be broadly categorized into financial, technical, institutional, and market barriers, which will each be discussed in-turn in this section.

Cost challenges associated with SCMs/ACMs are expected to worsen in the future as the supply of today's most common SCMs/ACMs decrease while the global demand for PC grows.[70] Both fly ash and GGBFS are byproducts of industrial processes (coal-fired power generation and pig iron production, respectively) that are either phasing out of production or facing pressure to decarbonize and reduce waste themselves in some regions.[71] A decline in these industrial processes will in turn be accompanied by a decline in industrial process byproducts. The supply gap will not only lead to higher SCM/ACM prices but also increased costs associated with sourcing SCMs/ACMs from less convenient locations. Nearly half of the fly ash that is available today in the U.S. goes unused because it is produced too far from the replacement location, is not of appropriate quality (due to type of coal burned or emissions controls implemented), or requires additional processing (which is either uneconomical or technically infeasible) to be suitable for beneficial use.[72,73] The dwindling supply of fly ash cannot be compensated by GGBFS, which is already limited in supply in the U.S. and also experiencing decline.[74]

Deposits of fly ash waste material can be harvested from landfills or disposal ponds, but this

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[66] American Coal Ash Association, "The Future of Fly Ash" (Iowa Better Concrete Conference, November 10, 2021), https://intrans.iastate.edu/app/uploads/sites/7/2021/11/A1B-Ward-Fly-Ash.pdf.
[67] Federal Highway Administration, "Use of Harvested Fly Ash in Highway Infrastructure (May 2021) https://intrans.iastate.edu/app/uploads/2020/09/use_of_harvested_fly_ash_TB.pdf
[68] Natural Pozzolan Association, "Sourcing Natural Pozzolans" http://www.pozzolan.org/sourcing-pozzolan.html
[69] For example, Terra CO_2 manufactures a low-carbon alternative for cement replacement.
[70] Global Cement and Concrete Association, "Concrete Future The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete."
[71] Czigler, Thomas et al., "Laying the Foundation for a Zero-Carbon Cement," McKinsey & Company, May 14, 2020, https://www.mckinsey.com/industries/chemicals/our-insights/laying-the-foundation-for-zero-carbon-cement.
[72] US Department of Transportation Federal Highway Administration, "Tech Brief Best Practices for Concrete Pavements Supplementary Cementitious Materials."
[73] Tritsch, Sutter, and Diaz-Loya, "Use of Harvested Fly Ash in Highway Infrastructure."
[74] Concrete Task Group of the Caltrans Rock Products Committee and Industry, "Fly Ash Current and Future Supply."

emerging procedure is technologically and geographically limited, costly, and requires additional processing.[75] Other potential replacement products, such as natural pozzolans, have the potential to meet demand but cannot be immediately used without additional processing and are currently not available at the scale needed to meet demand. In many cases, the technology exists to extract and re-process these alternative materials (e.g., disposed of fly ash and natural pozzolans) but they are not currently cost competitive with PC. As a result, increased replacement will not be possible in the future without innovation to increase the supply of SCMs/ACMs. The Global Cement and Concrete Association (GCCA) reports that the industry will need a stream of research and development funding to secure a sustainable supply of SCMs/ACMs, including mining natural pozzolans, to meet global demand.[76]

Institutional barriers associated with market acceptance remain a key challenge despite the legacy use of SCMs/ACMs throughout history. Since the 19th century, PC has been the trusted standard product, with well-defined and understood performance and usability characteristics. Innovative products with a lower clinker-to-cement ratio (and thus higher SCM/ACM blend) are not as widely trusted and may be dismissed as a less safe or easy-to-use option.[77] Carbon finance can alleviate these barriers by creating an appealing financial incentive for buyers to give alternative products closer consideration. Moreover, CRTs can also help fund new standards and testing protocols, which are often time-consuming and costly to develop.

On a per-tonne basis, some SCMs/ACMs have historically been lower or equal in cost to PC. However, concrete and cement producers that are not currently using SCM/ACM s face a "barrier to entry" cost to begin utilizing SCMs/ACMs associated with additional storage equipment and potentially new processing technology. To use SCMs/ACMs, a producer needs at least two silos to hold the material (one for PC and one for the SCM/ACM). If they want to use more than one SCM/ACM, multiple silos are required as the cementitious material must be stored individually.[78] Carbon finance provides the opportunity to mitigate some of the higher upfront costs associated with incorporating more SCMs/ACMs.

Without a widescale market-based strategy or federal regulations, concrete and cement producers lack an incentive to invest in technology that enables innovative additives to enter the market. The drivers for using SCMs/ACMs are currently counterbalanced and often outweighed by the supply gap and other financial and institutional barriers. Carbon finance can provide funds that will help the industry to alleviate these obstacles that are preventing new SCMs/ACMs from entering the market in the U.S.

More specifically, the revenue from CRTs can provide funds for research and development and help offset the costs related to transportation, storage, and processing (financial and technical barriers). This will allow more SCMs/ACMs to enter the market and combat existing supply constraints (market barrier). When more SCMs/ACMs are available in the market, the use of blended cement and SCM/ACM concrete may become more viable and economically attractive, which would thus encourage new standards to support the use of SCMs/ACMs (institutional barrier) and further incentivize the development of novel processing technologies (technical

[75] Tritsch, Sutter, and Diaz-Loya, "Use of Harvested Fly Ash in Highway Infrastructure."
[76] "GCCAA-Concrete-Future-Roadmap-Document-AW.Pdf," accessed December 9, 2021, https://gccassociation.org/concretefuture/wp-content/uploads/2021/10/GCCA-Concrete-Future-Roadmap-Document-AW.pdf.
[77] The Loreti Group, "Greenhouse Gas Emission Reductions from Blended Cement Production Issues Paper."
[78] Thomas Van Dam and Federal Highway Administration, "Tech Brief Supplementary Cementitious Materials and Blended Cements to Improve Sustainability of Concrete Pavements" (Iowa State University, November 2013), https://intrans.iastate.edu/app/uploads/2018/12/SCM/ACM _tech_brief.pdf.

barrier). Advancements in technology may enable new SCMs/ACMs to enter the market while overcoming limitations that prevent higher PC replacement levels (technical and market barriers). For example, traditional fly ash supply is currently insufficient and declining. Carbon finance could cover the cost barriers that currently prevent the technology advancements required to harvest, and process disposed of fly ash. This would allow innovative upgraded SCMs/ACMs (disposed of fly ash) to enter the market. This example can be applied to other novel SCMs/ACMs, including the extraction and processing of natural pozzolans and manufactured substitutes.

Appendix C Development of Conservative Regional Emission Factors for PC Production

C.1 Background Information

Environmental Product Declarations (EPDs) are developed and used to provide a certified emission profile at either an industry-wide average or product specific level. EPDs are based on ISO Standard 14025 and follow methodologies (within the Product Category Rule (PCR)) that are developed through a multi-stakeholder process typically including academic, government, industry, life-cycle assessment experts, etc. The development of the methodology is overseen by a third-party expert and certification requires additional, third-party verification. EPDs are broadly accepted to earn environmental credits in well-respected, widely used green rating systems such as LEED and are updated regularly as they are increasingly requested and encouraged by governmental agencies.

The Portland Cement Association (PCA) conducted an industry-wide EPD for PC in 2021 which is valid for a five-year period until March 12, 2026. The assessment is a Type III industry-average EPD describing PCs produced in the United States (US) by PCA members. The PC EPD is certified by ASTM to conform to the Sub-PCR*, as well as to the requirements of ISO 14025 and ISO 21930.The PC EPD is an average of PC production facilities across the country but accounts for different technologies and regional electricity differences with use of weighted averages.

The results of the EPD and underlying LCA are computed with the North American (N.A.) version of the Global Cement and Concrete Association (GCCA) Industry EPD tool for cement and concrete. The tool and the underlying LCA model and database have been previously verified to conform to the prevailing sub-product category rule (PCR) [11], ISO 21930:2017 (the core PCR) [10] as well as ISO 14025:2006 [7] and ISO 14040/44:2006 Amd: 2020 LCA standards [8], [9].

Although the individual PC facility data is confidential, the tool has a temporary public demo which allowed the Reserve to review each input value across the supply chain within the boundary. This provided a mechanism for the Reserve to identify variances and construct a conservative baseline approach for credit generation purposes under this protocol.

C.2 Conservative Approach for U.S. PC Baseline Emissions

The industry-wide PC EPD was reviewed to determine the percentage of emissions attributable to each stage of the production pathways.

According to the EPD, the majority of emissions (52%) for PC manufacturing are process emissions from clinker manufacturing. These emissions do not vary by region and only vary slightly by facility as they are set by chemistry and are a result of the calcination process to produce Calcium Oxide (CaO). The PCA's industry-wide EPD for PC determined that 0.48 tCO2e/tonne of PC is attributed to process emissions which the Reserve found to be a consistent and conservative. This emission factor can be used directly in Equation 5.12. The second most predominant emission source by percent of the total emissions is a result of on-site kiln fuel consumption at approximately 37% of total emissions. To reflect regional differences in fuel mixes at PC facilities across the U.S., the Reserve worked with the PCA's Labor Energy Input Survey to develop emission factors for fuel emissions by region which is summarized Table 5.2[79]. These emission factors can be applied to the regional average on-site fuel consumption to produce a regionally specific emission factor for tCO_2e per tonne of PC. The average fuel consumption for PC mining and production is found to be 3.8 mmBTU when electricity (at 0.52 mmBTU) for PC mining and production is removed from the total energy consumption for PC mining and production (4.282 mmBTU) according to the 2021 Labor Energy Input Survey issued by the PCA[80]. Similarly, grid electricity emissions vary by region which is accounted for by applying sub-regional eGRID emission factors to the average grid electricity consumption value from the Labor Energy Input Survey. As transportation emissions were not found to vary by region and are deminimis at 1% of total emissions, the Reserve provides project developers with an emission factor of 0.01 tCO_2e/tonne of PC. This is additionally conservative as there are baseline emissions associated with transport of cement to the ready-mix facility which are not included in our quantification. Waste emissions were found to be deminimis at less than 1% which resulted in an emission factor of 0 tCO2e/tonne of PC for waste. This approach developed by the Reserve provides project developers with conservative and regionally applicable emission factors for baseline PC emissions when plant specific data is unavailable.

C.3 LCCQuant Tool

To be developed.

[79] Plant specific information from PCA
[80] Labor Energy Input Survey (PCA for 2021 version)