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Low-Carbon Cement

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CLIMATE ACTION RESERVE

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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
~~OPC~~PC	~~Ordinary P~~Portland C~~c~~ement

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

~~4.~~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 ~~upgraded and/or novel~~ supplementary cementitious materials (~~SCM~~SCMs) or alternative cementitious materials (ACMs) that can partially or fully replace ~~ordinary portland cement~~ Portland Cement(~~OPC~~PC) during the production of concrete and reduce GHG emissions generated during ~~OPC~~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 ~~ordinary portland cement~~ Portland Cement(~~OPC~~PC), are attributable to a chemical reaction caused by a high-temperature process ("calcination") used to produce portland cement clinker (~~OPC~~PC clinker), the primary intermediate component for ~~OPC~~PC. The remainder of the emissions from typical cement production result from burning fossil fuels to create the heat required for calcination and the mining and transportation of the materials used during the production process.

~~OPC~~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 ~~OPC~~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 ~~OPC~~PC clinker is combined with gypsum and other materials and finally ground into ~~OPC~~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 ~~OPC~~PC Production

ASTM International, formerly known as the American Society for Testing and Materials, establishes procedures and standards for testing cements; to be ASTM-certified as ~~OPC~~PC, the product must include 90% to 95% ~~OPC~~PC clinker. Therefore, PC 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 ~~OPC~~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]

[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.

~~OPC~~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 effective strategies to reduce GHG emissions associated with concrete production is to replace some or all of the ~~OPC~~PC with ~~alternative~~ materials called supplementary cementitious materials (~~SCM~~SCMs) or alternative cementitious materials (ACMs). ~~SCM~~SCMs are defined as a slag cement or pozzolan that contributes to the properties of concrete or mortar through hydraulic or pozzolanic activity or both; and meets one of two ASTM standards (ASTM C618, C989,or C1240.). Alternative cementitious materials (ACMs) are manufactured clinkered, calcinated, or non-clinkered materials that can fully replace PC clinker in cement[6]. SCMs/ACMs can be used to reduce GHG emissions ~~from concrete production~~ by replacing ~~OPC~~PC clinker at the cement processing plant and/or ~~OPC~~replacing the amount of PC used at the ready mix concrete plant or in concrete products. In addition to reducing GHG emissions through ~~OPC~~PC replacement, SCMs/ACMs can also improve the performance of concrete[7].

Most ~~SCM~~SCMs 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 ~~SCM~~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.[8,9] Other materials that are byproducts of industrial processes including silica fume and non-ferrous slags, are also occasionally used as ~~SCM~~SCMs in specialty concretes. Finally, ~~naturall~~natural pozzolans ~~y pozzolans~~ including diatomaceous earths, volcanic ash, pumicites ~~rice husk~~ , and some calcined clays and shales can also be used as an ~~SCM~~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~~SCMs/ACMs to significantly reduce concrete's GHG footprint, a number of factors explain why ~~SCM~~SCMs/ACMs have not experienced widespread adoption by the cement and concrete industry including (1) regional supply constraints for certain ~~SCM~~SCMs (such as fly ash and GGBFS) that materially limit their accessibility in significant quantities, (2) the inability to use many ~~SCM~~SCMs beyond a certain replacement rate before negatively impacting the performance of concrete,[10] (3) diminishing supply of ~~SCM~~SCMs as a result of declining coal and changes with steel production processes, and (4) a general lack of market acceptance. Appendix A includes further information on ~~SCM~~SCM/ACM legal requirements and Appendix B includes information on ~~SCM~~SCM uses and limitations.

[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.
[6] https://highways.dot.gov/public-roads/autumn-2019/alternative-cementitious-materials-evolution-or
[7]
[8] American Coal Ash Association, "Production and Use Survey"
[9] 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.
[10] 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.

Despite regional ~~SCM~~SCM/ACM shortages, ~~upgraded and novel SCMs~~ some SCMs including natural pozzolans and harvested fly ash are becoming 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~~SCM/ACM industry will require innovative yet costly technological advancements to bring new ~~SCM~~SCMs/ACMs to market and fill the growing gap between supply and demand. These innovative advancements could allow for recovering and upgrading ~~SCM~~SCMs as well as processing novel ~~SCM~~SCMs/ACMs to meet concrete-grade specifications. ~~This protocol credits for alternatives to traditional SCMs, including upgraded and novel SCMs that can fully or partially replace OPC.~~ In addition to traditional SCMs, captured carbon dioxide that is introduced and mineralized directly into cement or into additives that go into cement, will be considered equivalent to an SCM because mineralized CO2 can – like SCMs – displace clinker. In addition, project developers will be able to count as an offset the quantity of CO2 mineralized, which would have been emitted in the absence of the project activity.

2.2 Project Definition

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

~~The protocol applies to projects that include:~~

1. ~~Production of upgraded SCMs that can fully or partially replace OPC~~
2. ~~Production of novel SCMs that can fully or partially replace OPC~~

~~Each category of activities covered by this protocol is described in detail below in Sections 2.2.1 and 2.2.2. SCMs are defined as inorganic materials that react pozzolanically or hydraulically.[11]~~ ~~SCM~~SCMs or ACMs can be processed to display cementitious properties to replace some or all ~~OPC~~PC in concrete production and/or concrete products. Eligible projects must meet applicable ~~SCM~~SCM or ACM ~~requirements in the region~~ASTM standards (Section 3.6). A single project may consist of a single eligible ~~SCM~~SCM/ACM or more than one type of eligible ~~SCM~~SCM/ACM.

~~An upgraded SCM/ACM is one that would otherwise be sent for disposal in an impoundment or landfill or not be beneficially used without the project. For example, upgraded fly ash or bottom ash is defined as material that does not meet regional concrete specifications for use as an SCM and would otherwise be sent to the landfill (e.g., unburned carbon content, particle size does not meet fineness requirements, too much calcium sulfate, or failure to meet other criteria specified by the applicable ASTM standard).~~

~~A novel SCM/ACM is one that has not been historically used as a PC replacement in the region at high levels. For example, natural pozzolans have generally not been used as a PC replacement at high levels due to geographic availability and cost.~~

Project crediting shall occur at an SCMSCM/ACM manufacturing site or group of SCMSCM/ACM manufacturing sites. An SCMSCM/ACM- manufacturing site is defined as a site that processes or manufacturers upgraded and/or novel SCMSCM/ACMs. The protocol is applicable to eligible SCMSCMs/ACMs that are sold domestically within the project country. As discussed further in Section 3.4.1, eligible SCMSCMs/ACMs must also exceed the Legal Requirement Test and meet the Performance Standard. The baseline scenario for all projects is the production/supply of OPCPC in the project region.

Multiple eligible SCMSCMs/ACMs may be produced at a single manufacturing site. If additional eligible upgraded or novel SCMSCMs/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 SCMsSCM/ACM products that are ineligible for under the protocol. This version of the protocol does not apply to the production of:

- Traditional Portland Limestone Cement (PLC)
- Traditional fresh fly ash
- Traditional GGBFS
- Silica fume
- Silica fume
- Calcined clays or metakaolin
- Limestone calcined clay
- Ternary blend of traditional fly ash, traditional GGBFS, silica fume, and/or calcined clays or metakaolin

Appendices A and B include further information on project eligibility.

2.2.1. Upgraded SCMs for Partial or Full OPC Replacement

An upgraded SCM is one that would otherwise be sent for disposal in an impoundment or landfill or not be beneficially used without the project. Eligible projects with upgraded SCMs may include any of the following materials:Upgraded fly ash or bottom ash is defined as material that does not meet regional concrete specifications for use as an SCM and would otherwise be sent to the landfill (e.g., unburned carbon content, particle size does not meet fineness requirements, too much calcium sulfate, or failure to meet other criteria specified by the applicable ASTM standard).

The following is a positive list of potentially eligible SCMs/ACMs under the protocol. This list is non-inclusive with an aim to remain technology agnostic and encourage the development and use of new, 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).

Disposed-of fly ash harvested from a landfill, ash pond, or other coal ash storage site

and processed for use as a replacement for OPC
Upgraded fly ash or bottom ash diverted from a landfill or impoundment and processed for use as a replacement for OPC

- Beneficiated ash (upgraded and/or harvested fly or bottom ash)
- Natural pozzolans (i.e. volcanic ash)
- Ground glass pozzolans
- Calcined clays/shale and/or metakaolin
- Limestone calcined clays
- 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)
- Manufactured ACMs (including clinkered materials such as calcium-sulfoaluminate (CSA) and calcium-aluminate cements (CAC), calcined materials such as magnesium phosphate cement (MPC) and magnesium oxychloride cement (MO), non-clinker materials such as alkali- or chemically-activated silicates or aluminosilicates (AA) including geopolymers)
- Hydroxide products (including portlandite ($Ca(OH)_2$) and brucite ($Mg(OH)_2$))
- Other novel SCMs (including biogenic limestone)
- Ternary blends of a SCMs/ACMs listed above*

Upgraded fly ash or bottom ash is defined as material that does not meet regional concrete specifications for use as an SCM and would otherwise be sent to the landfill (e.g., unburned carbon content, particle size does not meet fineness requirements, too much calcium sulfate, or failure to meet other criteria specified by the applicable ASTM standard). The upgraded SCMs that make up the project must be defined by the project developer at the time of project submittal. The upgraded SCM and/or mix of upgraded SCMs with novel SCMs must either partially or fully replace OPC during the production of ready mix concrete, and/or concrete products. The monitoring requirements are further discussed in Section 6.

2.2.2. Novel SCMs for Partial or Full OPC Replacement

A novel SCM is one that has not been historically used as an OPC replacement in the region at high levels. Eligible projects with novel SCMs may include any of the following materials:

- Natural pozzolans mined from geologic resources including volcanic ash or clays and shales (excluding calcined clays and metakaolin)
- Novel artificial pozzolans or treated calcined materials including rice husk ash
- Manufactured substitutes for fly ash, GGBFS, or limestone-derived OPC

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 the production of ready mix concrete, and/or concrete products. The monitoring requirements are further discussed in Section 6.
The novel SCMs that make up the project must be defined by the project developer at the time of project submittal. The novel SCM and/or mix of novel SCMs with upgraded SCMs must either partially or fully replace OPC during the production of cement, concrete, and/or concrete products. The monitoring requirements are further discussed in Section 6.

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 SCMSCM/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.[12] The project developer must be the SCM/ACM producer responsible for certifying that the SCM/ACM product meets ASTM standards, unless the rights to the emissions reductions have been transferred to another entity.

2.4 Project Aggregation

Eligible Low-Carbon Cement Projects* may be aggregated to improve cost-effectiveness while maintaining rigor in overall carbon inventory accounting. Individual Low-Carbon Cement Projects can benefit through participation in an aggregate by grouping the same or similar SCMs/ACMs to align with typical industrial sales. Similarly, verification of aggregated projects is considered across the broader population, which reduces the verification costs to individual Project Operators participating in an aggregate. An aggregate consists of two or more individual Forest Projects. 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*
		⟶	

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

Eligibility Rule VI:	Quality Standards	⟶	*Meet ASTM 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.[13] For SCM/ACM production to be eligible as a project under this protocol, all SCM/ACM materials must be sourced from within the United States or its territories and its final concrete product must also be sold and used within the United States or its territories.

3.2 Project Start Date

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

To be eligible, the project must be submitted to the Reserve no later than 12 months after the project start date.[14] Any project comprised of multiple SCMSCM/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 SCMSCMs/ACMs by the end of each additional eligible SCM's respective 12-month initial start-up period, to indicate that the SCMSCM/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.[15]

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 SCMs/ACMs or the inclusion of eligible SCMSCMs/ACMs in 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

[13] 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.
[14] 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.
[15] Please refer to the most current version of the Reserve Offset Program Manual, available at: http://www.climateactionreserve.org/how/program/program-manual/.

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 areis 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 continuous reporting was not maintained.[16] 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 Legal Requirement Test
1.2. The Performance Standard Test
2. The Legal Requirement Test

3.4.1 The Performance Standard TestThe 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, statues, 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 upgraded or novel SCMs at the project site. To satisfy the Legal Requirement Test, project developers must submit a signed Attestation of Voluntary Implementation form[17] 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 of upgraded or novel SCMs/ACMs. However, some states have legal requirements to beneficiate ash for use in concrete which would deem the project ineligible based on the legal requirement

[16] See zero-credit reporting period guidance and requirements in the Reserve Offset Program Manual, http://www.climateactionreserve.org/how/program-resources/program-manual.
[17] Attestation of Voluntary Implementation form available at https://www.climateactionreserve.org/wp-content/uploads/2019/12/Attestation-Voluntary-Implementation-12-16-2019.docx

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 SCMs, emission reductions may be reported to the Reserve up until the date that eligible SCMs are legally required to be produced. 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.

~~For this protocol, the Reserve uses a technology-specific threshold, sometimes referred to as a practice-based threshold. The Performance Standard Test is based on a specified practice that the Reserve has determined is rarely or never implemented in the absence of the carbon offset market. A summary of the study and analysis used to establish the Performance Standard Test is provided in Appendix B.~~

~~A project passes the Performance Standard Test if it involves one or more of the following activities:~~

- ~~Production of upgraded SCMs that can fully or partially replace OPC~~
- ~~1. Production of novel SCMs that can fully or partially replace OPC~~

~~Projects employing one or more of the qualifying practices are automatically considered additional. 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~~ Performance ~~Requirement~~ 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 SCMs/ACMs 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.

~~Both new and enhanced SCM/ACM manufacturing or processing facilities face financial barriers to project implementation, with new investment costs estimated to range from roughly X million USD to Y million USD and increased operating costs estimated to range from roughly X to Y million USD per year. Therefore, SCM/ACM projects automatically pass the performance standard test by demonstrating a similar or greater investment cost for the production of a SCM/ACM that meets quality standards.~~

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.

~~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, statues, 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 upgraded or novel SCMs at the project site. 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, state, or local regulations that obligate the production of upgraded or novel SCMs. A summary of the Reserve's research on legal requirements is provided in Appendix A.~~

~~If an eligible project begins operation at a SCM manufacturing site that later becomes subject to a regulation that calls for the production of eligible SCMs, emission reductions may be reported to the Reserve up until the date that eligible SCMs are legally required to be produced. 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[19] 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.

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

3.6.1 Applicable ASTM International Standards

Eligible SCMs/ACMs must meet applicable quality standards to ensure the product is competitive in the market and able to displace Portland cement. 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 product 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.

Table 3.1 ASTM Standards for Eligible SCMs/ACMs

Eligible SCM/ACM	**ASTM Standard Specifications**	**ASTM Standard Test Methods**
Beneficiated ash	C618-22: Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete	C311/C311M-22: Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
Natural pozzolans	C618-22: Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete	C311/C311M-22: Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
Ground glass pozzolans	C1866/C1866M – 20: Standard Specification for Ground-Glass Pozzolan for Use in Concrete	C109/C109M, C311/C311M, C1069, C1293, C1567
Calcined clays/shale and/or metakaolin	C989/C989M-22: Standard Specification for Slag Cement for Use in Concrete and Mortars	
Limestone calcined clays	C595/C595M – 21: Standard Specification for Blended Hydraulic Cements	C109/109M, C114, C151,C151M, C183/C183M, C185, C187, C188, C191, C204, C311/C311M, C430, C1012/C1012M, C1038/C1038M
CO_2 / Biochar	Standard Specification for Cement that Hardens by Carbonation	Standard Test Methods for Cementitious Materials that Harden by Carbonation
Ternary blends of a SCMs/ACMs listed above*	C595/C595M – 21: Standard Specification for Blended Hydraulic Cements	

Other artificial pozzolans or treated calcined materials (including rice husk ash)	C618 or C989 or other?	
Other waste by-products (including Bauxite residue (Red Mud), lime kiln dust, or cement kiln dust)	C618 or C989 or other?	
Manufactured ACMs	C618 or C989 or other?	
Hydroxide products (including portlandite ($Ca(OH)_2$) and brucite ($Mg(OH)_2$))	C618 or C989 or other?	
Other novel SCMs (including biogenic limestone)	C618 or C989 or other?	

3.6.2 Eligibility of Beneficiated Ash

Fresh fly ash is the most 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 fly and bottom ash that is currently in a landfill or is being sent to a landfill because it does not meet the ASTM specifications and it too costly to improve to be used in the market. Based on the lack of beneficiated ash in the cement market today and significant capital and operational costs associated with its improvement, the protocol considers beneficiated 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 C618-22: Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. To meet eligibility requirements, the 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 for the purposes of this protocol.

Table 3.2 Chemical Requirements under ASTM Standard C618-22

Chemical Requirement	**Before Processing**	**After Processing**
Silicon dioxide (SiO2) plus aluminum oxide (Al2O3) plus iron oxide (Fe2O3)	<50%	>50%

Sulfur trioxide (SO3)	>5%	<5%
Moisture content	>3%	<3%
%Loss on ignition	>6%	<6%

Table 3.3 Physical Requirements under ASTM Standard C618-22

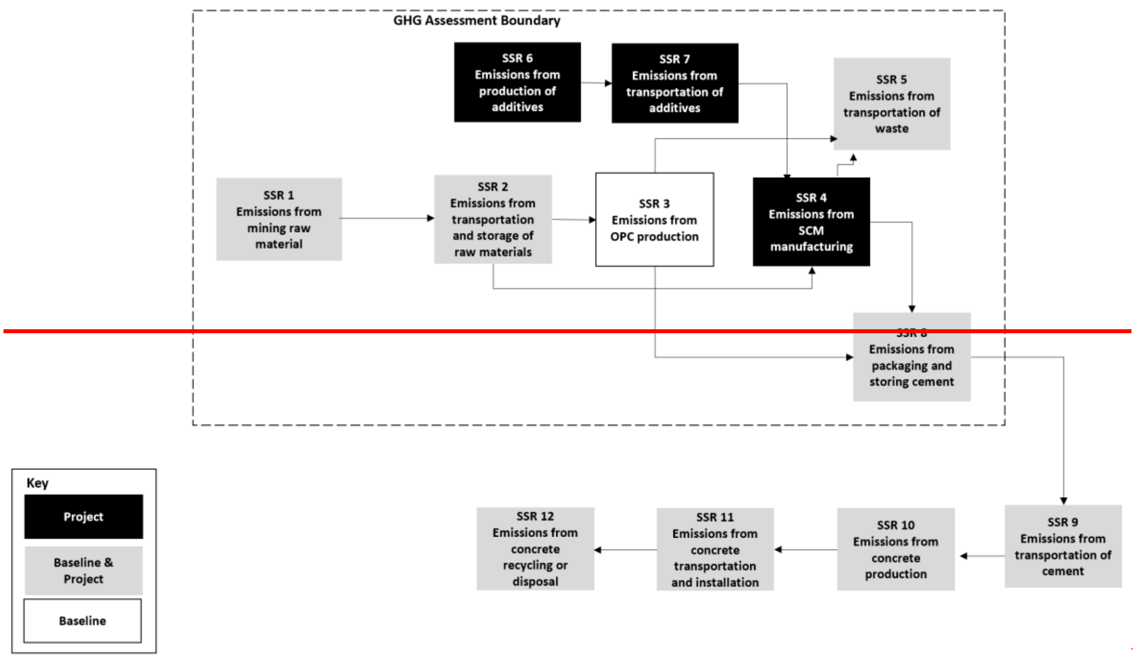
Chemical Requirement	**Before Processing**	**After Processing**
Fineness	>34%	<34%
Strength activity index:A	Does not meet 75B	Meets 75B
Water requirement, max, percent of control	>105%	<105%
Uniformity Requirements - Density, max variation from average - Percent retained on 45-μm (No. 325	>5%	<5%

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.



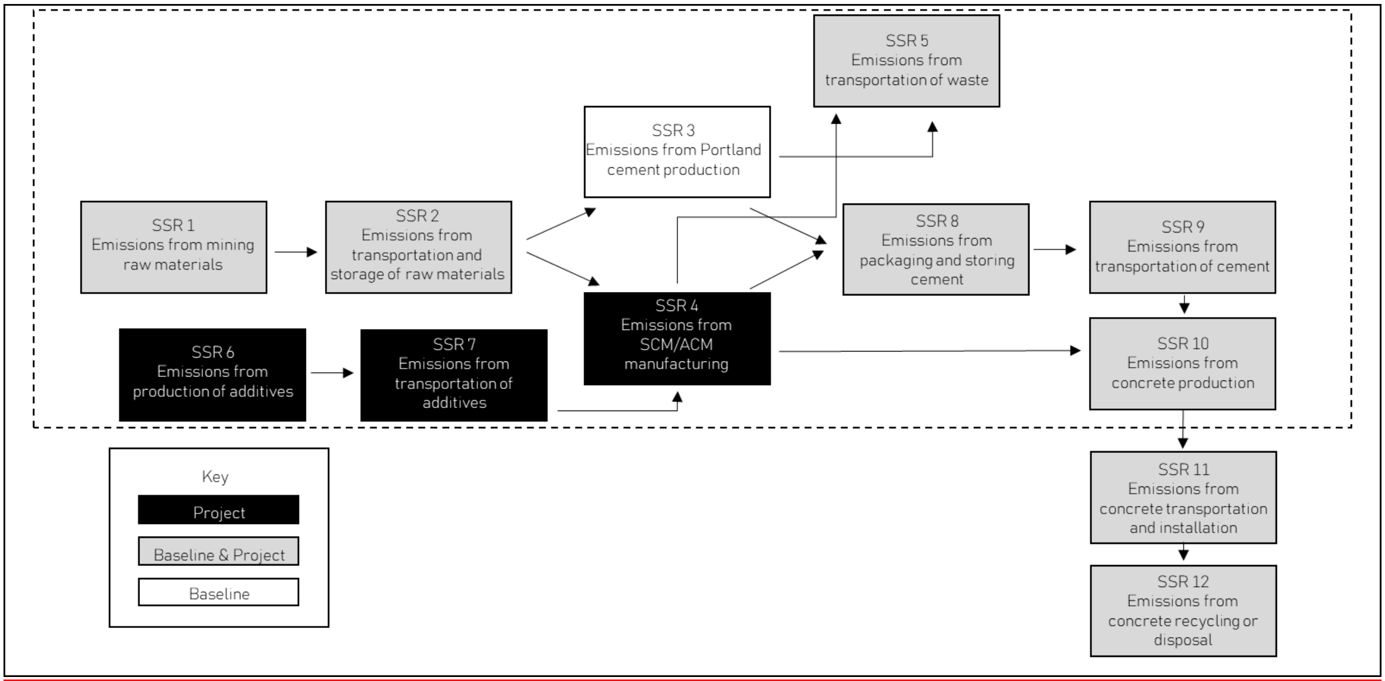


Figure 4.1. General illustration of the GHG Assessment Boundary

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

SSR	Source Description	Gas	Included (I) or Excluded (E)	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 ~~OPC~~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 ~~OPC~~PC production. Calculated in reference to ~~OPC~~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 Excluded (E)	Baseline (B) or Project (P)	Quantification Method	Justification/ Explanation
4	Emissions from ~~SCM~~SCM manufacturing	CO_2	I	P	GHG emissions based on	Energy consumption is a primary source of

					electricity and fuel consumption.	emissions for ~~SCM~~SCM 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~~SCM by weight. If additives make up greater than 5% of the final ~~SCM~~SCM 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~~SCM 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 Excluded (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	A GHG project will directly impact these emissions if additives

					emission factor for mode of transportation.	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 SCMSCM product by weight. If additives make up greater than 5% of the final SCMSCM 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 SCMSCM 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 packaging and storing cement	CO_2	I	B, P	GHG emissions based on electricity and fuel consumption.	Calculated in reference to 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
9	Emissions from transportation of cement	CO_2	IE	B, P	N/A	A GHG project will directly impact these emissions. Calculated in reference to transportation emissions.Excluded, as project activity is unlikely to impact emission relative to baseline activity
		CH_4	E			Excluded, as this emission source is considered negligible.
		N_2O	E			Excluded, as this emission source is considered negligible

10	Emissions from concrete production	CO_2	E~~E~~	B,P	N/A	Energy consumption is a primary source of emissions for SCM manufacturing. A GHG project will directly impact these emissions. ~~Excluded, as project activity is unlikely to impact emission relative to baseline activity~~
		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 Excluded (E)**	**Baseline (B) or Project (P)**	**Quantification Method**	**Justification/ Explanation**
11	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
12	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
13	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
14	Emissions from concrete recycling/disposal	CO_2	E	B,P	N/A	Excluded, as project activity is unlikely to impact emission relative to baseline activity
8	Emissions from end-of-life of waste	CO_2	I	B,P	N/A	A GHG project will directly impact these emissions. Calculated in reference to landfill, incineration, or recycling.

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 an ~~OPC~~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.

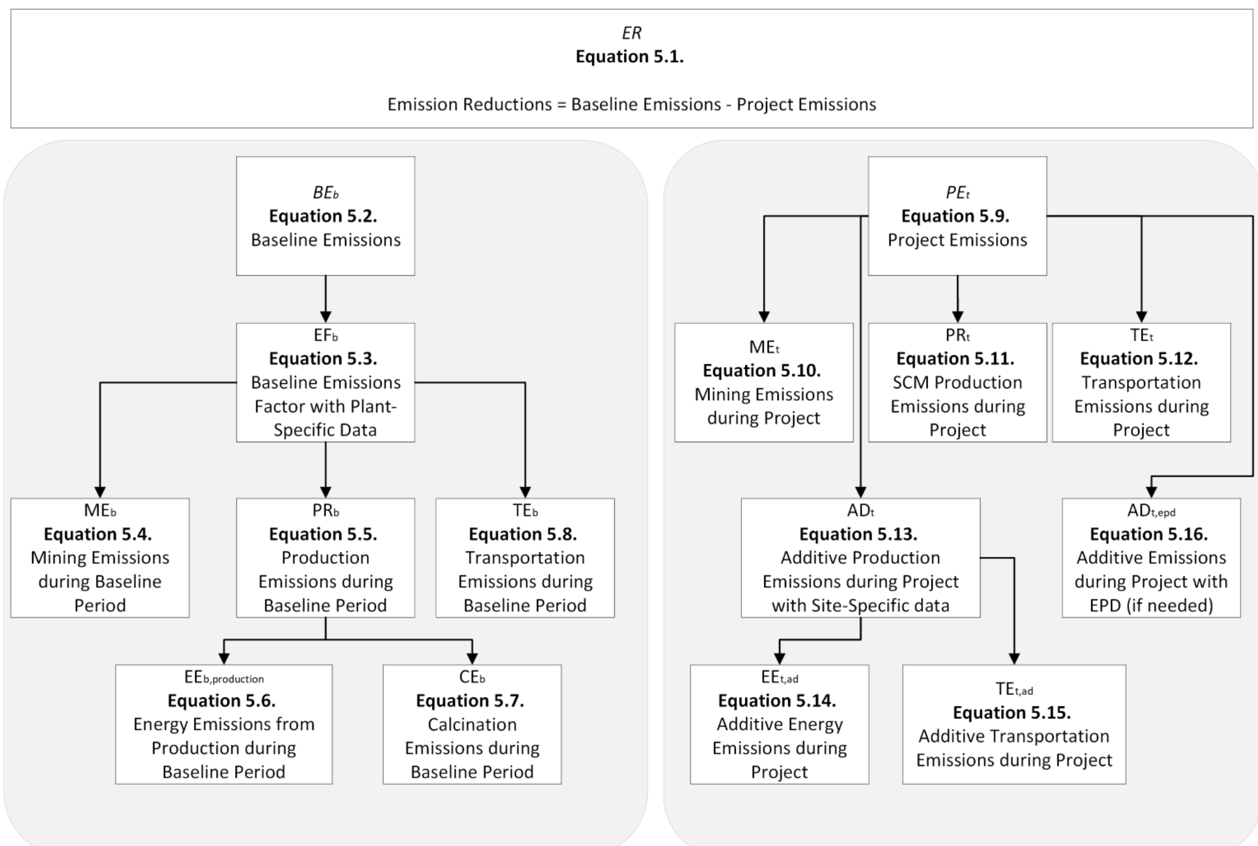


Figure 5.1. Organizational Chart of Equations for Low-Carbon Cement Projects

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 ~~OPC~~PC production, the appropriate weight adjustment factor, and the appropriate emission factor.

Equation 5.2. Quantifying Total Baseline GHG Emissions

$$BE\ \cancel{BE} = (Q_b \times R_b \times EF_b) + CO_2 \cancel{Q_b \times R_b \times EF_b}$$

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 ~~OPC~~PC that would have been produced during the reporting period.	tonnes
R_b	=	~~OPC~~PC to ~~SCM~~SCM weight adjustment factor in period during the reporting period.	percent
EF_b	=	CO_2 emission factor for ~~OPC~~PC production during the reporting period.	tCO_2e/tonne of ~~OPC~~PC
CO_{2CAP}	=	Quantity of CO_2 captured and permanently removed through mineralization into cement or cement additives	tonnes

Records that may satisfy a verifier as to quantity of ~~OPC~~PC that would have been produced may include invoices, sales records, receipts, or sales contracts for ~~SCM~~SCMs 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 upgraded or novel ~~SCM~~SCM required to replace one tonne of ~~OPC~~PC. For example, if one tonne of ~~OPC~~PC could be replaced by one tonne of upgraded ~~SCM~~SCM, the weight adjustment factor would be 1:1. However, if two tonnes of ~~OPC~~PC could be replaced with one tonne of upgraded ~~SCM~~SCM, the weight adjustment factor would be 2:1 (~~OPC~~PC:~~SCM~~SCM). 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 Emissions

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

- 5.3.1 Historical ~~OPC~~PC production records using plant-specific data
- 5.3.2 Estimated emission factor using Environmental Product Declarations (EPDs)
- 5.3.3 Published emission factor using regional data

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

If the source of ~~OPC~~PC (baseline) is 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 ~~OPC~~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 ~~OPC~~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.

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

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

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

Equation 5.4. Quantifying Mining Emissions for ~~OPC~~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 ~~OPC~~PC production during the look-back period.	tCO_2e
$EL_{b,mining,grid}$	=	Grid electricity consumption for ~~OPC~~PC mining during the look-back period.	kWh
$EF_{b,mining,grid}$	=	CO_2 emission factor for grid electricity consumed during the look-back period from the most recent U.S. Environmental Protection Agency (EPA) eGRID emission factor publication.[20] Projects shall use the annual total output emission rates for the subregion where the project is located.	tCO_2/kWh
$FC_{b,mining}$	=	Fuel consumption for ~~OPC~~PC mining during the look-back period.	tonnes of fuel
$EF_{b,mining,fuel}$	=	CO_2 emission factor for fuel consumed during the look-back period from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[21] Projects shall use the CO_2 factor for the appropriate fuel type.	tCO_2e/ tonne of fuel

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

$$PR_b = EE_b + CE_b$$

Where,			Units
PR_b	=	Production emissions for ~~OPC~~PC production during the look-back period.	tCO_2e
EE_b	=	Energy emissions for ~~OPC~~PC production during the look-back period.	tCO_2e
CE_b	=	Calcination emissions for ~~OPC~~PC production during the look-back period.	tCO_2e

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

Equation 5.6. Quantifying Energy Emissions for ~~OPC~~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 ~~OPC~~PC production during the look-back period.	tCO_2e
$EL_{b,production, grid}$	=	Grid electricity consumption for ~~OPC~~PC production during the look-back period.	kWh
$EF_{b,production,grid}$	=	CO_2 emission factor for grid electricity consumed during the look-back period from the most recent EPA eGRID emission factor publication.[22] Projects shall use the annual total output emission rates for the subregion where the project is located.	tCO_2/kWh
$FC_{b,production}$	=	Fuel consumption for ~~OPC~~PC production during the look-back period.	tonnes of fuel
$EF_{b,production,fuel}$	=	CO_2 emission factor for fuel consumed during the look-back period from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[23] Projects shall use the CO_2 factor for the appropriate fuel type.	tCO_2e/ tonne of fuel

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

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

Where,

			Units
CE_b	=	Calcination emissions for ~~OPC~~PC production during the look-back period.	tCO_2e
$R_{b,clinker}$	=	Clinker to cement ratio for ~~OPC~~PC production during the look-back period.	Percent
$EF_{b,clinker}$	=	CO_2 emission factor for clinker during the reporting period from the most recent national emissions data.[24]	tCO_2e/ tonne of clinker

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

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

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

Where,			Units
TE_b	=	Transport emissions for ~~OPC~~PC production during the look-back period.	tCO_2e
d_b	=	Distance traveled for ~~OPC~~PC production during the look-back period.	miles
$EF_{b,transport}$	=	CO_2 emission factor for mode of transport during the look-back. Period from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[25] Projects shall use the CO_2 factor for the appropriate transportation mode.	tCO_2e/ mile

5.1.1.2 Quantifying ~~OPC~~PC Emission Factor from Regional EPD (Approach 2)

Where the source of ~~OPC~~PC (baseline) is not known and Approach 1 is not applicable, project developers must use Approach 2 with type III environmental product declarations (EPDs) that provide an emission factor for ~~OPC~~PC production in the project region. A type III EPD provides transparent data on a product's GHG emissions based on a lifecycle assessment (LCA) report, which is verified by a third party and compliant with ISO 14025.[26] The EPD must account for cradle-to-gate GHG emissions from clinker production (quarry operations; crushing; dry mixing, grinding, and blending; operating kiln; cooling; storing) through cement production (grinding; packaging and storing) and align with the GHG Assessment Boundary in Figure 4.1.[27] Approach 2 would ensure regional specificity and the closest depiction of the historical ~~OPC~~PC production practices in the region. The emission factor reported in the most recent EPD may be applied in Equation 5.2.

Project developers pursuing Approach 2 should seek guidance from the Reserve to ensure the EPD they intend to use is sufficient.

5.1.1.3 Quantifying ~~OPC~~PC Emission Factor from National Data (Approach 3)

If plant-specific data (Approach 1) or a regional EPD (Approach 2) are unavailable or insufficient for the given region, project developers may use Approach 3 with published national or regional data for the clinker to cement ratio and clinker emission factor.[28] Project developers using Approach 3 must use a publicly available and peer-reviewed emission factor for ~~OPC~~PC production which may be applied in Equation 5.2.

5.1.2 Quantifying the Amount of CO2 Captured and Mineralized Into Cement or

[25] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[26] Available online at: https://www.iso.org/standard/38131.html
[27] For reference, the 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
[28] 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://gccassociation.org/gnr/

Cement Additives

For project activities where CO_2 is captured and utilized for cement or cement additive production, project developers must quantify the amount of CO_2 that was mineralized. This can be done through flow meter readings for injected CO_2, however project developers must consider the possibility of CO_2 escaping (i.e. CO_2 injected but not actually mineralized). CO_2 mineralization can take place in a closed chamber or reactor where the losses can be expected to be very low. In these cases, project developers shall, based on the manufacturer of the chamber or reactor, indicate in a conservative and transparent manner what the expected rate of loss of CO_2 will be and discount that from CO_{2cap}. For processes where a significant portion of the CO2 can escape (i.e. open environments such as cement mixing trucks), it is recommended that project developers take samples of the material (cement or additives) before and after the CO_2 mineralization process to assess loss. These samples can be tested for carbon content through tests such as acid digest or thermogravimetric analysis (TGA) accompanied by further chemical composition analysis. In these cases, baseline ($C_{sample,b}$) and project ($C_{sample,p}$) samples are destroyed, and the amount of carbon in the samples is measured. The delta between the two readings, multiplied by 44/12 (C to CO_2) and the quantity of material subjected to mineralization ($Q_{cement/additive}$) would yield the total amount of CO_2 mineralized.

Equation 5.9. Quantity of CO_2 captured and permanently removed through mineralization into cement or cement additives

$$CO_{2_{CAP}} = \left(Q_{cement} \times \left(C_{sample,p} - C_{sample,b}\right)\right) \times \frac{44}{12}$$

Where,			Units
CO_{2CAP}	=	Quantity of CO_2 captured and permanently removed through mineralization into cement or cement additives.	tCO_2e
Q_{cement}	=	Quantity of material subjected to mineralization.	tonnes
$C_{sample,p}$	=	Carbon within project sample after analysis.	grams
$C_{sample,b}$	=	Carbon within baseline sample after analysis.	grams

Note that any CO_2 source is eligible because even CO_2 used for industrial purposes and purchased from the merchant market is eventually re-emitted. The only exceptions – for which CO_2 would not be eligible to be part of the project activity – are (a) CO_2 sourced from emitters that are covered by a cap-and-trade program, and (b) CO_2 that is recovered from a geologic reservoir. If the source of the CO_2 is not known, no offsets can be calculated from the CO_2 injected/mineralized into the cement (given the possibility of the CO_2 coming from an ineligible source). However, offsets can still be calculated from the reduction in clinker usage as a result of the CO_2 mineralization.

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.~~9~~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 ~~SCM~~SCMs, plus
- Emissions from the transportation of ~~SCM~~SCMs 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 ~~OPC~~PC) if additives make up more than 5% of the final ~~SCM~~SCM by weight. If additives make up greater than 5% of the final ~~SCM~~SCM 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~~SCM product by weight. If total additives make up 5% or less of the final ~~SCM~~SCM product by weight, these emissions are considered negligible. See Section 5.2.1 for additional information on additives.
- Emissions from the capture, processing and transport of CO_2 that is injected/mineralized into the SCM or cement. Note that for quantification purposes, captured CO_2 can essentially follow the same equations as other SCMs in terms of emissions required to capture, compress and transport CO_2.

Equation 5.~~9~~10. Quantifying Project Emissions for ~~SCM~~SCM 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 manufacturing during the reporting period.	tCO_2e
$ME_{t,s}$	=	Mining emissions for SCM manufacturing during the reporting period for all eligible SCMs “s”.	tCO_2e
$PR_{t,s}$	=	Production emissions for SCM manufacturing during the reporting period for all eligible SCMs “s”.	tCO_2e
$TE_{t,s}$	=	Transport emissions for SCM inputs to manufacturing, storage, additives, and waste during the reporting period for all eligible SCMs “s”.	tCO_2e
$WE_{t,s}$		End-of-life of waste emissions generated during SCM manufacturing	tCO_2e
$AD_{t,s}$	=	Additive production emissions for SCM manufacturing during the reporting period.	tCO_2e

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

Where,			Units
PE	=	Project emissions for SCM manufacturing during the reporting period.	tCO_2e
$ME_{t,s}$	=	Mining emissions for SCM manufacturing during the reporting period for all eligible SCMs "s".	tCO_2e
$PR_{t,s}$	=	Production emissions for SCM manufacturing during the reporting period for all eligible SCMs "s".	tCO_2e
$TE_{t,s}$	=	Transport emissions for SCM inputs to manufacturing, storage, additives, and waste during the reporting period for all eligible SCMs "s".	tCO_2e
$AD_{t,s}$	=	Additive production emissions for SCM manufacturing during the reporting period.	tCO_2e

Equation 5.1011. Quantifying Mining Emissions for SCMSCM 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 SCMSCM manufacturing during the reporting period.	tCO_2e
$EL_{t,mining,grid}$	=	Grid electricity consumption for SCMSCM mining during the reporting period.	kWh
$EF_{t,mining,gri}$	=	CO_2 emission factor for grid electricity consumed during mining in the reporting	tCO_2/k

d		period from the most recent EPA eGRID emission factor publication.[29] Projects shall use the annual total output emission rates for the subregion where the project is located.	Wh
$FC_{t,mining}$	=	Fuel consumption for SCMSCM 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.[30] Projects shall use the CO_2 factor for the appropriate fuel type.	tCO_2/tonne of fuel

Equation 5.1112. Quantifying Production Emissions for SCMSCM 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 SCMSCM manufacturing during the reporting period.	tCO_2e
$EL_{t,production, grid}$	=	Grid electricity consumption for SCMSCM manufacturing or CO_2 capture/compression 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 eGRIDgrid emission factor publication.[31] 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 SCMSCM production CO_2 capture/compression 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.[32] 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 SCMSCM manufacturing facility that is sent to a landfill.

Equation 5.X. Quantifying End-of-Life Waste Emissions from SCM 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 manufacturing	tCO_2e
$qw_{t,s}$	=	Quantity of waste generated during SCM manufacturing.	t
$EF_{t,s,transport}$	=	CO_2 emission factor for end-of-life of waste from the most recent X. Projects shall use the CO_2 factor for the appropriate disposal method (landfill, incineration, recycling.	tCO_2/t

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

Equation 5.1312. Quantifying Transportation Emissions for SCMSCM Manufacturing

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

Where,			Units
$TE_{t,s}$	=	Transport emissions for SCMSCM inputs to manufacturing, storage, additives, captured CO_2, and waste during the reporting period for all eligible SCMSCMs "s".	tCO_2e
$d_{t,s}$	=	Distance traveled for SCMSCM manufacturing during the reporting period.	miles
$EF_{t,s,transport}$	=	CO_2 emission factor for mode of transport during the reporting period from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[33] Projects shall use the CO_2 factor for the appropriate transportation mode.	tCO_2/ mile

5.2.1 Hierarchical Approaches for Determining Additive Production Emissions

If additives make up greater than 5% of the final SCMSCM product by weight, the emissions associated with the primary additive(s) must be calculated. Secondary additives making up 5% or less of the total SCMSCM 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 SCMSCM 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 SCMSCM 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

5.2.1.1 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.[34] The emission factor reported in the most recent EPD may be applied in Equation 5.13.

[33] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[34] For reference, the 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

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

Equation 5.1413. Quantifying Additive Production Emissions for SCMSCM Process, if additives make up more than 5% of the weight of the final product

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

Where,			Units
$AD_{t,s}$	=	Emissions for additive production during the reporting period for all eligible SCMSCMs.	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

5.2.1.2 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.

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~~SCM 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 ~~OPC~~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:

- 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 ~~OPC~~PC is based on the amount of ~~SCM~~SCM 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 ~~SCM~~SCMs 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~~SCM 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~~SCM 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~~SCM/ACM ~~quantity is inaccessible or unsuitable~~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 manufacturing	tCO_2e	c	Each reporting period	
5.2	Q_b	Total quantity of ~~OPC~~PC that would have been produced during the reporting period	Tonnes	o	Monthly	Based off the amount of ~~SCM~~SCM produced during the reporting period
5.2	R_b	~~SCM~~SCM to ~~OPC~~PC weight adjustment factor in period during the reporting period	Percent	o	Each reporting period	

5.2,5.9	CO_{2CAP}	Quantity of CO_2 captured and permanently removed through mineralization into cement or cement additives.	tCO_2e	c	Each reporting period	
5.2, 5.3	EF_b	CO_2 emission factor for ~~OPC~~PC production during the reporting period	tCO_2/tonne of ~~OPC~~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 ~~OPC~~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 ~~OPC~~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 ~~OPC~~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 ~~OPC~~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 ~~OPC~~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.[35] Projects shall use the annual total output emission rates for the subregion where the project is located.

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

5.4	$FC_{b,mining}$	Fuel consumption for ~~OPC~~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 Inventories.[36] 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 ~~OPC~~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 ~~OPC~~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 ~~OPC~~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.[37] 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 ~~OPC~~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

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

						Inventories.[38] Projects shall use the CO_2 factor for the appropriate fuel type.
5.7	$R_{b,clinker}$	Clinker to cement ratio for ~~OPC~~PC production during the look-back period	Percent	o	Each reporting period	If using Approach 1: Plant-Specific data
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 ~~OPC~~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.[39] 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
5.9	Q_{cement}	Quantity of material subjected to mineralization	tonnes	m	Monthly	
5.9	$C_{sample,p}$	Carbon content in project sample		m	Monthly	
5.9	$C_{sample,b}$	Carbon content in baseline sample		m	Monthly	

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

5.10~~9~~, 5.11~~0~~	$ME_{t,s}$	Mining emissions for ~~SCM~~SCM manufacturing during the reporting period for all eligible ~~SCM~~SCMs "s"	tCO_2e	c	Each reporting period	
5.10~~9~~, 5.12~~1~~	$PR_{t,s}$	Production emissions for ~~SCM~~SCM manufacturing during the reporting period for all eligible ~~SCM~~SCMs "s"	tCO_2e	c	Each reporting period	
5.10~~9~~, 5.13~~2~~	$TE_{t,s}$	Transport emissions for ~~SCM~~SCM inputs to manufacturing, storage, additives, and waste during the reporting period for all eligible ~~SCM~~SCMs "s"	tCO_2e	c	Each reporting period	
5.10~~9~~, 5.14~~3~~	$AD_{t,s}$	Additive production and transportation emissions for ~~SCM~~SCM 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~~0~~	$EL_{t,mining, grid}$	Grid electricity consumption for ~~SCM~~SCM mining during the reporting period	kWh	m	Monthly	
5.11~~0~~	$EF_{t,mining,grid}$	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.[40] Projects shall use the annual total output emission rates for the subregion where the project is located.
5.11~~0~~	$FC_{t,mining}$	Fuel consumption for ~~SCM~~SCM mining during the reporting period.	tonnes of fuel	m	Monthly	

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

5.11~~0~~	$EF_{t,mining,fuel}$	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.[41] Projects shall use the CO_2 factor for the appropriate fuel type.
5.12~~1~~	$EL_{t,production,grid}$	Grid electricity consumption for ~~SCM~~SCM manufacturing during the reporting period	kWh	m	Monthly	
5.12~~1~~	$EF_{t,production,grid}$	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.[42] Projects shall use the annual total output emission rates for the subregion where the project is located.
5.12~~1~~	$FC_{t,production}$	Fuel consumption for ~~SCM~~SCM 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~~1~~	$EF_{t,production,fuel}$	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.[43] Projects shall use the CO_2 factor for the appropriate fuel type.
5.13~~2~~	$d_{t,s}$	Distance traveled for ~~SCM~~SCM manufacturing during the reporting period	miles	m	Monthly	

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

5.1~~2~~3	$EF_{t,s,transport}$	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.[44] Projects shall use the CO_2 factor for the appropriate transportation mode.
5.1~~3~~4	$Q_{t,ad}$	Quantity of additives used during the reporting period	tonnes	m	Quarterly	
5.1~~3~~4	$EF_{t,a}$	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).

[44] 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

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 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 ~~SCM~~SCMs
- 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

7.3 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~~SCM. 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 ~~SCM~~SCMs 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.

7.3.1 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.

7.3.2 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.

7.3.3 Verification Site Visit Schedule

A site visit 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; and
3. 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 ~~upgraded SCM~~SCMs/ACMs that can fully or partially replace ~~OPC~~PC • ~~Production of novel SCMs that can fully or partially replace OPC~~	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 ~~SCM~~SCMs that can replace ~~OPC~~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~~SCM 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~~SCM project	No
2.1	Verify when the ~~SCM~~SCM 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~~SCM 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.	No
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 ~~OPC~~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 sales volumes.	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.
Blended cement	A mix of ~~ordinary portland cement~~ Portland Cementand supplementary cementitious materials 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.).
Novel ~~SCM~~SCM	~~SCM~~SCM that has not been historically used as an ~~OPC~~PC replacement in the region at high levels.

Pozzolan	Material that chemically reacts with moisture and calcium hydroxide to display cementitious properties.
~~Ordinary portland cement~~ Portland Cement(~~OPC~~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~~SCM concrete	Concrete that has one or more supplementary cementitious materials combined with ~~ordinary portland cement~~ Portland Cementand other materials at a ready mix concrete batch plant.
Supplementary cementitious materials (~~SCM~~SCM)	Siliceous or siliceous aluminous materials that can be processed to display cementitious properties and can be blended with or replace ~~ordinary portland cement~~ Portland Cementin concrete production.
Upgraded ~~SCM~~SCM	~~SCM~~SCM that would otherwise be sent to the landfill or not be beneficially used because it does not meet the quality standards for use as a replacement for ~~OPC~~PC without application of a technology or process that improves the ~~SCM~~SCM to a quality level than is typically used for concrete-grade in the project region
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~~SCMs required to replace one tonne of ~~OPC~~PC, as identified in Section 5.

10 References

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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.[45] 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.[46] 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.[47,48]

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 ~~SCM~~SCMs, blended cement, or ~~SCM~~SCM 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).[49] California's GHG cap-and-trade program also applies to cement plants; however, cement imported into California is not covered by the program.[50]

In California, the California Department of Transportation (Caltrans) already sets minimum amounts of required ~~SCM~~SCMs in state pavement and structure applications. These minimum

45 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.
46 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.
47 Baer, Louis, "Energy & Environment Regulatory Priorities," Portland Cement Association, 2019, https://www.cement.org/issues-advocacy/regulatory-priorities/energy-environment-regulatory-priorities.
48 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.
49 Johnson, "California Enacts Legislation to Slash Cement Emissions."
50 "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.

requirements include 20% to 25% natural pozzolan or fly ash, 12% silica fume or metakaolin, or 50% GGBFS.[51] However, Caltrans has reported concerns around how the worsening shortage of suitable ~~SCM~~SCMs could impact current and future state construction projects.[52]

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.[53] 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.[54] 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.[55] 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.[56]

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 permit the use of fly ash, GGBFS, and silica fume in cement and concrete projects; however, the use of these ~~SCM~~SCMs is not required nor even specifically recommended. The EPA's CPG guidelines state that ~~SCM~~SCM 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 ~~SCM~~SCMs due to their lower GHG emissions; for example, the use of ~~SCM~~SCMs 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.

According to the Reserve's understanding of existing requirements in the U.S., there are currently no regulations that require the production of the eligible ~~SCM~~SCMs in Section 3.4.1. If any state agencies specifically require the replacement of ~~OPC~~PC with the ~~upgraded or novel~~ ~~SCM~~SCMs identified in the protocol, projects that fall under the legislation in these regions may be ineligible for crediting.

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[51] Caltrans, "Revised Standards Specifications," October 15, 2021.
[52] Concrete Task Group of the Caltrans Rock Products Committee and Industry, "Fly Ash Current and Future Supply," *Caltrans Office of Structural Materials*, 2020, 25.
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[54] 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.
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[56] 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.

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 ~~SCM~~SCMs to market. ~~Upgraded SCMs (e.g., harvested fly ash, upgraded fly ash diverted from a landfill) and novel SCMs (e.g., natural pozzolans mined from geologic resources, manufactured replacements for OPC, etc.)~~SCMs/ACMs were identified by our research as innovative categories ~~of SCMs~~ that have the potential to bolster the regional supply of ~~SCM~~SCMs in the United States. Through this protocol, carbon financing will incentivize the market to identify and recover these ~~upgraded and novel SCM~~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~~SCMs would not constitute eligible projects under the protocol. ~~Silica fume is costly and rarely used and calcined clays are also limited in use and require high energy consumption for kiln heating, therefore these SCMs would not be eligible under the protocol.~~

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 ~~Upgraded and Novel SCM~~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.[57] 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.[58] Based on this market penetration to date, these

[57] NRMCA?
[58] Other?

products were found to be ineligible under this protocol.

The Project Developer must demonstrate that the usage rate of the novel SCMs/ACMs 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 PC production in the United States.

The production of novel and upgraded SCMSCMs/ACMs is 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.[59] 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 deployed at scale.[60,61] 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 SCMSCMs. The Natural Pozzolan Association website currently lists four raw natural pozzolan producers that are in operation along with a few emerging companies.[62] 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.[63] Upgraded and novel SCMSCMs 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 SCMSCMs/ACMs in the United States

The amount of SCMSCMs used in cement have remained largely stagnant in the U.S. While significant drivers exist to utilize SCMSCMs, the industry faces challenges in overcoming supply constraints. Increasing the use of SCMSCMs 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 SCMSCMs are expected to worsen in the future as the supply of today's most common SCMSCMs decrease while the global demand for OPCPC grows.[64] 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

[59] 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.
[60] 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.
[61] 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
[62] Natural Pozzolan Association, "Sourcing Natural Pozzolans" http://www.pozzolan.org/sourcing-pozzolan.html
[63] For example, Terra CO_2 manufactures a low-carbon alternative for cement replacement.
[64] Global Cement and Concrete Association, "Concrete Future The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete."

pressure to decarbonize and reduce waste themselves in some regions.[65] 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~~SCM prices but also increased costs associated with sourcing ~~SCM~~SCMs 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.[66,67] 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.[68]

Deposits of fly ash waste material can be harvested from landfills or disposal ponds, but this emerging procedure is technologically and geographically limited, costly, and requires additional processing.[69] 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 ~~OPC~~PC. As a result, increased replacement will not be possible in the future without innovation to increase the supply of ~~SCM~~SCMs. 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 ~~SCM~~SCMs, including mining natural pozzolans, to meet global demand.[70]

Institutional barriers associated with market acceptance remain a key challenge despite the legacy use of ~~SCM~~SCMs throughout history. Since the 19th century, ~~OPC~~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~~SCM blend) are not as widely trusted and may be dismissed as a less safe or easy-to-use option.[71] 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 ~~SCM~~SCMs have historically been lower or equal in cost to ~~OPC~~PC. However, concrete and cement producers that are not currently using ~~SCM~~SCMs face a "barrier to entry" cost to begin utilizing ~~SCM~~SCMs associated with additional storage equipment and potentially new processing technology. To use ~~SCM~~SCMs, a producer needs at least two silos to hold the material (one for ~~OPC~~PC and one for the ~~SCM~~SCM). If they want to use more than one ~~SCM~~SCM, multiple silos are required as the cementitious material must be stored individually.[72] Carbon finance provides the opportunity to mitigate some of the higher upfront

[65] 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.
[66] US Department of Transportation Federal Highway Administration, "Tech Brief Best Practices for Concrete Pavements Supplementary Cementitious Materials."
[67] Tritsch, Sutter, and Diaz-Loya, "Use of Harvested Fly Ash in Highway Infrastructure."
[68] Concrete Task Group of the Caltrans Rock Products Committee and Industry, "Fly Ash Current and Future Supply."
[69] Tritsch, Sutter, and Diaz-Loya, "Use of Harvested Fly Ash in Highway Infrastructure."
[70] "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.
[71] The Loreti Group, "Greenhouse Gas Emission Reductions from Blended Cement Production Issues Paper."
[72] Thomas Van Dam and Federal Highway Administration, "Tech Brief Supplementary Cementitious Materials and

costs associated with incorporating more SCMSCMs.

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 SCMSCMs 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 SCMSCMs 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 SCMSCMs to enter the market and combat existing supply constraints (market barrier). When more SCMSCMs are available in the market, the use of blended cement and SCMSCM concrete may become more viable and economically attractive, which would thus encourage new standards to support the use of SCMSCMs (institutional barrier) and further incentivize the development of novel processing technologies (technical barrier). Advancements in technology may enable new SCMSCMs to enter the market while overcoming limitations that prevent higher OPCPC 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 SCMSCMs (disposed of fly ash) to enter the market. This example can be applied to other novel SCMSCMs, including the extraction and processing of natural pozzolans and manufactured substitutes.

Blended Cements to Improve Sustainability of Concrete Pavements" (Iowa State University, November 2013), https://intrans.iastate.edu/app/uploads/2018/12/SCM_tech_brief.pdf.