U.S.

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
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
PC	Portland Cement
PDR	Project Data Report
PLC	Portland Limestone Cement
QA/QC	Quality assurance/quality control
SCM	Supplementary cementitious material
SSRs	Sources, sinks, and reservoirs
t	Tonne (or metric ton)
tCO_2e	Tonnes of carbon dioxide equivalent

1 Introduction

The Climate Action Reserve (Reserve) Low-Carbon Cement Protocol provides guidance to account for, report, and verify greenhouse gas (GHG) emission reductions associated with the production and processing of supplementary cementitious materials (SCMs) or alternative cementitious materials (ACMs) that can replace portland cement (PC) in ready-mix or concrete products to reduce associated GHG emissions. The Reserve conducted both a Performance Standard Test and Legal Requirement Test to determine which SCMs/ACMs are additional and eligible under Version 1.0 of the Low-Carbon Cement Protocol. 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.

The **Climate Action Reserve** is the most trusted, efficient, and experienced offset registry for global carbon markets. A pioneer in carbon accounting, the Reserve promotes and fosters the reduction of greenhouse gas (GHG) emissions through credible market-based policies and solutions. As a high-quality offset registry for voluntary carbon markets, it establishes rigorous standards involving multi-sector stakeholder workgroup development and local engagement and issues carbon credits in a transparent and publicly available system. The organization also supports compliance carbon markets in California, Washington and internationally. The Reserve is an environmental nonprofit organization headquartered in Los Angeles, California with staff members located around the world. For more information, please visit www.climateactionreserve.org.

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[1] and Section 8 of this protocol.

The Reserve develops protocols aligned with the laws, norms, and on-the-ground context of a specific jurisdiction or jurisdictions to establish standardized eligibility and additionally criteria and baseline scenarios. This protocol is thus aligned with the laws, norms, and context of United States, including North Carolina's Coal Ash Management Act of 2014 and the California Department of Transportation (CalTrans) Standard Specifications. See Section(s) *3.4.2 The Legal Requirement Test* and *Appendix A Development of the Performance Standard Threshold* for further information on how these laws were incorporated in the Performance Standard Test.

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.[2]

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

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 PC, are attributable to a chemical reaction caused by a high-temperature process ("calcination") used to produce portland cement clinker (PC clinker), the primary intermediate component for PC. The remainder of the emissions from typical cement production result from mining, processing (including grinding) and transportation of materials used during the production process.

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

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

Figure 2.1. Chemical Reaction for Calcination during traditional PC Production

ASTM International, formerly known as the American Society for Testing and Materials, establishes procedures and standards for testing cements and concretes. To be ASTM-certified as PC, the product must include 90% to 95% PC clinker and is defined by the ASTM as a hydraulic cement produced by pulverizing clinker, consisting essentially of crystalline hydraulic calcium silicates, and usually containing one or more of the following: water, calcium sulfate, up to 5 % limestone, and processing additions. The clinker-to-cement ratio, or the proportion of PC clinker integrated in each batch of cement, is a critical component in determining the emissions intensity of cement. In 2021, U.S. cement plants emitted roughly 69,000,000 tonnes of carbon dioxide equivalent (tCO_2e).[4]

PC makes up only a small portion of the concrete mix by mass (approximately 10%); however, it comprises roughly 80% to 90% of concrete's total GHG emissions.[5] Thus, one of the most effective strategies to reduce GHG emissions associated with concrete production is to replace some or all of the PC clinker with materials called SCMs or ACMs. SCMs are defined by ASTM

[3] "Cement technology roadmap plots path to cutting CO2 emissions 24% by 2050" International Energy Association, April, 2018, https://www.iea.org/news/cement-technology-roadmap-plots-path-to-cutting-co2-emissions-24-by-2050
[4] Environmental Protection Agency, "U.S. Cement Industry Carbon Intensities (2019)," *Environmental Protection Agency*, October 2021, 2. http://www.epa.gov/system/files/documents/2023-04/Minerals_Profile_04-06-2023%20508c.pdf
[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.

International as inorganic material that contributes to the properties of a cementitious mixture through hydraulic or pozzolanic activity, or both.[6] ACMs are manufactured clinkered, calcined, or non-clinkered materials that can fully replace PC clinker in cement.[7] SCMs/ACMs can both be used to reduce GHG emissions by replacing PC clinker at the cement processing plant and/or replacing the PC used at the ready-mix concrete plant or in concrete products. In addition to reducing GHG emissions through PC replacement, some SCMs/ACMs can also improve the performance of concrete.[8]

Most 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 SCMs used in cement and concrete production are fresh coal ash and traditional slag cement, 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 coal ash and approximately 2,600,000 tonnes of traditional slag cement.[9,10] Other materials that are byproducts of industrial processes include silica fume and non-ferrous slags; however, these are only occasionally used in specialty concretes. Finally, natural pozzolans including diatomaceous earths, volcanic ash, pumicites, and some calcined clays and shales are also used as an SCM.

Traditionally, ACMs have been used by industry for infrastructure repairs as many of these formulations offer rapid set, shrinkage compensation effects, and rapid early strength development.[7] 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 SCMs/ACMs to significantly reduce concrete's GHG footprint, there are a number of factors that impede the widespread adoption of SCMs/ACMs by the cement and concrete industry including (1) regional and seasonal supply constraints for certain SCMs (such as coal ash and traditional slag cement) that materially limit their accessibility in significant quantities, (2) the inability to use many SCMs beyond a certain replacement rate before negatively impacting the performance of concrete,[11] (3) diminishing supply of SCMs as a result of declining coal and changes with steel production processes (fresh coal ash and traditional slag cement), and (4) a general lack of market acceptance. Appendix A includes further information on SCM/ACM legal requirements and Appendix B includes information on SCM/ACM uses and limitations.

Despite regional SCM/ACM shortages, some SCMs/ACMs including natural pozzolans and harvested coal ash are becoming more available however, they are not ready to be deployed at scale due to significant economic hurdles, and their current supply is insufficient to meet growing demand. The concrete, cement, and SCM/ACM industries will require innovative yet

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[6] ASTM International. "C125: Standard Terminology Relating to Concrete and Concrete Aggregates," ASTM International, October 4, 2021.

[7] US Department of Transportation, "Alternative Cementitious Materials: An Evolution or Revolution?" Kurtis, 2019, https://highways.dot.gov/public-roads/autumn-2019/alternative-cementitious-materials-evolution-or.

[8] Design of Steel-Concrete Composite Structures Using High-strength Materials, "Standard Terminology Relating to Concrete and Concrete Aggregates," Liew, 2021, https://www.sciencedirect.com/topics/engineering/supplementary-cementitious-material

[9] American Coal Ash Association, "Production and Use Survey"

[10] Geological Survey, "Iron and Steel Slag Statistics and Information," https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-slag-statistics-and-information.

[11] Barbara Pacewska and Iwona Wilińska, "Usage of Supplementary Cementitious Materials: Advantages and Limitations," *Journal of Thermal Analysis and Calorimetry* 142, no. 1 (October 1, 2020): 371–93, https://doi.org/10.1007/s10973-020-09907-1.

costly technological advancements to bring new SCMs/ACMs to market and fill this growing gap between supply and demand. Although these innovations will support the development of novel SCMs/ACMs, new or updated quality standards will be needed to ensure these novel products meet concrete-grade specifications to gain market acceptance.

2.2 Project Definition

For the purpose of this protocol, the GHG reduction project is defined as the production of SCMs or ACMs that can replace PC. The project results in the avoidance of GHG emissions from PC production. SCMs/ACMs can be processed to display cementitious properties to replace some or all PC clinker in concrete production and/or concrete products. Eligible projects must meet applicable ASTM standards (Section 3.6) when an ASTM standard for the product is available. A single project may consist of a single eligible SCM/ACM or more than one type of eligible SCM/ACM material.

Project crediting shall occur at an SCM/ACM manufacturing site or group of SCM/ACM manufacturing sites. A SCM/ACM manufacturing site is defined as a site that processes or manufactures SCM/ACMs. The protocol is applicable to eligible SCMs/ACMs that are sold domestically within the project country. As discussed further in Section 3.4, eligible SCMs/ACMs must also exceed the Legal Requirement Test and meet the Performance Standard Test. The baseline scenario for all projects is the production/supply of PC in the project region.

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

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. The project developer by default is the SCM/ACM supplier or manufacturer, but a project developer may also be low-carbon cement technology suppliers, and/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, as they are the entity with responsible for the reduction in GHG emissions that are being credited, unless the rights to the emissions reductions have been transferred to another entity.

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

3 Eligibility Rules

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

Eligibility Rule I:	Location	→	*U.S. and its tribal lands and territories*
Eligibility Rule II:	Project Start Date	→	*No more than 12 months prior to project submission*
Eligibility Rule III:	Project Crediting Period	→	*Emission reductions may only be reported during the crediting period; the crediting period may be renewed one time*
Eligibility Rule IV:	Additionality	→	*Exceed legal requirements*
		→	*Meet performance standard*
Eligibility Rule V:	Regulatory Compliance	→	*Compliance with all applicable laws*
Eligibility Rule VI:	Quality	→	*Meet applicable 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] All phases of sourcing, production, and end use of the SCM/ACM must occur in the United States, U.S. tribal lands and territories. Project activities may occur in locations where activities from other carbon project types are occurring, as long as such projects are in good standing with the program in which they were or are enrolled. However, such project stacking is subject to prior approval from the Reserve and guidance for any adjustments that may be required of the Low-Carbon Cement project to ensure additionality and to prevent double-counting of credits.

3.2 Project Start Date

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

To be eligible, the project must be submitted to the Reserve no later than 12 months after the project start date.[14] The start date is defined in relation to the commencement of SCM/ACM production, not other activities that may be associated with project initiation or research and development. The Reserve allows project developers to undergo a start-up testing period for a maximum of 9 months to complete project initiation activities. Thus, the project developer may select a start date within 9 months of when production of the SCM/ACM product first

[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.

commences (**Figure 2.2**). The project developer must provide verifiable evidence to support that this period of time prior to the start date of the project was not in business or functioning at scale (either as a % of total batch scale of reduced batch tonnage). Documentation may include, but is not limited to, performance standard checks to confirm operability, internal communication, and/or project monitoring data.

Figure 2.2 Example of an Initial Start-up Testing Period

Any project comprised of multiple SCM/ACM manufacturing sites must select a single project start date, which shall be the first start date of the multiple project sites. Additional project activities may be implemented at the same manufacturing site in the same project at any time; however, project developers must submit a revised listing form covering these additional eligible SCMs/ACMs by the end of each additional SCM/ACM 12-month initial start-up period, to indicate that the SCM/ACM manufacturer will begin reporting with the project by the end of that start-up period.

Projects may always be submitted for listing by the Reserve prior to their start date. For projects that are transferring to the Reserve from other offset registries, start date guidance can be found in the Reserve Offset Program Manual.[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 SCM/ACM or the inclusion of eligible SCM/ACM 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 to this protocol for a maximum of two ten-year crediting periods after the project start date, or until the project activity is enforced by law, including under an emissions cap or other emissions trading scheme (ETS).

The project crediting period begins at the project start date regardless of whether sufficient monitoring data is available to verify GHG reductions. However, the project will not start generating credits until monitoring data is available, which must begin within 12 months after the start date of the project (see Section 6.3). Projects will be eligible to apply for a second crediting period provided the project meets the eligibility requirements of the most current version of the protocol at the time of such application. If a project developer wishes to apply for eligibility under

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

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

Projects must satisfy the following tests to be considered additional:

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

3.4.1 The Performance Standard Test

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

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 A.

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

- Portland Limestone Cement (PLC) (ASTMC595)
- Traditional fresh coal ash (fly or bottom ash) (ASTM C618)
- Traditional slag cement (ASTM C989)
- Silica fume (ASTM C1240)

Other products known to have the potential to displace PC that are not currently common practice in the U.S., include:

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

- Beneficiated coal ash (upgraded and/or harvested coal or bottom ash)
- Raw natural pozzolans (i.e., volcanic ash)
- Calcined clays/shale and/or metakaolin
- Limestone calcined clay cements (LC3)
- Carbon dioxide (CO_2)[17]
- Other artificial pozzolans or treated calcined materials (including rice husk ash)
- Other waste by-products (including Bauxite residue (Red Mud), lime kiln dust, or cement kiln dust)
- Novel ACMs (including clinkered, calcined, and non-clinkered materials)
- Hydroxide products (including portlandite ($Ca(OH)_2$) and brucite ($Mg(OH)_2$))[18]
- Other novel SCM/ACM s (including biogenic limestone, etc)
- Blends including one or more eligible SCMs/ACMs[19]
- Biochar

Products not on the negative list are assumed to have a usage rate in concrete products at near zero (first-of-its kind) but are required to meet quality standards and be within the GHG Assessment Boundary. However, the Reserve may ask project developers to demonstrate that a specific product has a usage rate in concrete of near zero with insufficient data to calculate a penetration rate or provide evidence that production of the SCM/ACM product is less than 5% of the cementitious materials market in the United States.

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 replace PC during cement production or during the production of concrete or concrete products. The monitoring requirements are further discussed in Section 6.

3.4.2 The Legal Requirement Test

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

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

1. The production of a SCM/ACM, including under the circumstances relevant to the project, must not be legally required;
2. The use of SCM/ACM, in those ways it is being applied under the project, must not be legally mandated; and
3. Emissions from SCM/ACM manufacturing sites that are not included under an emissions cap.

To satisfy the Legal Requirement Test, project developers must submit a signed Attestation of

[17] The Reserve will review CO_2 mineralization specifics to determine if the quantification is accurate and if CO_2 use is within the project boundary for each specific project individually.

[18] Portlandite 'through manufactured calcination or as a precipitation product or as any other manufacturing process not traditional PC production.

[19] Except for blending of fresh coal ash with beneficiated coal ash to meet ASTM specifications.

Voluntary Implementation form[20] prior to the commencement of verification activities each time the project is verified (see Section 8). In addition, the project's Monitoring Plan (Section 6) must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the Legal Requirement Test.

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

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

3.5 Regulatory Compliance

To meet the next 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[21] prior to the commencement of verification activities each time the project is verified. Project developers are also required to disclose in writing to the verifier any and all instances of legal violations – material or otherwise – caused by the project activities.

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

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

3.6 ASTM International Standards

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

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

displace PC via other standards specifications that will be reviewed by the Reserve. Project developers should reference Low-Carbon Cement ASTM Standard Guidelines for more information.

3.6.1 Eligibility of Beneficiated Ash

Fresh coal ash is currently the most commonly used SCM in the U.S. for cement and concrete production. Based on market penetration rates at this time, fresh ash has been categorized as an ineligible project activity under the protocol. However, there is a significant amount of coal ash that is currently in a landfill or is being sent to a landfill because it does not meet the ASTM specifications and it is too costly to improve the product for use as cementitious material. Based on the lack of beneficiated coal ash in the cement market today and the significant capital and operational costs associated with its improvement, the protocol considers beneficiated coal ash to be an eligible project activity. This section of the protocol aims to explain what constitutes as beneficiated ash with respect to the ASTM standards. To meet eligibility requirements, the unprocessed product must be insufficient according to a representative 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 chemical or physical requirement categories. For example, if the moisture content is above 3.0% and is processed to lower the moisture content to 3.0% or less, the product would be considered beneficiated and eligible for the purposes of this protocol. Harvested coal ash cannot be mixed with fresh coal ash as the mechanism to meet the standard specifications. Project developers should reference Low-Carbon Cement ASTM Standard Guidelines for more information.

3.7 Project Stacking

As described in Section 3.1, Low-Carbon Cement Projects may take place in locations where other carbon projects have occurred or are currently occurring and there is overlap between the project activities attributable to the Low-Carbon Cement Project and those attributable to the co-located project type. However, Project Operators must obtain prior approval from the Reserve to stack a Low-Carbon Cement Project with project activities from another carbon project type that were or are currently in the same location. The Reserve may determine at its sole discretion if such stacking is allowed, as well as if any reconciliation between the Low-Carbon Cement Project and the project with which it is stacked is necessary and what the requirements for such reconciliation may be.

3.8 Social and Environmental Safeguards

The Reserve requires project developers to demonstrate that their GHG projects will not give rise to environmental or social harm. Moreover, offset projects can create long-term social and environmental benefits.

This Protocol includes specific social and environmental safeguards that must be considered in the project design and implemented throughout the project life to help guarantee that the project will have positive environmental and social outcomes. In addition, all projects must comply with the Reserve's Offset Program Manual, including the section on regulatory compliance and programmatic environmental and social safeguards. The safeguards in the protocol are intended to respect internal governmental processes, customs, and rights of employees and communities while ensuring projects are beneficial, both socially and environmentally. The sections on monitoring, reporting, and verification (MRV) (Sections 7 and 8) specify the criteria for verification of each of these safeguards and consequences for failure to achieve the minimum thresholds.

The social safeguards requirements include:

1. Labor and Safety: The project developer must attest that the project is in material compliance with all applicable laws, including labor or safety laws. See Section 3.6 Regulatory Compliance for further information.

2. Dispute Resolution: The Reserve holds public comment on all listed projects prior to registration and has an ongoing dispute resolution process. See the Reserve Offset Program Manual and website for further information on programmatic and project specific public consultation and dispute resolution processes. Projects that receive material complaints will not be registered until a satisfactory dispute resolution plan has been approved.

The environmental safeguards requirements include:

1. Air and Water Quality: The project developer must attest that the project is in material compliance with all applicable laws, including environmental regulations (e.g., air and water quality). See Section 3.6 Regulatory Compliance and Appendix A Associated Environmental Impacts for further information.

2. Mitigation of Pollutants: Projects must be designed and implemented to mitigate potential releases of pollutants that may cause degradation of the quality of soil, air, surface and groundwater such as those described in Appendix A, and project developers must acquire the appropriate local permits prior to installation to prevent violation of all applicable laws.

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.

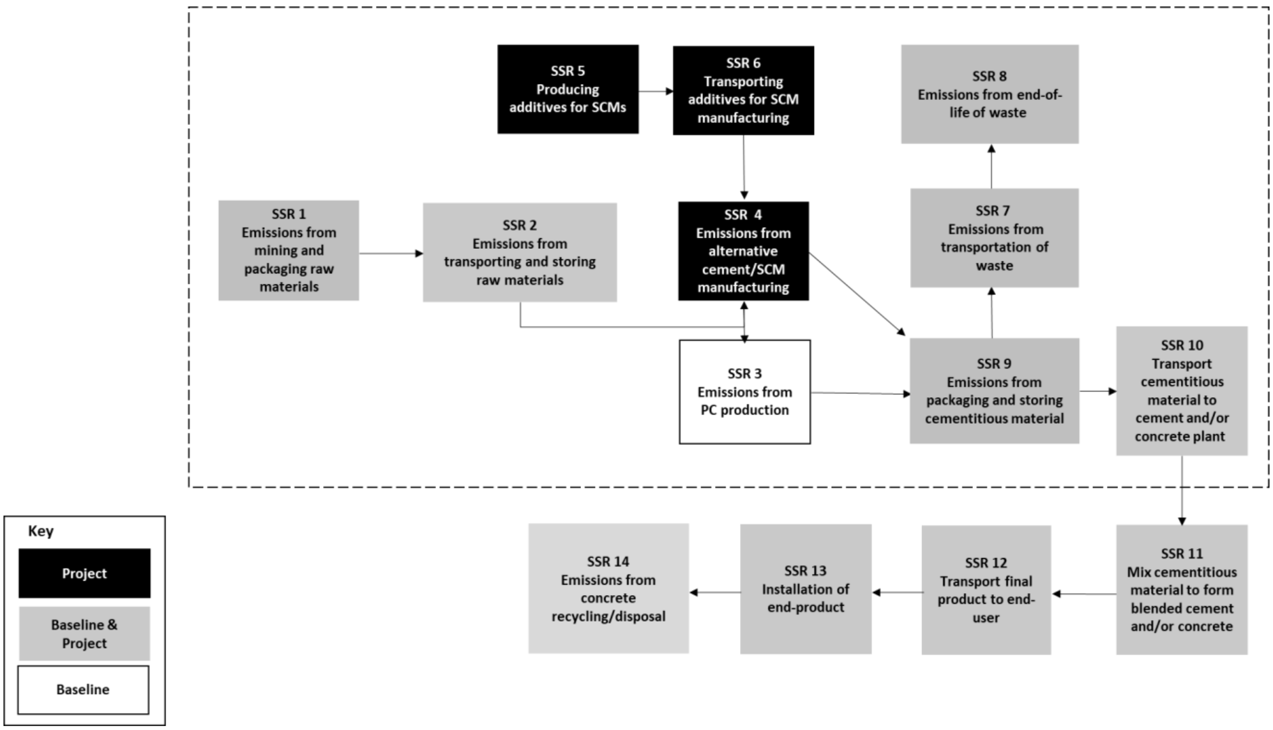

Figure 4.1. General illustration of the GHG Assessment Boundary

Table 4.1. Description of all Sources, Sinks, and Reservoirs

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

SSR	Source Description	Gas	Included (I) or Excluded (E)	Baseline (B) or Project (P)	Quantification Method	Justification/ Explanation
4	Emissions from ACM/SCM manufacturing	CO_2	I	P	GHG emissions based on electricity and fuel consumption.	Energy consumption is a primary source of emissions for SCM/ACM manufacturing. A GHG project will directly impact these emissions.
		CH_4	E	P	N/A	Excluded, as this emission source is considered negligible.
		N_2O	E	P	N/A	Excluded, as this emission source is considered negligible.
5	Emissions from production of additives for SCM	CO_2	I	P	GHG emissions based on electricity and fuel consumption.	A GHG project will directly impact these emissions if additives make up a significant portion of the final product. The source is considered negligible if additives make up 5% or less of the final SCM/ACM by weight. If additives make up greater than 5% of the final SCM/ACM product by weight, the emissions associated with the primary additive(s) must be calculated in reference to additive production, however, secondary additives may be excluded from the calculation up to 5% of the total SCM/ACM product by weight.
		CH_4	E	P	N/A	Excluded, as this emission source is considered negligible.
		N_2O	E	P	N/A	Excluded, as this emission source is considered negligible.

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

SSR	Source Description	Gas	Included (I) or Excluded (E)	Baseline (B) or Project (P)	Quantification Method	Justification/ Explanation
8	Emissions from End-of-Life Waste	CO_2	I	B, P	GHG emissions based on waste and emission factor for type of waste.	A GHG project will directly impact these emissions. Calculated in reference to landfill, incineration, or recycling.
		CH_4	E		N/A	Excluded, as this emission source is considered negligible.
		N_2O	E		N/A	
9	Emissions from packaging and storing cementitious material	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
10	Emissions from transportation of cementitious material to cement and/or concrete plan	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
11	Emissions from mixing cementitious material to form blended cement and/or concrete	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 transportation of product to end-user	CO_2 CH_4 N_2O	E	B,P	N/A	Excluded, as project activity is unlikely to impact emission relative to baseline activity.

SSR	Source Description	Gas	Included (I) or Excluded (E)	Baseline (B) or Project (P)	Quantification Method	Justification/ Explanation
13	Emissions from implementation 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 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

5 Quantifying GHG Emission Reductions

GHG emission reductions from a low-carbon cement project are quantified by comparing actual project emissions to baseline emissions at a PC production site. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary (see Section 4) that would have occurred in the absence of the low-carbon cement project. In the case of low-carbon cement projects as per this protocol, baseline emissions are GHG emission sources from the production of PC . Project emissions are actual GHG emissions that occur at sources within the GHG Assessment Boundary when implementing the low-carbon project. Project emissions for low-carbon cement projects are those associated with the production of SCM/ACM. Project emissions must be subtracted from the baseline emissions to quantify the project's total net GHG emission reductions (**Equation *5.1***). Project developers should use the LCC QuanTool to determine their baseline and project emissions according to the below equations.[22]

Equation 5.1. Calculating GHG Emission Reductions

$$\boldsymbol{ER = BE - PE}$$

Where,

			Units
ER	=	Total emission reductions for the reporting period	tCO_2e
BE	=	Total baseline emissions for the reporting period, from all SSRs in the GHG Assessment Boundary (as calculated in Section 5.1)	tCO_2e
PE	=	Total project emissions for the reporting period, from all SSRs in the GHG Assessment Boundary (as calculated in Section 0)	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.

[22] The LCC QuanTool is built upon the quantification section of this protocol, allowing for Project Owners to conduct project quantification without first developing their own tool. It is updated periodically to enhance usability or correct errors.

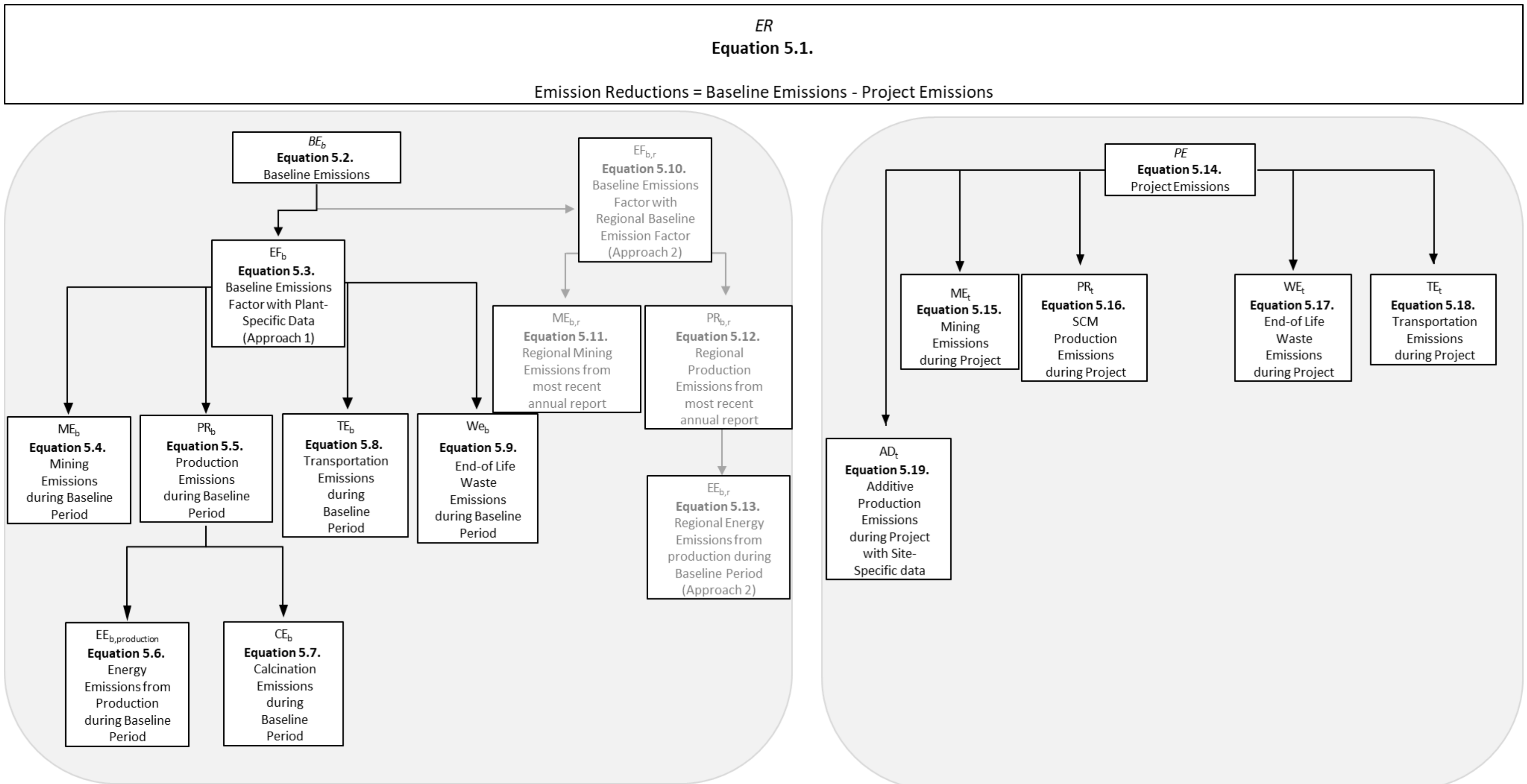

Figure 5.1. Organizational Chart of Equations for Low-Carbon Cement Project

5.1 Quantifying Baseline Emissions

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

Equation 5.2. Quantifying Total Baseline GHG Emissions

$$BE = (Q_b \times R_b \times EF_{b/b,r})$$

Where,			Units
BE	=	Total baseline emissions for the reporting period, from all SSRs in the GHG Assessment Boundary	tCO_2e
Q_b	=	Total quantity of PC that would have been produced during the reporting period	t
R_b	=	PC to SCM/ACM weight adjustment factor in percent during the reporting period	percent
$EF_{b/b,r}$	=	CO_2 emission factor for PC production during the reporting period (refer to Section 5.1.1.1 and Section 5.1.1.2)	tCO_2e/t of PC

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

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

5.1.1 Hierarchical Approaches for Determining Baseline PC Emission Factor

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

5.1.1.1 Historical PC production records using plant-specific data; or
5.1.1.2 Regional PC Emission Factors

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

If the facility location is known and historical records are available, project developers must use Approach 1 if historical production records or data to support historical production are available. Approach 1 would ensure site specificity and the closest depiction of the historical PC production practices at the site. Three years' worth of data from the rolling baseline look-back period is required to set an average mining emission factor, transport emission factor, and production emission factor (**Equation *5.3***). Records that may satisfy a verifier as to historical PC production may include product specific Environmental Product Declarations (EPDs) for PC,[23,24] energy bills, fuel use receipts, invoices or receipts for clinker. This list is not exhaustive and is meant to provide 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 Approach 2.

For equations with emission factors, project developers must use the most recent annual Environmental Protection Agency (EPA) eGRID subregion emission factors for electricity and emission factors from the EPA's Emissions Factor Hub[25] for fuel consumption. If project developers would like to use alternative emission factors, there must be reasonable justification (e.g., that an emission factor from a local utility is a better representation than the subregional emission factor from eGRID) to support that these values are more accurate than the EPA emission factor values.

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

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

Where,

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

[23] https://www.astm.org/products-services/certification/environmental-product-declarations/epd-pcr.html
[24] Project developers may use information from publicly available product-specific PC EPDs available on the ASTM International webpage. Use of this information to support plant specific baseline quantification is subject to review and approval by the verification body.
[25] https://www.epa.gov/climateleadership/ghg-emission-factors-hub

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

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

Where,			Units
ME_b	=	Mining emissions for PC production during the look-back period	tCO_2e
$EL_{b,mining,\ grid}$	=	Grid electricity consumption for PC mining during the look-back period	kWh
$EF_{b,mining,grid}$	=	CO_2 emission factor for grid electricity consumed from the most recent U.S. Environmental Protection Agency (EPA) eGRID emission factor publication.[26] Projects shall use the most recent total output emission rates for the subregion where the project is located	tCO_2/kWh
$FC_{b,mining}$	=	Fuel consumption for PC mining during the look-back period	t of fuel
$EF_{b,mining,fuel}$	=	CO_2 emission factor for fuel consumed from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[27] Projects shall use the CO_2 factor for the appropriate fuel type	tCO_2e/ t of fuel

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

$$PR_b = EE_b + CE_b$$

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

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

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

Where,			Units
EE_b	=	Energy emissions for PC production during the look-back period	tCO_2e
$EL_{b,production,\ grid}$	=	Grid electricity consumption for PC production during the look-back period	kWh
$EF_{b,production,\ grid}$	=	CO_2 emission factor for grid electricity consumed from the most recent EPA eGRID emission factor publication.[28] Projects shall use the most recent annual total output emission rates for the subregion where the project is located	tCO_2/kWh
$FC_{b,production}$	=	Fuel consumption for PC production during the look-back period	t of fuel
$EF_{b,production,fuel}$	=	CO_2 emission factor for fuel consumed from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[29] Projects shall use the CO_2 factor for the appropriate fuel type	tCO_2e/ t of fuel

[26] Available online at: https://www.epa.gov/egrid
[27] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[28] Available online at: https://www.epa.gov/egrid
[29] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

As previously mentioned, a product must include 90% to 95% clinker to be ASTM-certified as PC. Based on an industry-wide average of 91% clinker ratio, the PCA's industry-wide EPD for PC determines that 0.48 tCO2e/t of PC is attributed to calcination process emissions. Project developers shall use 0.48 tCO2e/t of PC for CE_b unless they can show verifiable evidence that the PC product has a different percentage of clinker.

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

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

Where,

			Units
CE_b	=	Calcination emissions for PC production during the look-back period	tCO_2e
$R_{b,clinker}$	=	Clinker to cement tonnage for 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 (see below information)[30]	tCO_2e/ t of clinker

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

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

Where,

			Units
TE_b	=	Transport emissions for PC production during the look-back period	tCO_2e
d_b	=	Fuel quantity or distance traveled for PC production and delivery during the look-back period (in gallons, miles, etc.)	unit
$EF_{b, transport}$	=	CO_2 emission factor for mode of transport from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[31] Projects shall use the CO_2 factor for the appropriate transportation mode	tCO_2e/ unit

The emissions for both transportation of raw materials and transportation of the cementitious material must be included in **Equation *5.8***. If the project developer does not have access to the fuel quantity or distance travelled for transporting the PC product to the ready-mix concrete facility or other end-user, the project developer must use a conservative baseline emission value of 0 tCO_2e for those emissions.

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

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

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

Where,

			Units
WE_b	=	End-of-life waste emissions generated during PC manufacturing	tCO_2e
qw_b	=	Quantity of waste generated during PC manufacturing	t
$EF_{b,transport}$	=	CO_2 emission factor for end-of-life of waste from the most recent Ecoinvent or similar database.[32] Projects shall use the CO_2 factor for the appropriate disposal method (landfill, incineration, recycling)	tCO_2/t

5.1.1.2 Quantifying a Regional PC Emission Factor (Approach 2)

Where the source of PC (baseline) is not known and Approach 1 is not applicable, project developers must use Approach 2 that was developed by the Reserve to quantify a regional PC emission factor through use of regional consumption values and emission factors for fuel mixes and grid electricity. See Appendix C for more information. In cases where the project has multiple locations, the below calculations must be completed for each region and summed using a weighted average by tonnage sales. Regions for the purposes of the baseline calculations are based on SCM/ACM sales assuming that the displaced PC would have previously been sourced from those same regions.

Equation 5.10. Determining Regional Baseline Emission Factor

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

Where,

			Units
$EF_{b,r}$	=	Regional average CO_2 emission factor for PC production from the most recent annual report	tCO_2e/t of PC
$ME_{b,r}$	=	Regional average production and mining emission factor for PC production from the most recent annual report (calculated with **Equation *5.11***)	tCO_2e /t of PC
$PR_{b,r}$	=	Regional average production and mining emission factor for PC production from the most recent annual report (calculated with ***Equation 5.12*** and **Equation *5.13***)	tCO_2e /t of PC
$TE_{b,r}$	=	Average transport emission factor for PC production from the most recent annual report = 0 tCO_2e /tonne of PC (on-site mining and production transportation emissions are included fuels in **Equation *5.11*** and ***Equation 5.12***)	tCO_2e /t of PC
$WE_{b,a}$	=	Average end-of-life waste emission factor for PC production from the most recent annual report = 0 tCO_2e /tonne of PC	tCO_2e /t of PC

[32] Ecoinvent is a Life Cycle Inventory (LCI) database available at: https://ecoinvent.org/the-ecoinvent-database/

Equation 5.11. Determining Regional Mining Emissions for PC Production ($ME_{b,r}$)

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

Where,			Units
$ME_{b,r}$	=	Regional mining emissions for PC production from the most recent annual report	tCO_2e
$EL_{b,mining,\ grid}$	=	Regional grid electricity consumption for PC mining from the most recent annual report (see **Table 5.1**)	BTU/t of PC
$EF_{b,mining,grid}$	=	CO_2 emission factor for grid electricity consumed from the most recent U.S. Environmental Protection Agency (EPA) eGRID emission factor publication.[33] Projects shall use the most recent total output emission rates for the subregion where the project is located	tCO_2e/BTU
$FC_{b,mining}$	=	Regional fuel consumption for PC mining from the most recent annual report (see **Table 5.2**)	BTU/t of PC
$EF_{b,mining,fuel}$	=	CO_2 emission factor for fuel consumed from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[34] Projects shall use the CO_2 factor for the appropriate fuel type	tCO_2e/ BTU

Equation 5.12. Determining Regional Production Emissions for PC Production ($PR_{b,r}$)

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

Where,			Units
$PR_{b,r}$	=	Regional production emission factor for PC production and mining from the most recent annual report	tCO_2e /t of PC
$EE_{b,r}$	=	Regional energy emissions for PC production and mining from the most recent annual report (calculated with **Equation *5.13***)	tCO_2e /t of PC
$CE_{b,a}$	=	Average calcination emissions for PC production from the most recent annual report =0.48 tCO_2e /tonne of PC	tCO_2e /t of PC

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

Equation 5.13. Determining Regional Energy Emissions for PC Production

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

Where,			Units
$EE_{b,r}$	=	Regional energy emission factor for PC production and mining	tCO_2e/t of PC
$EL_{b,r,grid}$	=	Regional grid electricity consumption for PC production from the most recent annual report (see ***Table 5.1***)	BTU/t of PC
$EF_{b,r,production,grid}$	=	CO_2 emission factor for grid electricity consumed from the most recent EPA eGRID emission factor publication.[35] Projects shall use the most recent annual total output emission rates for the subregion where the project is located	tCO_2e/BTU
$FC_{b,r}$	=	Average fuel consumption for PC production from the most recent annual report (see ***Table 5.2*** and ***Table 5.3***)	BTU/t of PC
$EF_{b,r,fuel}$	=	CO_2 emission factor for fuel consumed from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[36] Projects shall use the CO_2 factor for the appropriate fuel type	tCO_2e/BTU

Table 5.1. Regional Electricity Consumption for PC Mining and Production (BTU/tonne of PC)

		Mining	Production
Regional	**West**	563.26	444,098.25
	Midwest	954.88	499,413.48
	South	678.30	486,587.02
	Northeast	8,279.12	539,891.98
State	**Arizona**	2,789.58	432,067.92
	California	2,115.51	433,518.29
	Florida	10,836.93	470,031.01
	Indiana	4,000.19	587,625.49
	Missouri	3,949.26	473,887.76
	Pennsylvania	11,716.44	500,207.09
	Texas	728.67	452,227.10

Table 5.2. Regional Transport Fuel Consumption for PC Mining and Production (BTU/tonne of PC)

		Diesel		Gasoline	
		Mining	Production	Mining	Production
Regional	**West**	2,998.81	38,899.04	40.56	1,637.09
	Midwest	1,811.86	27,890.44	180.48	1,177.14
	South	1,122.84	38,897.02	72.84	2,185.37
	Northeast	4,740.03	40,077.66	15.85	1,068.85
State	**California**	10,557.28	43,994.61	-	-
	Florida	2,132.93	42,250.21	-	-
	Indiana	9,200.27	21,904.48	-	-
	Missouri	7,668.93	25,184.88	-	-
	Pennsylvania	5,434.81	27,410.82	-	-
	Texas	4,162.03	27,288.67	-	-

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

Table 5.3. Regional Kiln Fuel Consumption for PC Production (BTU/tonne of PC)

		Coal Consumption	Natural Gas Consumption	Pet Coke Consumption
Regional	**West**	2,039,445.33	1,008,806.43	472,221.03
	Midwest	1,310,097.16	579,183.26	658,298.78
	South	1,037,706.67	1,245,224.90	552,127.90
	Northeast	290,424.48	1,694,051.72	843,736.51
State	**Arizona**	2,028,879.87	757,308.24	277,122.77
	California	1,492,024.60	366,502.81	962,952.28
	Florida	831,659.08	1,401,791.44	469,530.38
	Indiana	2,405,846.16	139,572.85	12,647.64
	Missouri	919,574.31	150,031.41	854,984.38
	Pennsylvania	435,636.72	1,696,209.63	583,667.97
	Texas	500,056.45	1,914,973.22	857,052.59

5.2 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 *5.14***, project emissions equal:

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

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

Equation 5.14. Quantifying Project Emissions for SCM/ACM Manufacturing

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

Where,

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

Equation 5.15. Quantifying Mining Emissions for SCM/ACM Manufacturing

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

Where,

			Units
ME_t	=	Mining emissions for inputs to SCM/ACM manufacturing during the reporting period	tCO_2e
$EL_{t,mining,\ grid}$	=	Grid electricity consumption for SCM/ACM mining during the reporting period	kWh
$EF_{t,mining,grid}$	=	CO_2 emission factor for grid electricity consumed during mining in the reporting period from the most recent EPA eGRID emission factor publication.[37] Projects shall use the annual total output emission rates for the subregion where the project is located	tCO_2/kWh
$FC_{t,mining}$	=	Fuel consumption for SCM/ACM mining during the reporting period	t 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.[38] Projects shall use the CO_2 factor for the appropriate fuel type	tCO_2/t of fuel

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

Equation 5.16. Quantifying Production Emissions for SCM/ACM Manufacturing

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

Where,

			Units
$PR_{t,s}$	=	Production emissions for SCM/ACM manufacturing during the reporting period	tCO_2e
$EL_{t,production,grid}$	=	Grid electricity consumption for SCM/ACM manufacturing during the reporting period	kWh
$EF_{t,production,grid}$	=	CO_2 emission factor for grid electricity consumed during the reporting period from the most recent EPA eGRID emission factor publication.[39] Projects shall use the annual total output emission rates for the subregion where the project is located	tCO_2/kWh
$FC_{t,production}$	=	Fuel consumption for SCM/ACM production during the reporting period	t 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.[40] Projects shall use the CO_2 factor for the appropriate fuel type	tCO_2/t of fuel
PE_t	=	Process CO_2 emissions (depending on the chemistry of the SCM/ACM)	tCO_2e

Equation 5.17. Quantifying End-of-Life Waste Emissions from SCM/ACM Manufacturing

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

Where,

			Units
$WE_{t,s}$	=	End-of-life waste emissions generated during SCM/ACM manufacturing	tCO_2e
$qw_{t,s}$	=	Quantity of waste generated during SCM/ACM manufacturing	t
$EF_{t,s,transport}$	=	CO_2 emission factor for end-of-life of waste from the most recent ecoinvent or similar database.[41] Projects shall use the CO_2 factor for the appropriate disposal method (landfill, incineration, recycling	tCO_2/t

Waste can be defined as any byproduct material generated at the SCM/ACM manufacturing facility that is sent to a landfill.

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, transporting waste to a disposal facility, and transportation of the product to the SCM/ACM customer. It is the Reserve's understanding that the transportation of one SCM/ACM product can go to hundreds of ready-mix concrete facilities. To reduce administrative burden for a de minimis source of emissions, the project developer must demonstrate that the distance traveled to deliver the SCM/ACM product to the customer are de minimis (within 5%) compared to the distance traveled to deliver the baseline PC product to its customer. If this is the case, project developers set transportation emissions from the SCM/ACM production facility to their customer as 0 tCO_2e/t product. To calculate this estimate for 10 or fewer deliveries within the reporting period, the project developer must show each transportation distance. For more than 10 deliveries, the project developer must provide 10 samples of deliveries at

[39] Available online at: https://www.epa.gov/egrid
[40] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[41] Available online at: https://ecoinvent.org/the-ecoinvent-database/

random[42] to assess this estimate. If these transportation emissions for the project are higher than 5%, project developers must include these emissions in their calculations.

Equation 5.18. Quantifying Transportation Emissions for SCM/ACM Manufacturing and Delivery

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

Where,

			Units
$TE_{t,s}$	=	Transport emissions for SCM/ACM inputs to manufacturing, storage, additives, delivery and waste during the reporting period for all eligible SCMs/ACMs "s"	tCO_2e
$d_{t,s}$	=	Distance traveled for SCM/ACM manufacturing and delivery (if more than 5% compared to PC delivery) during the reporting period (in gallons, miles, etc)	unit
$EF_{t,s,transport}$	=	CO_2 emission factor for mode of transport during the reporting period from the most recent EPA Emission Factors for Greenhouse Gas Inventories.[43] Projects shall use the CO_2 factor for the appropriate transportation mode	tCO_2/ unit

5.2.1 Determining Additive Production Emissions

If additives make up greater than 5% of the final SCM/ACM product by weight, the emissions associated with the primary additive(s) must be calculated. Secondary additives making up 5% or less of the total SCM/ACM product by weight may be considered negligible and 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 all additives.

If primary and secondary additives make up 5% or less of the final SCM/ACM by weight, their production emissions are considered negligible and the GHG emissions calculated in ***Equation 5.18*** 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.

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 an 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.[44] The emission factor reported in the most recent EPD may be applied in ***Equation 5.18***. Project developers should seek guidance from the Reserve to ensure the EPD or other reference they intend to use is sufficient.

[42] Project developers must demonstrate to the verifier that the 10 sample are representative distances in comparison to the geography of their customer base and product sales.
[43] Available online at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[44] 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

Equation 5.19. Quantifying Additive Production Emissions for SCM/ACM 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 SCMs/ACMs	tCO_2e
$Q_{t,ad}$	=	Quantity of additives used during the reporting period	t
$EF_{t,a}$	=	CO_2 emission factor for additive production during the reporting period	tCO_2/t

5.3. Secondary Effects

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

The project developer must complete the Attestation of SCM/ACM Use form which includes questions that provide reasonable assurances the SCM/ACM is being purchased instead of PC. Additionally, the project must support these claims with specific language (see Section 8.5.2) within sales receipts, bill of lading, or other verifiable documentation.

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 6.1** will be collected and recorded.

At a minimum, the Monitoring Plan shall include the frequency of data acquisition; a record keeping plan (see Section 7.3 for minimum record keeping requirements); the frequency of quality assurance/quality control (QA/QC) activities; the role of individuals performing each specific monitoring activity; and a detailed project diagram. The Monitoring Plan must include QA/QC provisions to ensure that data acquisition is carried out consistently and with precision.

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

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

6.1 Monitoring Requirements for Energy Consumption

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

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

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

6.2 Monitoring Requirements for Quantity & Quality Analysis

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

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

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

- Regional factors that are approved by the Reserve and deemed acceptable to a verifier.
- The quantity of PC is based on the amount of SCM/ACM produced and/or sold during the reporting period. The project may use a combination of scales, invoices, contracts, and other sales evidence deemed acceptable to a verifier.

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

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

- To monitor the quantity of waste generated from the project, the project may use a combination of scales, invoices, contracts, and other sales evidence deemed acceptable to a verifier.

6.3 Missing Data Substitution

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

6.4 Monitoring Parameters

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

Table 6.1. Low-Carbon Cement Project Monitoring Parameters

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
General Project Parameters						
N/A	Regulations	Project developer attestation of compliance with regulatory requirements relating to the project	Environmental regulations	N/A	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	
Baseline Quantification Parameters						
5.2	Q_b	Total quantity of PC that would have been produced during the reporting period	Tonnes	o	Monthly	Based off the amount of SCM/ACM produced during the reporting period
5.2	R_b	SCM/ACM to PC weight adjustment factor in period during the reporting period	Percent	or, m	Each reporting period	
5.2, 5.3	EF_b	CO_2 emission factor for PC production during the reporting period	tCO_2/tonne of PC	c	Once at verification	Approach 1: Plant-Specific data
5.3, 5.4	ME_b	Mining emissions for PC production during the look-back period	tCO_2e	c	Once at verification	Approach 1: Plant-Specific data

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
5.3, 5.5	PR_b	Production emissions for PC production during the look-back period	tCO_2e	c	Once at verification	Approach 1: Plant-Specific data
5.3, 5.8	TE_b	Transport emissions for PC production during the look-back period	tCO_2e	c	Once at verification	Approach 1: Plant-Specific data
5.3, 5.9	WE_b	End-of-life of waste emissions generated during PC production.	tCO_2e	c	Each reporting period	Approach 1: Plant-Specific data
5.3	Q	Quantity of PC produced during the look-back period	tonnes	m	Once at verification	Approach 1: Plant-Specific data
5.4	$EL_{b,mining,grid}$	Grid electricity consumption for PC mining during the look-back period	kWh	m	Monthly	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	From the most recent EPA eGRID emission factor publication.[45] Projects shall use the annual total output emission rates for the subregion where the project is located.
5.4	$FC_{b,mining}$	Fuel consumption for PC mining during the look-back period	tonnes of fuel	m	Monthly	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	From the most recent EPA Emission Factors for Greenhouse Gas Inventories.[46] Projects shall use the CO_2 factor for the appropriate fuel type.

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

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
5.5, 5.6	EE_b	Energy emissions for PC production during the look-back period	tCO_2e	c	Each reporting period	Approach 1: Plant-Specific data
5.5, 5.7	CE_b	Calcination emissions for PC production during the look-back period	tCO_2e	c	Monthly	Approach 1: Plant-Specific data
5.6	$EL_{b,production,\ grid}$	Grid electricity consumption for PC production during the look-back period	kWh	m	Monthly	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	From the most recent EPA eGRID emission factor publication.[47] Projects shall use the annual total output emission rates for the subregion where the project is located.
5.6	$FC_{b,production}$	Fuel consumption for PC production during the look-back period.	tonnes of fuel	m	Monthly	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	From the most recent EPA Emission Factors for Greenhouse Gas Inventories.[48] Projects shall use the CO_2 factor for the appropriate fuel type.
5.7	$R_{b,clinker}$	Clinker to cement ratio for PC production during the look-back period	Percent	o, r, m	Each reporting period	Approach 1: Plant-Specific data

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

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
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	Approach 1: Plant-Specific data
5.8	d_b	Distance traveled for PC production during the look-back period	miles	m	Monthly	Approach 1: Plant-Specific data
5.8, 5.9	$EF_{b,transport}$	CO_2 emission factor for mode of transport during the look-back period	tCO_2/ mile	r	Each reporting period	From the most recent EPA Emission Factors for Greenhouse Gas Inventories.[49] Projects shall use the CO_2 factor for the appropriate transportation mode.
5.2, 5.10	$EF_{b,r}$	Regional CO_2 emission factor for PC production from the most recent annual report	tCO_2/tonne of PC	r,c	Each reporting period	Approach 2: Regional Emission Factor for PC Production
5.10, 5.11	$ME_{b,r}$	Regional mining emissions for PC production from the most recent annual report	tCO_2/tonne of PC	c	Each reporting period	Approach 2: Regional Emission Factor for PC Production
5.10, 5.12	$PR_{b,r}$	Regional production emissions for PC production from the most recent annual report	tCO_2/tonne of PC	c	Each reporting period	Approach 2: Regional Emission Factor for PC Production
5.10	$TE_{b,r}$	Transportation emissions for PC production from the most recent annual report	tCO_2/tonne of PC	r	Each reporting period	Approach 2: Regional Emission Factor for PC Production
5.10	$WE_{b,r}$	Waste emissions for PC production from the most recent annual report	tCO_2/tonne of PC	r	Each reporting period	Approach 2: Regional Emission Factor for PC Production

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

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
5.12, 5.13	$EE_{b,r}$	Regional energy emissions for PC production from the most recent annual report	tCO_2/tonne of PC	c	Each reporting period	Approach 2: Regional Emission Factor for PC Production
5.12	$CE_{b,r}$	Calcination emissions for PC production	tCO_2/tonne of PC	r	Each reporting period	Approach 2: Regional Emission Factor for PC Production
5.13	$EL_{b,r,agrid}$	Regional average grid electricity consumption for PC production from the most recent annual report	BTU	r	Each reporting period	Approach 2: Regional Emission Factor for PC Production
5.13	$FC_{b,r}$	Regional average fuel consumption for PC production from the most recent annual report.	BTU	r	Each reporting period	Approach 2: Regional Emission Factor for PC Production
5.13	$EF_{b,r,fuel}$	Regional fuel-mix emission factor for PC production from the most recent annual report.	tCO_2/BTU	r	Each reporting period	Approach 2: Regional Emission Factor for PC Production
Project Quantification Parameters						
5.1, 5.13	PE	Total project emissions for the reporting period, from all SSRs in the GHG Assessment Boundary	tCO_2e	c	Each reporting period	
5.14, 5.15	$ME_{t,s}$	Mining emissions for SCM/ACM manufacturing during the reporting period for all eligible SCMs/ACMs “s”	tCO_2e	c	Each reporting period	
5.14, 5.16	$PR_{t,s}$	Production emissions for SCM/ACM manufacturing during the reporting period for all eligible SCM/ACM s “s”	tCO_2e	c	Each reporting period	

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
5.14, 5.17	$WE_{t,s}$	End-of-life of waste emissions generated during SCM/ACM manufacturing	tCO2e	c	Each reporting period	
5.14, 5.18	$TE_{t,s}$	Transport emissions for SCM/ACM inputs and delivery during the reporting period for all eligible SCM/ACM s "s"	tCO_2e	c	Each reporting period	
5.14, 5.19	$AD_{t,s}$	Additive production and transportation emissions for SCM/ACM manufacturing during the reporting period.	tCO_2e	c	Each reporting period	
5.15	$EL_{t,mining,\ grid}$	Grid electricity consumption for SCM/ACM mining during the reporting period.	kWh	m	Monthly	
5.15	$EF_{t,mining,grid}$	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.[50] Projects shall use the annual total output emission rates for the subregion where the project is located.
5.15	$FC_{t,mining}$	Fuel consumption for SCM/ACM mining during the reporting period.	tonnes of fuel	m	Monthly	
5.15	$EF_{t,mining,fuel}$	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.[51] Projects shall use the CO_2 factor for the appropriate fuel type.

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

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
5.16	$EL_{t,production,\ grid}$	Grid electricity consumption for SCM/ACM manufacturing during the reporting period	kWh	m	Monthly	
5.16	$EF_{t,production,grid}$	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.[52] Projects shall use the annual total output emission rates for the subregion where the project is located.
5.16	$FC_{t,production}$	Fuel consumption for SCM/ACM production during the reporting period.	tonnes of fuel	m	Monthly	
5.16	$EF_{t,production,fuel}$	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.[53] Projects shall use the CO_2 factor for the appropriate fuel type.
5.16	PE_t	Process CO_2 emissions (depending on the chemistry of the SCM/ACM)	tCO_2e	m	Monthly	
5.18	$d_{t,s}$	Distance traveled for SCM/ACM manufacturing during the reporting period	miles	m	Monthly	

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

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference (r) Operating Records (o)	Measurement Frequency	Comment
5.17, 5.18	$EF_{t,s,transport}$	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.53 Projects shall use the CO_2 factor for the appropriate transportation mode.
5.19	$Q_{t,ad}$	Quantity of additives used during the reporting period	tonnes	m	Quarterly	
5.19	$EF_{t,a}$	CO_2 emission factor for additive production during the reporting period	tCO_2/tonne of additive	r	Each reporting period	

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 submit a low-carbon cement project for listing:

- Project Submittal form

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

- Verification Report
- Verification Statement
- Project Diagram (if changed from previous reporting period)
- Project Data Report
- Signed Attestation of Title form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Regulatory Compliance form
- Signed Attestation of SCM/ACM Use
- LCCQuant Tool

At a minimum, the above project documentation will be available to the public (except for the project diagram) via the Reserve's online registry unless project developer retract documentation due to commercial or competitive sensitives. 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/.

7.1.1 Project Data Report

A Project Data Report (PDR) is a required document for reporting information about a project. The document must be submitted for every reporting period. A PDR template has been prepared by the Reserve and is available on the Reserve's website. The template is arranged to assist in ensuring that all requirements of the protocol are addressed. PDRs are intended to serve as the main project document that thoroughly describes how the project meets eligibility requirements, discusses the quantification methodologies utilized to generate project estimates, and outlines how the project complies with terms for additionality. PDRs must be of professional quality and free of incorrect citations, missing pages, incorrect project references, etc.

7.2 Joint Project Verification

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

7.3 Record Keeping

For purposes of independent verification and historical documentation, project developers are required to keep all information outlined in this protocol for a period of 10 years after the information is generated or 7 years after the last verification. This information is made publicly available unless project developers redact specific information if the information is commercially or competitively sensitive in nature.

System information the project developer must retain includes:

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

7.4 Reporting Period and Verification Cycle

Project developers must report GHG reductions resulting from project activities during each reporting period. A reporting period must represent a full production cycle, defined as the full length of time for producing an SCM/ACM. A reporting period may exceed 12 months in length when a single production and distribution cycle exceeds 12 months, in which case the reporting period may match the length of typical production/distribution timelines at a maximum of a 24 month period. One site visit is required per verification or per year, whichever is less frequent. Reporting periods must be contiguous; there must be no time gaps in reporting during the crediting period of a project once the initial reporting period has commenced. Occasionally, certain types of maintenance activities may be required at the manufacturing site that may interrupt project activities. Such maintenance periods, defined as a period during which no SCMs/ACMs are produced, are permissible with the following caveats to ensure continuous reporting for the project:

- Maintenance periods must be included within the dates of a reporting period to ensure continuous reporting.
- The data generated during the maintenance period shall be excluded when performing the calculations in Section 5.
- Monitoring equipment may be removed during these maintenance periods, as necessary.

- Once production commences following a maintenance period, the monitoring requirements of Section 6 must resume in a timely manner.

7.4.1 Reporting Periods

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

7.4.2 Verification Periods

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

7.4.3 Verification Site Visit Schedule

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

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

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

8 Verification Guidance

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

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

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

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

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

8.1 Standard of Verification

The Reserve's standard of verification for low carbon cement projects is the Low-Carbon Cement Protocol (this document), the Reserve Offset Program Manual, and the Verification Program Manual. To verify a low-carbon cement project report, verification bodies apply the guidance in the Verification Program Manual and this section of the protocol to the standards described in Sections 2 through 7 of this protocol. Sections 2 through 7 provide eligibility rules, methods to calculate emission reductions, performance monitoring instructions and requirements, and procedures for reporting project information to the Reserve. Project developers may choose to have a verification body conduct multiple project verifications at a single facility or a number of facilities under a joint 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 6.1** 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 theproject start date	Once during first verification (unless new project sites are added to the project)
Location	United States and U.S. territories and tribal areas	Once during first verification
Performance Standard	▪ For novel SCMs/ACMs, project developer must show there is insufficient data to support that the product is near zero (first-of-its kind) in the U.S. market. ▪ For current SCM/ACM products, the product must be less than 5% of the cementitious materials market in the U.S.	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 mustbe in material compliance with all applicable laws	Every verification
Quality Standard	Applicable and appropriate certificate documentation demonstrating quality standards of SCM/ACM product in accordance with ASTM International standards	Every verification

8.4 Core Verification Activities

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

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

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

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

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

Verifying emission reduction estimates
The verification body further investigates areas that have the greatest potential for material misstatements and then confirms whether or not material misstatements have occurred. This involves site visits to the project to ensure the systems 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.

8.5.1 Project Eligibility and CRT Issuance

Table 8.2 lists the criteria for reasonable assurance with respect to eligibility and CRT issuance for 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.

Table 8.2 Eligibility Verification Items

Protocol Section	Eligibility Qualification Item	Apply Professional Judgment?
2.1 – 2.3	Verify that the project meets the definition of an SCM/ACM project	No
2.1	Verify that the SCM/ACM manufacturing site is existing, upgraded, relocated or restarted	No
2.2	Verify ownership of the reductions by reviewing the Attestation of Title and verify that purchasers of the Low-Carbon Cement have waived their rights to the GHG emissions reduction through review of language within sales receipts, bill of lading, or other verifiable documentation.	No
3.1	Verify that the project only consists of activities at a SCM/ACM manufacturing site operating within the U.S. or its territories	No
3.2	Verify eligibility of project start date	No
3.2	Verify accuracy of project start date based on operational records	No

Protocol Section	Eligibility Qualification Item	Apply Professional Judgment?
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 (or, if not available, another approved standard) and confirm execution of the Attestation of SCM/ACM Use form.	Yes
6	Verify that monitoring meets the requirements of the protocol. If it does not, verify that a variance has been approved for monitoring variations.	No
n/a	If any variances were granted, verify that variance requirements were met and properly applied	Yes

8.5.1 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 does not have access to PC plant specific historical records if Approach 2 in the baseline	No
5	Verify that the project developer correctly calculated the PC weight adjustment factor	No

Protocol Section	Qualification Item	Apply Professional Judgment?
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 that additive emissions were appropriately calculated and quantified, if applicable	No
5	Verify SCM/ACM displaced PC at cement facility or ready-mix concrete plant or concrete production site though review of specific language within sales receipts, bills of lading, or other verifiable documentation and completion of the Attestation of SCM/ACM Use form	Yes
5	Verify that the use of an SCM/ACM did not increase additives at the concrete facility or end-user site compared to PC through review of specific language within sales receipts, bills of lading, or other verifiable documentation, completion of the Attestation of SCM/ACM Use form and ASTM standard report (when applicable).	Yes

8.5.2 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	Items that Inform 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

8.5.3 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 joint 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 for every project under the joint verificaon.

9 Glossary of Terms

Accredited verifier	A verification firm approved by the Climate Action Reserve to provide verification services for project developers.
Additionality	Project activities that are above and beyond "business as usual" operation, exceed the baseline characterization, and are not mandated by regulation.
Alternative cementitious material (ACM)	ACMs are manufactured clinkered, calcined, or non-clinkered materials that can fully replace PC clinker in cement
Blended cement	A mix of portland cement and at least one supplementary cementitious material or limestone that is developed at the cement plant or blending plant and meets specific ASTM standards.
Carbon dioxide (CO2)	The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.
CO2 equivalent (CO2e)	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.
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).
End-user	The entity which is the first point of sale that purchases the SCM/ACM product instead of PC.
Fossil fuel	A fuel, such as coal, oil, and natural gas produced by the decomposition of ancient (fossilized) plants and animals.
Fresh coal 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 (CO2), methane (CH4), nitrous oxide (N2O), sulfur hexafluoride (SF6), 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 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.
Traditional Slag cement	Material recovered as a by-product during crude iron production that can be utilized in concrete production.
Indirect emissions	Reductions in GHG emissions that occur at a location other than where the reduction activity is implemented, and/or at sources not owned or controlled by project participants.
Metric ton (t, tonne)	A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1 short tons.
MMBtu	One million British thermal units.
Transport emissions	Emissions from the transportation of materials, products, and waste resulting from the combustion of fuels in company owned or controlled mobile combustion sources (e.g., cars, trucks, tractors, dozers, etc.).
Pozzolan	Material that chemically reacts with moisture and calcium hydroxide to display cementitious properties.
Portland Cement (PC)	The most common type of cement is manufactured by grinding clinker and mixing it with other minor raw materials.
Project baseline	A “business as usual” GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.
Project developer	An entity that undertakes a GHG project, as identified in Section 2.2 of this protocol.
SCM/ACM concrete	Concrete that has one or more supplementary cementitious materials combined with portland Cement and other materials at a ready-mix concrete batch plant.
Supplementary cementitious materials (SCM)	SCMs are defined by ASTM International as inorganic material that contributes to the properties of a cementitious mixture through hydraulic or pozzolanic activity, or both.
Verification	The process used to ensure that a given participant’s GHG emissions or emission reductions have met the minimum quality standard and complied with the Reserve’s procedures and protocols for calculating and reporting GHG emissions and emission reductions.
Verification body	A Reserve-approved firm that is able to render a verification opinion and provide verification services for operators subject to reporting under this protocol.

Weight Adjustment Factor	Ratio for the amount of SCM/ACM s required to replace one tonne of PC, as identified in Section 5.

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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.

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Thomas Van Dam and Federal Highway Administration, "Tech Brief Supplementary Cementitious Materials and Blended Cements to Improve Sustainability of Concrete Pavements" (Iowa State University, November 2013), https://intrans.iastate.edu/app/uploads/2018/12/SCM/ACM tech_brief.pdf.

Tritsch, Sutter, and Diaz-Loya, "Use of Harvested Coal Ash in Highway Infrastructure."

US Department of Transportation Federal Highway Administration, "Tech Brief Best Practices for Concrete Pavements Supplementary Cementitious Materials."

Appendix A Development of the Performance Standard Threshold

The initial Performance Standard analysis for the Low Carbon Cement Protocol Version 1.0 was adopted in 2023. The protocol will only be applicable to project activities that bring innovative SCM/ACMs to market. Through this protocol, carbon financing will incentivize the market to identify and recover these SCM/ACM sources to help fill the nation's supply void. As traditional coal ash and traditional slag cement are already being used at appreciable volumes today, production of these SCM/ACM s would not constitute eligible projects under the protocol.

A.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."

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

Using regional benchmarks conducted by NRMCA, the national average of cement used in the United States is approximately 81%, Portland cement, 14% coal ash cement and 4% traditional slag cement.[54] 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.[55] Based on the current market penetration rate, these products were found to be ineligible under this protocol.

Products not on the negative list are assumed to have a usage rate in concrete products at near zero (first-of-its kind) but are required to meet quality standards and be within the GHG Assessment Boundary. However, the Reserve may ask project developers to demonstrate that a specific product has a usage rate in concrete of near zero with insufficient data to calculate a penetration rate or provide evidence that production of the SCM/ACM product is less than 5% of the cementitious materials market in the United States.[56]

The production of SCM/ACM are an emerging industry that is not commonly used in the U.S. today. Annually, there are millions of tonnes of coal 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.[57] Currently, landfilled coal 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 coal ash because the technology is prohibitively expensive and has not been

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[54] www.nrmca.org/wp-content/uploads/2020/02/NRMCA_REGIONAL_BENCHMARK_Nov2019.pdf
[55] https://www.sciencedirect.com/topics/materials-science/silica-fume
[56] https://www.usgs.gov/centers/national-minerals-information-center/cement-statistics-and-information
[57] American Coal Ash Association, "The Future of Coal Ash" (Iowa Better Concrete Conference, November 10, 2021), https://intrans.iastate.edu/app/uploads/sites/7/2021/11/A1B-Ward-Coal-Ash.pdf.

deployed at scale.[58,59] The industry also lacks sufficient testing and research on the performance of harvested coal ash, which faces additional hurdles due to varying quality, weathering, and contamination.

There are similarly only a handful of natural pozzolan producers in the U.S. as pozzolans are expensive to produce and have varying chemical properties that make them less attractive than traditional SCMs/ACMs. The Natural Pozzolan Association website currently lists four raw natural pozzolan producers that are in operation along with a few emerging companies.[60] 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.[61] Upgraded and novel SCMs/ACMs are currently uncommon in the cement and concrete industry as they face multiple barriers as discussed in Section A.3.

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

The amount of SCM/ACMs used in cement have remained largely stagnant in the U.S. While significant drivers exist to utilize SCM/ACMs, the industry faces challenges in overcoming supply constraints. Increasing the use of SCM/ACMs 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 this section.

Cost challenges associated with SCMs/ACMs are expected to worsen in the future as the supply of today's most common SCMs/ACMs decrease while the global demand for PC grows.[62] Both coal ash and traditional slag cement are byproducts of industrial processes (coal-fired power generation and pig iron production, respectively) that are either phasing out of production or facing pressure to decarbonize and reduce waste themselves in some regions.[63] A decline in these industrial processes will in turn be accompanied by a decline in industrial process byproducts. The supply gap will not only lead to higher SCM/ACM prices but also increased costs associated with sourcing SCMs/ACMs from less convenient locations. Nearly half of the coal 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.[64,65] The dwindling supply of coal ash cannot be compensated by traditional slag cement, which is already limited in supply in the U.S. and also experiencing decline.[66]

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[58] American Coal Ash Association, "The Future of Coal Ash" (Iowa Better Concrete Conference, November 10, 2021), https://intrans.iastate.edu/app/uploads/sites/7/2021/11/A1B-Ward-Coal-Ash.pdf.
[59] Federal Highway Administration, "Use of Harvested Coal Ash in Highway Infrastructure (May 2021) https://intrans.iastate.edu/app/uploads/2020/09/use_of_harvested_coal_ash_TB.pdf
[60] Natural Pozzolan Association, "Sourcing Natural Pozzolans" http://www.pozzolan.org/sourcing-pozzolan.html
[61] For example, Terra CO_2 manufactures a low-carbon alternative for cement replacement.
[62] Global Cement and Concrete Association, "Concrete Future The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete."
[63] 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.
[64] US Department of Transportation Federal Highway Administration, "Tech Brief Best Practices for Concrete Pavements Supplementary Cementitious Materials."
[65] Tritsch, Sutter, and Diaz-Loya, "Use of Harvested Coal Ash in Highway Infrastructure."
[66] Concrete Task Group of the Caltrans Rock Products Committee and Industry, "Coal Ash Current and Future Supply."

Deposits of coal 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.[67] 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 coal ash and natural pozzolans) but they are not currently cost competitive with PC. As a result, increased replacement will not be possible in the future without innovation to increase the supply of SCMs/ACMs. The Global Cement and Concrete Association (GCCA) reports that the industry will need a stream of research and development funding to secure a sustainable supply of SCMs/ACMs, including mining natural pozzolans, to meet global demand.[68]

Institutional barriers associated with market acceptance remain a key challenge despite the legacy use of SCMs/ACMs throughout history. Since the 19th century, PC has been the trusted standard product, with well-defined and understood performance and usability characteristics. Innovative products with a lower clinker-to-cement ratio (and thus higher SCM/ACM blend) are not as widely trusted and may be dismissed as a less safe or easy-to-use option.[69] Carbon finance can alleviate these barriers by creating an appealing financial incentive for buyers to give alternative products closer consideration. Moreover, CRTs can also help fund new standards and testing protocols, which are often time-consuming and costly to develop.

On a per-tonne basis, some SCMs/ACMs have historically been lower or equal in cost to PC. However, concrete and cement producers that are not currently using SCM/ACMs face a “barrier to entry” cost to begin utilizing SCMs/ACMs associated with additional storage equipment and potentially new processing technology. To use SCMs/ACMs, a producer needs at least two silos to hold the material (one for PC and one for the SCM/ACM). If they want to use more than one SCM/ACM, multiple silos are required as the cementitious material must be stored individually.[70] Carbon finance provides the opportunity to mitigate some of the higher upfront costs associated with incorporating more SCMs/ACMs.

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

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

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[67] Tritsch, Sutter, and Diaz-Loya, “Use of Harvested Coal Ash in Highway Infrastructure.”
[68] “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.
[69] The Loreti Group, “Greenhouse Gas Emission Reductions from Blended Cement Production Issues Paper.”
[70] Thomas Van Dam and Federal Highway Administration, “Tech Brief Supplementary Cementitious Materials and Blended Cements to Improve Sustainability of Concrete Pavements” (Iowa State University, November 2013), https://intrans.iastate.edu/app/uploads/2018/12/SCM/ACM _tech_brief.pdf.

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

Appendix B Development of the Legal Requirement Test

B.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.[71] 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.42F[72] 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.[73,74]

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

Despite a lack of Federal regulations to reduce GHG emissions from cement production, there has been momentum at the state level to decarbonize the cement sector. In 2021, California enacted Senate Bill 596, which mandates the California Air Resources Board (CARB) to create and implement a plan to reach net-zero GHG emissions in the cement sector by at least 2045, including an interim goal of reducing emissions by at least 40% by mid-2035 (compared to 2019 levels). [75] California's GHG cap-and-trade program also applies to cement plants; however, cement imported into California is not covered by the program.[76] Therefore, SCM manufacturers that sell product to CA cement facilities would be ineligible for crediting under the protocol. However, SCMs/ACMs sold to ready-mix facilities in California are still eligible under this protocol.

The California Department of Transportation (CalTrans) Standard Specifications include a threshold for the minimum SCM content of concrete used in state projects.[77] Section 90 of the Standard Specifications requires that the concrete must have at least 15% SCM replacement for when the aggregates are "innocuous" and SCMs must replace 25% of the PC when the aggregates are "non-innocuous". Most California ready mix producers have access to innocuous aggregates; thus, the Caltrans SCM replacement rate is typically 15%.

Project proponents that sell qualified SCMs into California are eligible under the protocol; however, SCMs sold to Caltrans and used below the minimum threshold are ineligible for

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[71] 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.

[72] 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.

[73] Baer, Louis, "Energy & Environment Regulatory Priorities," Portland Portland Cement Association, 2019, https://www.cement.org/issues-advocacy/regulatory-priorities/energy-environment-regulatory-priorities.

[74] 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.

[75] Johnson, "California Enacts Legislation to Slash Cement Emissions."

[76] "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.

[77] https://dot.ca.gov/-/media/dot-media/programs/design/documents/2022_stdspecs-a11y.pdf

crediting. SCMs sold to Caltrans and used above the minimum threshold are eligible for crediting. Due to the complex chain of custody, many SCM manufacturers may be unable to track the destination of their products (i.e., it may be difficult for SCM manufacturers to accurately prove how many SCMs are used in Caltrans projects). Project proponents that cannot track final SCM use may estimate the volume of material used by Caltrans by applying a conservative 6% discount factor to the total quantity of SCMs sold into California (**Equation *5.13***).[78]

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.[79] 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.[80] 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.[81] 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.[82]

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

At a state level, the North Carolina Coal Ash Management Act created a legal requirement for the "installation and operation" of three "ash beneficiation projects, each capable of annually processing 300,000 tons of ash to specifications appropriate for cementitious products".[83] These three ash beneficiation projects are located at Duke Energy's Buck Combined Cycle Facility in Rowan County, H.F. Lee Steam Electric Plant in Wayne County, and the Former Caper Fear Facility in Chatham County.[84]

As stated in Section 3.4.1 of the protocol, the legal requirement test is applicable to both the

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[78] According to the Portland Cement Association's 2021 and 2022 Apparent Use Report by State and Market, approximately 6% of PC used in California is consumed by state highways (urban and rural). Notably, this is a conservative value and includes cement used beyond Caltrans projects.

[79] Addabbo Jr, Joseph et al., "NY State Senate Bill S542A," Pub. L. No. S542A (2021), https://www.nysenate.gov/legislation/bills/2021/s542/amendment/a.

[80] 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.

[81] Chris Hansen, Barbara McLachlan, and Tracey Bernett, "Global Warming Potential For Public Project Materials," Pub. L. No. HB21-1303 (2021).

[82] 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.

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

[84] ViewFile.aspx (ncuc.gov)

production of SCMs/ACMs and use of SCMs/ACMs in concrete. According to the Reserve's understanding of existing requirements in the U.S., there are currently no Federal regulations that require the production or use of the eligible SCMs/ACMs. If any state agencies specifically require the production of SCMs/ACMs or the replacement of PC with SCMs/ACM, projects that fall under the legislation in these regions may be ineligible for crediting. Currently, two examples of state level legislation that would deem a project ineligible for crediting include the North Carolina Coal Ash Management Act and Caltrans minimum requirement to include 20% to 25% natural pozzolan or coal ash in state pavement and structure applications. Note, the North Carolina Coal Ash Management Act mandates harvesting of coal ash from three specific sites in North Carolina. Other coal ash harvesting projects not mandated under this Act are eligible if they meet all other eligibility requirements. For the mandated use examples with Caltrans, use of SCMs/ACMs above and beyond that minimum requirement could be eligible for crediting under the protocol if the project meets all other eligibility requirements.

Appendix C Development of Conservative Regional Emission Factors for PC Production

The Reserve determined the need for a regional approach to assess baseline PC emission when plant-specific PC data is unavailable to project developers and worked with the Portland Cement Association (PCA) to construct regional energy consumption summaries for the purposes of this protocol. This approach is fundamentally conservative as minor PC baseline emission sources included in the boundary are set at 0 tCO_2/tonne of PC and takes into account regional differences with fuel type and grid electricity.

C.1 Background Information

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

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

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

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

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

The industry-wide PC EPD was reviewed to determine the percentage of emissions attributable to each stage of the production pathways. According to the EPD, the majority of emissions (52%) for PC manufacturing are process emissions from clinker manufacturing. These emissions do not vary by region and only vary slightly by facility as they are set by chemistry and are a result of the calcination process to produce Calcium Oxide (CaO). The PCA's industry-wide EPD for PC determined that at a 91% clinker ratio, 0.48 tCO2e/tonne of PC is attributed to calcination process emissions. The Reserve found this to be a consistent and conservative average as PC calcination emissions only vary due to clinker content within 90-95% clinker. Therefore, this emission factor can be used directly in ***Equation 5.12***.

The second most predominant emission source by percent of the total emissions is a result of on-site kiln fuel consumption at approximately 37% of total emissions. To reflect regional differences in fuel mixes at PC facilities across the U.S., the Reserve worked with the PCA's Labor Energy Input Survey to develop emission factors for fuel emissions by region, which is summarized **Table 5.2**.[85] These emission factors can be applied to the regional average on-site fuel consumption to produce a regionally specific emission factor for tCO_2e per tonne of PC. The average fuel consumption for PC mining and production is found to be 3.8 mmBTU when electricity (at 0.52 mmBTU) for PC mining and production is removed from the total energy consumption for PC mining and production (4.282 mmBTU) according to the 2021 Labor Energy Input Survey issued by the PCA.[86] Similarly, grid electricity emissions vary by region, which is accounted for by applying sub-regional eGRID emission factors to the average grid electricity consumption value from the Labor Energy Input Survey.

As the emissions associated with transportation of raw materials were not found to vary by region and are deminimis at 1% of total emissions, the Reserve provides project developers with an emission factor of 0 tCO_2e/tonne of PC. This is additionally conservative as the baseline emissions associated with transport of cement to the ready-mix facility are set at 0 tCO2e/tonne of PC. Waste emissions were found to be deminimis at less than 1%, which resulted in an emission factor of 0 tCO2e/tonne of PC for waste. This approach developed by the Reserve provides project developers with conservative and regionally applicable emission factors for baseline PC emissions when plant specific data is unavailable.

[85] Plant specific information from the PCA – available upon request
[86] Labor Energy Input Survey (PCA for 2021 version) – available upon request