VCS Methodology

VM0031

Methodology for Precast Concrete Production using Sulphur Substitute

Version 1.0

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Sectoral Scopes 4 & 6

Methodology developed by:

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In partnership with:

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1 SOURCES

This methodology is based on the draft *Quantification Protocol for the Use of Sulphur Concrete in Precast Applications v0.4*, issued under the Alberta Specified Gas Emitters Regulation. The methodology references the following CDM tools:

- *Combined tool to identify the baseline scenario and demonstrate additionality*
- *Tool for the demonstration and assessment of additionality*

In addition, technical and good practice guidance was obtained from Environment Canada's annual GHG reporting, the US EPA's Emission Inventory, the Intergovernmental Panel on Climate Change (IPCC), and various other reliable sources of information pertaining to the concrete production industry. The good practice guidance and best science used to develop the quantification methodology are presented in Section 10.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

Concrete is a commonly used material for infrastructure, industrial and construction applications, consisting of aggregate (rock and sand), water and cement. The production of calcium and/or magnesium carbonate-derived cement (often from limestone) releases significant amounts of greenhouse gases (GHG).

Traditional cementitious binders derived from limestone and clay rely on the chemical bonds formed upon contact with water to bind together aggregate material (sand and rock) to form concrete. This binder (clinker) is a key component of cement. The production of clinker results in the release of a significant amount of GHG from two main sources: process emissions and combustion emissions. Carbon dioxide process emissions occur as a by-product of the calcination process, where a calcium or magnesium carbonate such as limestone is heated with clay to form clinker (primarily calcium oxide) and carbon dioxide. Additional GHG emissions occur because heat for the calcination process is normally supplied via the combustion of fossil fuels, releasing carbon dioxide, methane and nitrous oxide as a result.

Portland cement can be completely substituted with modified heated sulphur to form a stable, hard concrete product, avoiding the process and combustion emissions associated with the manufacture of Portland cement.

This methodology is applicable to processes that involve the substitution of calcium and/or magnesium carbonate-derived cement, known as Portland cement, with an alternative binder, such as a modified heated sulphur product, during the production of concrete and other concrete-based products such as pre-cast pipe, paving stones, slabs and tanks. This methodology is not applicable to projects employing standard poured-in-place concrete production processes, or supplementary cementing material (SCM) products.

For the purposes of this methodology, a project is considered a set or series of pre-cast concrete products, produced at one facility, where the pre-cast products have similar functional specifications to the same pre-cast products in the baseline scenario. The project may consist of emission reductions from several product sets or series if they are all cast at the same facility, provided the baseline scenario selected is appropriate for all products to be included in the project.

The baseline scenario is specified as the production of concrete using traditional cementitious binders derived from limestone and clay that rely on the chemical bonds formed upon contact with water to bind together aggregate material (sand and rock). This binder (clinker) is a key component of Portland cement.

The project proponent may be the technology owner, facility owner, agent or otherwise of products produced with sulphur concrete. Right of use must be established and demonstrated at the project level as specified and required by the VCS rules. Where the project proponent is not the owner of the precast concrete facility (eg, is the technology owner, agent of the products produced, or the end user), there must exist a contractual agreement, or otherwise, between the project proponent and the relevant parties to avoid the risk of double counting with other participants in the supply chain. Note that as emission reductions generated by projects that apply this methodology are attributed partly to indirect emission from electricity production, projects developed in jurisdictions that have cap-and-trade programs require assessment to ensure double counting does not occur. Therefore, the project proponent must be aware of the VCS rules on double counting when a proposed project occurs in a jurisdiction with a cap and trade program covering the electrivity sector, which might render the project unviable.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Aggregate
Materials or substances that are included in an concrete product which do not serve to bind the aggregate, rather they facilitate or modify the binder (or binder substitute) properties to better meet production requirements or product specifications.
Aggregates including fly ash and slag are cementitious materials partially displacing Portland cement in the baseline product, however can also be included in sulphur concrete products.

Binder
Material that serves as an adhesive that binds with the aggregate to form concrete

Concrete
Composite building material made from the combination of aggregate and a cement binder

Portland Cement
Finely ground, usually grey-coloured mineral powder that when mixed with water, acts as a glue to bind together aggregate to form concrete

Precast Products
Form of construction where concrete is cast in a reusable mould or form, which is then cured in a controlled environment. Examples of precast products include paving stones, planters, traffic barriers, holding tanks and retaining walls, among many others.

Sulphur Cement
Product composed of molten elemental sulphur and a proprietary modifier that acts as a glue to bind together aggregate to form sulphur concrete. Sulphur cement requires no water to form sulphur concrete.

4 APPLICABILITY CONDITIONS

This methodology is applicable to the production of sulphur concrete for precast applications where the following conditions are met:

1. The baseline scenario is the production of precast concrete products using Portland cement, as demonstrated using the procedure set out in Section 6.
2. The project activity may take place at existing (retrofitted) or new (greenfield) precast concrete production facilities.
3. The use of recycled concrete is not eligible in either the baseline or project scenario.
4. The handling, storage, mix production temperature and other key factors specified by the manufacturer for the proper and safe use of sulphur cement have been followed by the project proponent.
5. The resulting sulphur concrete product meets all applicable legal and technical requirements. In the absence of technical specifications for concrete, the project proponent must demonstrate that sulphur concrete produced under the project scenario provides the equivalent function to concrete that would have been produced under the baseline scenario.
6. The pouring and forming processes must be comparable between the baseline and project scenarios for an equivalent product. The quantity of aggregate used (on a mass basis) in the baseline scenario must be comparable to the quantity of aggregate used in the project scenario for an equivalent product.

7. For projects that consist of multiple project activity instances (ie, multiple pre-cast concrete production lines), all concrete used and all concrete products must have been produced from the same facility.

5 PROJECT BOUNDARY

Sources, sinks and reservoirs (SSRs) included in project and baseline quantification include those that are within the project site (the physical, geographic location of the cement production facility), as well as others that are off-site.

The project proponent must account for:

- Direct emissions avoided by displacing Portland cement production and use with sulphur cement production and use
- Direct emissions due to fuel combustion at the precast concrete facility for:
  - Heating of aggregate.
  - Additional heating of the sulphur additive.
- Direct emissions due to fuel combustion and process emissions outside the precast concrete facility for:
  - Production of the sulphur modifier;.
  - Transport of the modifier and modified sulphur product.
- Indirect emissions due to the generation of electricity generation (if applicable).
- Indirect emissions due to the degassing of sulphur (if applicable).

A generalized process flow diagram of a typical project and baseline are presented in below Figure 1 and Figure 2 respectively.

Figure 1: Flow Diagram of Baseline Emissions

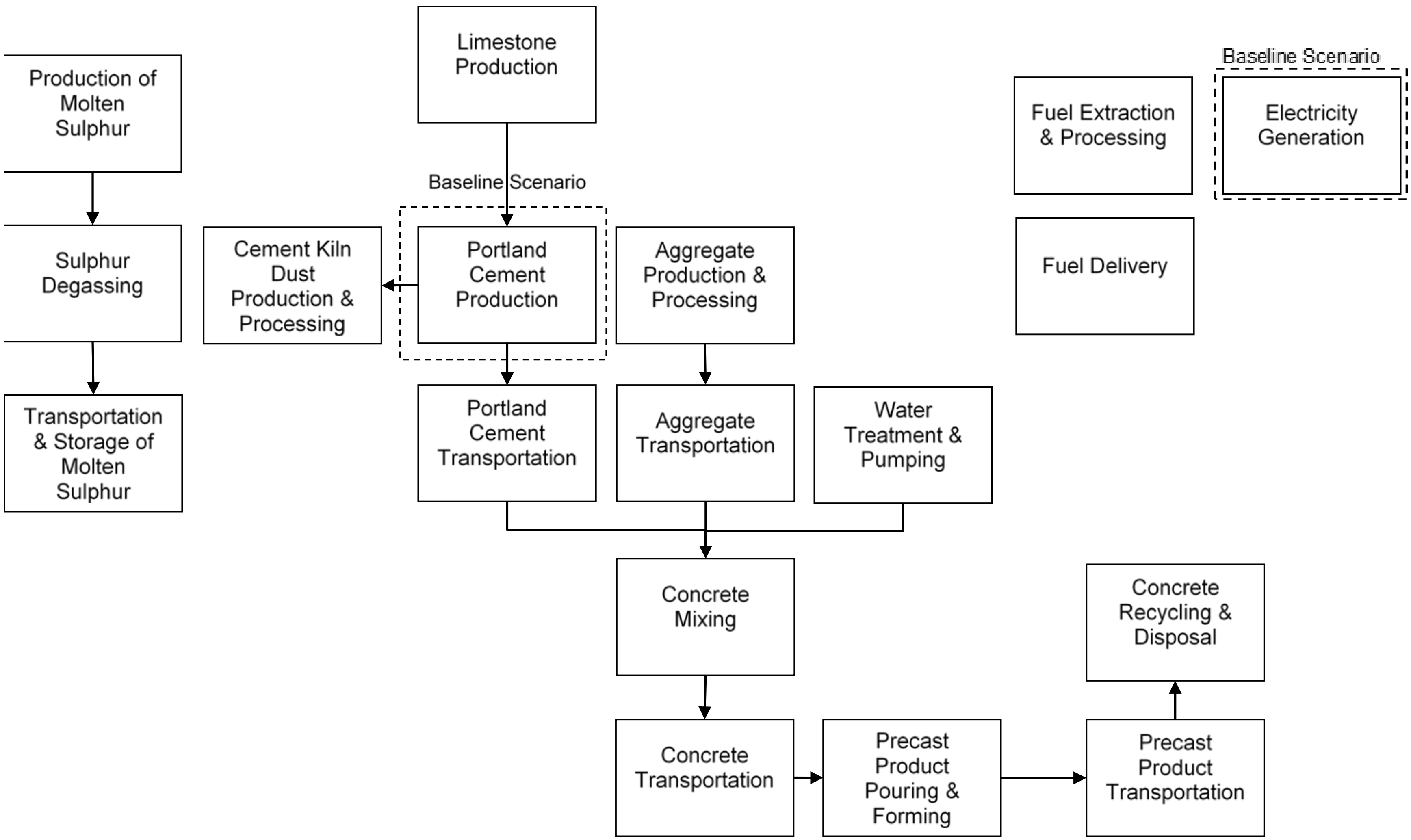
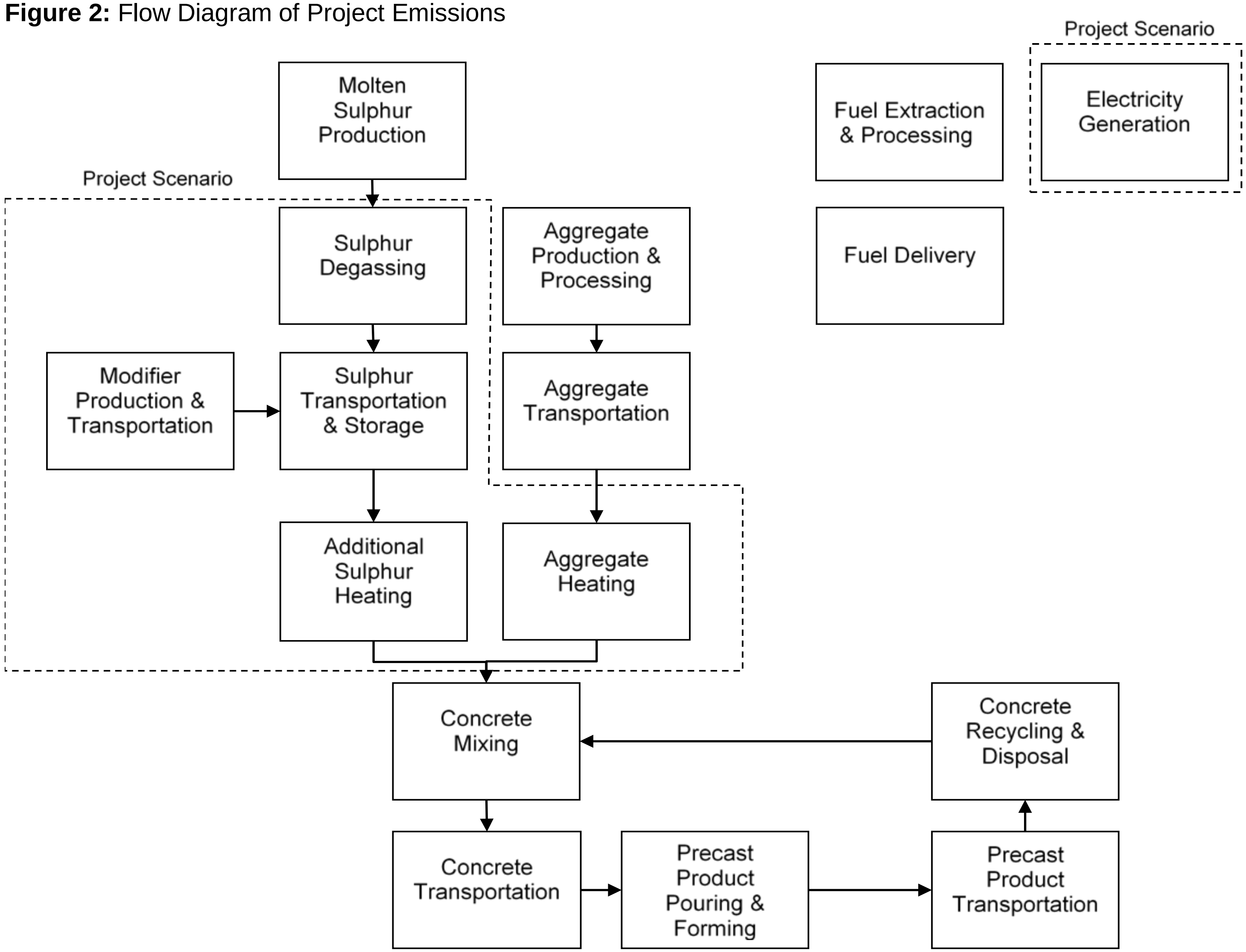


Figure 2: Flow Diagram of Project Emissions



The SSRs represented in Figures 1 and 2 above were compared and the relevancy evaluated to determine if they must be included or excluded from the quantification methodology. Table 1 below provides justification for the inclusion or exclusion of each of the potential SSRs in the project and baseline scenarios. The project proponent must justify the baseline and project SSRs selected for quantification in the project.

Table 1: GHG Sources, Sinks and Reservoirs

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
Baseline	Production of molten sulphur	Related	CO_2	No	Excluded as the quantity of molten sulphur produced in the project and baseline scenarios are functionally equivalent. Sulphur is a by-product of gas processing and petroleum refining and would be produced in both the project and baseline scenarios in the same quantity.
			CH_4	No	
			N_2O	No	
	Sulphur degassing	Related	CO_2	No	If sulphur degassing was occurring in the baseline scenario, it will continue under the project scenario and emissions will be equivalent. Project-specific emissions from sulphur degassing are accounted for in the project scenario, therefore it is conservative to exclude this SSR.
			CH_4	No	
			N_2O	No	
	Transportation and storage of molten sulphur	Related	CO_2	No	If transportation and storage of molten sulphur was occurring in the baseline, it will continue under the project scenario and will be equivalent. Project-specific emissions from the transportation and storage of molten sulphur are accounted for in the project scenario, therefore it is conservative to exclude this SSR.
			CH_4	No	
			N_2O	No	
	Limestone production	Related	CO_2	No	Less limestone will be produced in the project scenario and therefore emissions will be lower in the project scenario. The emissions from this SSR are relatively low and difficult to estimate accurately. Exclusion of this SSR is conservative.
			CH_4	No	
			N_2O	No	
	Portland cement	Related	CO_2	Yes	The production of Portland cement in the baseline scenario has relevant emissions and
			CH_4	Yes	

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
	production		N_2O	Yes	must be included.
	Cement kiln dust production and processing	Related	CO_2	No	Cement kiln dust (CKD) refers to the portion of the cement raw materials that does not become part of the clinker. CO_2 might be emitted from CKD that is not recycled to the Portland cement production process. CKD is not produced in the project scenario, therefore it is conservative to exclude its production and processing related emissions.
			CH_4	No	
			N_2O	No	
	Portland cement transportation	Related	CO_2	No	The quantity of Portland cement that is transported in the project scenario would be less than the quantity in the baseline scenario; therefore it is conservative to exclude these emissions.
			CH_4	No	
			N_2O	No	
	Aggregate production and processing	Related	CO_2	No	Excluded as the same quantity of aggregate would be produced and processed in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Transportation of aggregate	Related	CO_2	No	Excluded as the same quantity of aggregate would be transported in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Water treatment and pumping	Related	CO_2	No	Emissions from this SSR are avoided in the project scenario. This emission reduction is not the focus of this methodology. Emissions are excluded as it is conservative to do so.
			CH_4	No	
			N_2O	No	
	Fuel extraction/processing	Related	CO_2	No	Fuel production and extraction emissions are higher in the baseline than in the project and hence conservative to exclude.
			CH_4	No	
			N_2O	No	
	Fuel delivery	Related	CO_2	No	The quantity of fuel consumed in the baseline scenario for the production of Portland cement will be greater than the quantity of fuel consumed in the project scenario for mixing sulphur concrete. Emissions are excluded as it is conservative to do so.
			CH_4	No	
			N_2O	No	
	Electricity generation	Related	CO_2	Yes	Indirect emissions from electricity use may be a significant source of emissions. The project
			CH_4	Yes	

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
			N_2O	Yes	proponent must include electricity in the methodology if it is demonstrated to be conservative.
	Concrete mixing	Controlled	CO_2	No	The process for concrete mixing is equivalent in the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Concrete transportation	Controlled	CO_2	No	The same quantity of concrete will be transported in the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Precast product pouring and forming	Controlled	CO_2	No	The process for pouring and forming will not change between the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Precast product transportation	Affected	CO_2	No	There is no difference in the transportation related emissions between the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Concrete recycling or disposal	Affected	CO_2	No	Excluded for simplification. Recycling emission reductions are not applicable to this method and disposal emissions are equivalent between project and baseline.
			CH_4	No	
			N_2O	No	
Project	Production of molten sulphur	Related	CO_2	No	Excluded as the quantity of molten sulphur produced in the project and baseline scenarios are functionally equivalent. Sulphur is a by-product of gas processing and would be produced in both the project and baseline scenarios in the same quantity
			CH_4	No	
			N_2O	No	
	Sulphur degassing	Related	CO_2	Yes	If sulphur degassing is occurring as a result of the project and the producer would otherwise not be degassing the sulphur, the emissions will be additional to the baseline scenario.
			CH_4	Yes	
			N_2O	Yes	
	Transportation and storage of molten sulphur	Related	CO_2	Yes	Transportation and storage emissions in the project scenario are deemed to be additional to baseline scenario transportation and storage and must be included.
			CH_4	Yes	
			N_2O	Yes	
	Modifier	Related	CO_2	Yes	Emissions associated with the production and

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
	production and transportation		CH_4	Yes	transportation of the sulphur modifier is directly related to the project and must be included.
			N_2O	Yes	
	Aggregate production and processing	Related	CO_2	No	Excluded as the same quantity of aggregate would be produced and processed in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Transportation of aggregate	Related	CO_2	No	Excluded as the same quantity of aggregate would be transported in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Fuel extraction and processing	Related	CO_2	No	Fuel extraction and production used for Additional sulphur heating in the project will be less than baseline fuel extraction and production and therefore conservative to exclude.
			CH_4	No	
			N_2O	No	
	Fuel delivery	Related	CO_2	No	Excluded as the emissions from transportation are likely negligible.
			CH_4	No	
			N_2O	No	
	Electricity generation	Related	CO_2	Yes	Indirect emissions from electricity use may be a significant source of emissions. The project proponent must include electricity in the methodology if it is demonstrated to be conservative.
			CH_4	Yes	
			N_2O	Yes	
	Additional sulphur heating	Controlled	CO_2	Yes	Any heat derived from sources that emit greenhouse gases is additional to the baseline scenario and must be included.
			CH_4	Yes	
			N_2O	Yes	
	Aggregate heating	Controlled	CO_2	Yes	Any heat derived from sources that emit greenhouse gases is additional to the baseline scenario and must be included.
			CH_4	Yes	
			N_2O	Yes	
	Concrete mixing	Controlled	CO_2	No	The process for concrete mixing is equivalent in the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Concrete transportation	Controlled	CO_2	No	The same quantity of concrete will be transported in the baseline and project
			CH_4	No	

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
			N_2O	No	scenarios.
	Precast product pouring and forming	Controlled	CO_2	No	The process for pouring and forming will not change between the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Precast product transportation	Controlled	CO_2	No	There is no difference in the transportation related emissions between the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Concrete recycling or disposal	Controlled	CO_2	No	Excluded for simplification. Recycling emission reductions are not applicable to this method and disposal emissions are equivalent between project and baseline.
			CH_4	No	
			N_2O	No	

*Gas types listed are those that are relevant at least once to the project or baseline scenario. No refrigerants are relevant to this methodology.

The temporal project boundary includes the operation of an existing or new precast concrete facility during the incorporation of a sulphur binder. SSRs related to the construction and decommissioning of the facility are considered outside the scope of this methodology and have been excluded from quantification. This is reasonable given the minimal emissions associated with the construction and decommissioning phases and the long operational life of the facility.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario for projects applying this methodology is the production of precast concrete products using Portland cement. The project proponent must demonstrate that this is the most reasonable and credible baseline for their project using the most recent version of the CDM tool *Combined tool to identify the baseline scenario and determine additionality*. The project proponent must use this tool to identify all realistic and credible baseline alternatives, and to identify barriers and to assess which alternatives are prevented by these barriers. In doing so, relevant local regulations governing the use of different technologies, and technical specifications of concrete products must be taken into account.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Additionality must be assessed and demonstrated using the latest version of the CDM tools *Combined tool to identify the baseline scenario and demonstrate additionality* or *Tool for the demonstration and assessment of additionality.*

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

The production of clinker results in the release of significant process GHG emissions and combustion GHG emissions. Carbon dioxide process emissions occur as a by-product of the calcination process, where a calcium or magnesium carbonate such as limestone is heated with clay to form clinker (primarily calcium oxide) and carbon dioxide. The heat required for the calcination process is typically supplied from the combustion of fossil fuels, resulting in the emission of further carbon dioxide as well as smaller amounts of methane and nitrous oxide.

Baseline quantification in this methodology is projection based, which uses projections of reductions or removals in the project to estimate the baseline activity that would have occurred in the absence of the project. The calculation of the emissions related to the production of Portland cement in the baseline scenario will be based on the mass of sulphur cement used in the project scenario. An equivalency factor will be used to provide functional equivalence between the mass of sulphur cement and Portland cement. Finally, an emission factor representing the mass of carbon dioxide equivalent greenhouse gas emissions per tonne of Portland cement displaced will be applied.

Emissions under the baseline scenario (in tonnes CO_2e) are determined using the following equation:

$$BE_y = \frac{BE_{Portland} + BE_{Electricity}}{1000} \tag{1}$$

Where:

BE_y	=	Baseline emissions in a given year (y) (t CO_2e)
$BE_{Portland}$	=	Emissions due to the production of Portland cement (kg CO_2e)
$BE_{Electricity}$	=	Emissions due to electricity generation for the production of Portland cement (kg CO_2e)

The emissions due to the production of Portland cement under the baseline scenario are calculated as follows:

$$BE_{Portland} = Mass_{Precast} \times \%_{PC} \times EF_{Portland\ Cement\ Production} \tag{2}$$

Where:

$BE_{Portland}$	=	Emissions due to the production of Portland cement (kg CO_2e)
$Mass_{Precast}$	=	Mass of finished precast products containing sulphur cement (t)
$\%_{PC}$	=	Ratio of Portland cement used in the finished precast product (unitless)

$EF_{Portland\ Cement\ Production}$ = Emission factor for the production of Portland cement (kg CO_2e/t)

The emission factor for Portland cement production are calculated as follows:

$$EF_{Portland\ Cement\ Production} = \frac{Mass_{Clinker}}{Mass_{Cement}} \times EF_{Clinker} \quad (3)$$

Where:

$EF_{Portland\ Cement\ Production}$ = Emission factor for the production of Portland cement (kg CO_2e/t)

$Mass_{Clinker}/Mass_{Cement}$ = Clinker to cement ratio (unitless)

$EF_{Clinker}$ = Emission factor of clinker (kg CO_2e/t)

The emissions due to electricity generation for the production of Portland cement under the baseline scenario are as follows:

$$BE_{Electricity} = Electricity_{B} \times EF_{Elec} \quad (4)$$

Where:

$BE_{Electricity}$ = Emissions due to electricity generation for the production of Portland cement (kg CO_2e)

$Electricity_{B}$ = Electricity used for the production of Portland cement (kWh)

EF_{Elec} = Emissions factor for electricity (kg CO_2e/kWh)

8.2 Project Emissions

Emissions under the project scenario (in tonnes CO_2e) are determined using the following equation:

$$PE_y = \frac{PE_{Degassing} + PE_{Additional\ S\ Heating} + PE_{Agg\ Heating} + PE_{S\ Trans\&Storage} + PE_{Modifier} + PE_{Elec}}{1000} \quad (5)$$

Where:

PE_y = Project emissions in a given year (y)

$PE_{Degassing}$ = Emissions due to sulphur degassing (kg CO_2e)

$PE_{Additional\ S\ Heating}$ = Emissions due to the additional heating requirements of sulphur concrete (kg CO_2e)

$PE_{Agg\ Heating}$ = Emissions due to heating the aggregate (kg CO_2e)

$PE_{STrans\&Storage}$ = Emissions due to the transportation and storage of sulphur (kg CO_2e)

$PE_{Modifier}$ = Emissions due to the production and transportation of the sulphur modifier (kg CO_2e)

$PE_{Electricity}$	=	Emissions due to the generation of electricity for use in the precast sulphur concrete facility (kg CO_2e)

The emissions due to sulphur degassing under the project scenario are calculated as follows:

$$PE_{Degassing} = \sum_{x,k} \left(Vol\ Fuel_{DG,k} \times EF\ Fuel_{k,x} \times GWP_x \right) + \left(Vol_{vent\ gas} \times MF_{CO2} \times \frac{m_{CO2}}{V_{STP}} \right) \qquad (6)$$

Where:

$PE_{Degassing}$	=	Emissions due to sulphur degassing (kg CO_2e)
Vol $Fuel_{k,DG}$	=	Volume of each type of fuel combusted for degassing (L, m^3 or other)
EF $Fuel_{k,x}$	=	Emissions factor for fuel combustion for each type of fuel (k) used and GHG (x) listed (kg CO_2e/L, m^3 or other)
$Vol_{vent\ gas}$	=	volume of degassing vent gas incinerated (m^3)
MF_{CO2}	=	Molar fraction of CO_2 in degassing vent gas incinerated (%)
M_{CO2}	=	Molar mass of CO_2 (kg/mol)
V_{STP}	=	Volume of one kg-mole of an ideal gas at standard temperature and pressure (m^3)
GWP_x	=	Global warming potential for each GHG (kg CO_2e)
x	=	Value for each GHG (CO_2, CH_4 and N_2O)

The emissions for additional heating of sulphur are calculated as follows:

$$PE_{Additional\ S\ Heating} = \sum_{x,k} (Vol\ Fuel_{AH,k} \times EF\ Fuel_{k,x} \times GWP_x) \qquad (7)$$

Where:

$PE_{Additional\ S\ Heating}$	=	Emissions due to the additional heating requirements of sulphur concrete (kg CO_2e)
$VolFuel_{k,AH}$	=	the volume of each type of fuel combusted for additional sulphur heating (L, m^3 or other)
EF $Fuel_{k,x}$	=	the emissions factor for fuel combustion for each type of fuel (k) used and GHG (x) listed (kg CO_2e/L, m^3 or other)
GWP_x	=	Global warming potential for each GHG (kg CO_2e)
x	=	Value for each GHG (CO_2, CH_4 and N_2O)

The emissions for heating of aggregate are calculated as follows:

$$PE_{Agg\ Heating} = \sum_{x,k} \left(Vol\ Fuel_{AG,k} \times EF\ Fuel_{k,x} \times GWP_x \right) \qquad (8)$$

Where:

$PE_{Agg\ Heating}$	=	Emissions due to heating the aggregate (kg CO_2e)
$VolFuel_{k,AG}$	=	Volume of each type of fuel combusted for aggregate heating (L, m^3 or other)
$EF\ Fuel_{k,x}$	=	Emissions factor for fuel combustion for each type of fuel (k) used and GHG (x) listed (kg CO_2e/L, m^3 or other)
GWP_x	=	Global warming potential for each GHG (kg CO_2e)
x	=	Value for each GHG (CO_2, CH_4 and N_2O)

The emissions due to transportation and storage of molten sulphur under the project scenario are calculated as follows:

$$PE_{S\ Trans\&Storage} = Mass\ Distance \times EF_{Transport} \quad (9)$$

Where:

$PE_{STrans\&Storage}$	=	Emissions due to the transportation and storage of sulphur (kg CO_2e)
Mass Distance	=	Mass of sulphur multiplied by the distance shipped from sulphur manufacturing facility to pre-cast manufacturing facility (t km)
$EF_{Transport}$	=	Emissions factor for transportation of sulfur (kg CO_2e/t km)

The emissions due to the production and transportation of modifier are calculated as follows:

$$PE_{Modifier} = (M_{Modifier} \times EF_{Modifier}) + (Mass\ Distance_{Modifier} \times EF_{Transport}) \quad (10)$$

Where:

$PE_{Modifier}$	=	Emissions due to the production and transportation of the sulphur modifier (kg CO_2e)
$M_{Modifier}$	=	Mass of modifier used (t)
$EF_{Modifier}$	=	Emission factor for modifier production (kg CO_2e/t)
$Mass\ Distance_{Modifier}$	=	Mass of modifier and the distance shipped from modifier manufacturing facility to facility where modifier is added to sulphur (t km)
$EF_{Transport}$	=	Emissions factor for truck transportation (kg CO_2e/ t km)

The emissions due to electricity generation for operating the sulphur concrete facility are calculated as follows:

$$PE_{Electricity} = Electricity_P \times EF_{\ Elec} \quad (11)$$

Where:

$PE_{Electricity}$	=	Emissions due to the generation of electricity for use in the precast sulphur concrete facility (kg CO_2e)
$Electricity_P$	=	Electricity used in operating the sulphur concrete facility (kWh)
EF_{Elec}	=	Emissions factor for electricity (kg CO_2e/kWh)

8.3 Leakage

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

8.4 Summary of GHG Emission Reduction and/or Removals

The emission reductions for this project activity are calculated as follows:

$$ER_y = BE_y - PE_y \qquad (12)$$

Where:

ER_Y	=	Net GHG emissions reductions and/or removals in year y
BE_Y	=	Baseline emissions in year y
PE_y	=	Project emissions in year y

9 MONITORING

9.1 Data and Parameters Available at Validation

The data specified below must be made available at validation by the project proponent. Default values may vary according the physical location of the project activity. The project proponent must provide evidence and justification that the values presented here are applicable to the project activity, or provide and justify project-specific values as needed.

Should the data parameters listed below not be available at the time of validation, the project proponent must provide a plan for determination and/or monitoring the data during the project. All parameters used must be reviewed on an annual basis to ensure the most current value is used in calculations.

Data / Parameter	$EF_{Portland\ Cement\ Production}$
Data unit	kg CO_2e/t
Description	Emission factor for the production of Portland cement
Equations	2
Source of data	Calculation using site specific data if available, or reference values if no site specific data is available
Value applied	
Justification of choice of data or	The pThe project proponent mustmay use site-specific

description of measurement methods and procedures applied	emission factors for accuracy if a specific facility factor can be justified for the baseline cement production facility. Reference values may be calculated if site specific information is not available using data published by the World Business Council for Sustainable Development based on region. See Appendix A for guidance. The project proponent must justify that the $EF_{Portland\ Cement\ Production}$ in Appendix A is conservative for the project.
Purpose of data	Calculation of baseline emissions
Comment	Aggregation of multiple product types may specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter:	EF Fuel
Data unit	kg (CO_2, CH_4, N_2O) per L, m3 or other of each type of fuel used
Description	Emissions factors for fuel combustion
Equations	6, 7 and 8
Source of data	Estimation; reference values must be obtained from regional, national, or international GHG inventories. In the absence of local or regional data, reference values may be obtained from the most recent version of the IPCC guidelines for national GHG inventories.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	National emissions factors, or emissions factors created by local industry using internationally accepted procedures mustmay be used preferentially. Regional emissions factors may be used if national or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable. In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for national GHG inventories.
Purpose of data	Calculation of project emissions

Comment	Review best practice guidance and accepted standards. Reference values are generally available. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter:	M_{CO2}
Data unit	kg/mol
Description	Molar mass of carbon dioxide
Equations	6
Source of data	General Chemistry book, 9th Edition, Ebbing & Gammon
Value applied	0.04401
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of data	Calculation of project emissions
Comment	This parameter is not likely to become out of date.

Data / Parameter	V_{STP}
Data unit	m^3
Description	Volume of one kg-mole of an ideal gas at standard temperature and pressure
Equations	6
Source of data	General Chemistry book, 9th Edition, Ebbing & Gammon
Value applied	23.6449
Justification of choice of data or description of measurement methods and procedures applied	The standard temperature and pressure conditions are 15°C and 101.325 kPa.
Purpose of data	Calculation of project emissions
Comment	This parameter is not likely to become out of date.

Data / Parameter	$Mass_{clinker}$ / $Mass_{Cement}$
Data unit	Percent

Description	Ratio of clinker to cement
Equations	3
Source of data	Site specific data, or reference values
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The project proponent mustuse site-specific factors for accuracy if a specific facility can be justified for the baseline cement production facility. Reference values may be calculated using data published by the World Business Council for Sustainable Development based on region. See Appendix A for guidance. If site-specific factors are used, the project proponent must justify that the values are conservative for the project, and uncertainty is tracked where possible. The project proponent must also justify that the $EF_{Portland\ Cement\ Production}$ in Appendix A is conservative for the project.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must provide justification for factor used based on the region, kiln type and / or baseline facility records. Aggregation of multiple product types may specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$EF_{Clinker}$
Data unit	kg CO_2e per tonne of clinker
Description	Emission factor for the production of clinker
Equations	3
Source of data	Site specific values as provided by the project proponent records, or reference values, such as those found in the World Business Council for Sustainable Development, Cement Industry Energy and CO2 Performance “Getting the Numbers Right” report.
Value applied	
Justification of choice of data or description of measurement	Proponents must use site-specific emission factors for accuracy if a specific facility can be justified for the baseline

methods and procedures applied	cement production facility. Reference values may be calculated, using data published by the World Business Council for Sustainable Development based on region. See Appendix A for guidance. The project proponent must justify that the $EF_{Portland\ Cement\ Production}$ in Appendix A is conservative for the project.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must provide justification for factor used based on the region, kiln type, fuel type and / or baseline facility records. Aggregation of multiple product types may specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	EF_{Elec}
Data unit	kg CO_2e per kWh
Description	Emissions factor for electricity
Equations	4 and 11
Source of data	Estimation; local or regional grid factors are preferable. If local factors are unavailable, reference values may be obtained from national and international GHG inventories may be used. In the absence of national data, reference values may be obtained from the most recent version of the IPCC guidelines for national GHG inventories. The value used must be consistent with the source of generation.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Review of best practice guidance and accepted standards. Reference values are generally available for each regional grid.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and source of elecricity used in the project. Default values must be sourced from recognized, credible sources and be geographically and

	temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$Electricity_B$
Data unit	kWh
Description	Electricity used for operating the precast concrete facility
Equations	4
Source of data	Estimation based on historical data from electrical meter
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Metering of electricity may be direct or by a utility provider. Measurement mustbe continuous, with monthly aggregation (totalized).
Purpose of data	Calculation of baseline emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$EF_{Transport}$
Data unit	kg CO_2e/t km
Description	Emissions factor for transportation
Equations	9 and 10
Source of data	Fleet data (such as fleet-wide average emissions per distance), or default data may be used if fleet data is unavailable.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	An emissions factor developed using internationally accepted practices may be generated for a fleet of vehicles, representing actual emissions due to fuel consumption per distance. If not available, regional data must be used and, in its absence, IPCC defaults may be used from the most recent version of IPCC Guidelines for national GHG inventories.
Purpose of data	Calculation of project emissions
Comment	Proponents may propose a fleet-specific emissions factor if

	sufficient documentation is available. The emissions factor must be reviewed at each verification period if actual fuel consumption is used in the emissions factor calculation. If retained shipping manifests, copies of shipping logs, or invoices from the supplier are used for the calculation, the resulting emissions factor must be cross checked against national or regional transport or fleet emission factors. If a default value is used, proponents mustjustify that it is conservative.

Data / Parameter	MF_{CO2}
Data unit	%
Description	Molar fraction of carbon dioxide in incinerated vent gas
Equations	8
Source of data	Facility-specific theoretical values are obtained from computer modeling or simulation, or through trial applications.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Continuous measurement of this parameter is not economically feasible and estimation must provide an accurate value, as this parameter is not likely to vary significantly over the project life.
Purpose of data	Calculation of project emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

9.2 Data and Parameters Monitored

The data parameters specified below must be monitored during the project.

Data / Parameter:	$Mass_{Precast}$
Data unit	Tonne
Description	Mass of precast products produced
Equations	2
Source of data	Measurement or calculation.
Description of measurement methods and procedures to be applied	The mass of finished products may be measured, or if measurement not feasible, the mass could be calculated based on a material balance, or could be calculated based

	on design specifications.
Frequency of monitoring or recording	Per product type
QA/QC procedures to be applied	If a measurement approach is used, then regular calibration and maintenance of scales as per requirements of meter manufacturers ensures quality weight measurements.
Purpose of data	Calculation of baseline emission
Calculation method	N/A
Comment	Aggregation of multiple product types may specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation.

Data / Parameter	$\%_{PC}$
Data unit	Unitless
Description	Ratio of Portland cement in finished product
Equation	3
Source of data	Estimated based on design criteria of product
Description of measurement methods and procedures to be applied	This percentage represents the amount of Portland cement that would have been contained within the finished product (in the baseline) compared to other components such as aggregate, water. Design criteria must be justified based on technical specifications or performance requirements of the product. Historical production specifications may also be used for justification of design criteria. This is a unitless value.
Frequency of monitoring/recording	Per product
QA/QC procedures to be applied	This parameter varies in the project scenario and must be monitored for each product but is not actually measured. Design specifications are sufficient to ensure accuracy on this parameter.
Purpose of data	Calculation of baseline emission
Calculation method	N/A
Comment	The use of manufacturer's specifications provides a method for establishing functional equivalence between the product used in the baseline scenario and the product used in the project scenario. Aggregation of multiple product types may

	specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation.

Data / Parameter	Vol Fuel
Data unit	L, m^3 or other
Description	Volume of fuel combusted during the project
Equations	6
Source of data	Measurement of volume of fuel used.
Description of measurement methods and procedures to be applied	The project proponent may measure the volume of fuel consumed in one of two ways: 1. Direct metering or reconciliation of volumes received and in storage; 2. Reconciliation of volume of fuel purchased within a given time period.
Frequency of monitoring/recording	Monthly
QA/QC procedures to be applied	Regular calibration and maintenance of meters as per requirements of meter manufacturers ensures quality metering. Cross-checking of metered or purchased volumes compared to theoretical fuel use must occur at each verification period. Minor variations must be immaterial on a quarterly or annual basis. Long term trends must align with theoretical expectations and remain consistent on a per volume of product basis.
Purpose of data	Calculation of project emission
Calculation method	N/A
Comment	None

Data / Parameter	Mass Distance
Data unit	t km
Description	Mass distance of sulphur transported to the concrete facility
Equations	9
Source of data	Measurement of mass of sulphur received and distance the sulphur traveled.

Description of measurement methods and procedures to be applied	Direct measurement of mass of sulphur received and distance traveled based on manifests or supplier invoices.
Frequency of monitoring/recording	Each shipment
QA/QC procedures to be applied	Regular calibration and maintenance of scales as per requirements of meter manufacturers ensures quality weight measurements. Retention of shipping manifests, copies of shipping logs, or invoices from the supplier must be cross checked against processed volumes and distances estimated based on shipping routes. Minor variations must be immaterial on a quarterly or annual basis.
Purpose of data	Calculation of project emission
Calculation method	N/A
Comment	None

Data / Parameter	$M_{Modifier}$
Data unit	t
Description	Mass of modifier used in sulphur cement
Equations	10
Source of data	Measurement of mass of sulphur modifier
Description of measurement methods and procedures to be applied	Direct measurement of mass of modifier used in the concrete facility.
Frequency of monitoring/recording	Per shipment of modifier
QA/QC procedures to be applied	Regular calibration and maintenance as per requirements of meter/scale manufacturers ensures quality metering. Mass balance of all product constituents must align with metered values and provide a suitable confirmation that measurement equipment is providing accurate information between calibration intervals. Minor variations must be immaterial on a quarterly or annual basis.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$EF_{Modifier}$
Data unit	kg CO_2e/ t
Description	Emissions factor for modifier production
Equations	10
Source of data	Estimated based on manufacturer's specifications, fuel used, and electricity used.
Description of measurement methods and procedures to be applied	Value provided by the modifier manufacturer based on fuel and electricity consumed.
Frequency of monitoring/recording	Per shipment of modifier, to be updated annually by manufacturer of modifier
QA/QC procedures to be applied	Compare to historical values and analyze trends to confirm the estimate for emission factor is within a realistic range. Cross reference with manufacturer utility invoices for energy consumption to also ensure accuracy on estimate.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	Mass $Distance_{Modifier}$
Data unit	t km
Description	Mass distance of modifier transported to the concrete facility
Equations	10
Source of data	Measurement of mass of modifier received and the distance the modifier traveled.
Description of measurement methods and procedures to be applied	Direct measurement of mass of modifier received and distance traveled based on manifests or supplier invoices.
Frequency of monitoring/recording	Each shipment
QA/QC procedures to be applied	Regular calibration and maintenance of scales as per requirements of meter manufacturers ensures quality weight measurements. Retention of shipping manifests, copies of shipping logs, or invoices from the supplier must be cross checked against processed volumes and distances estimated based on shipping routes. Minor variations must be immaterial on a quarterly or annual basis.

Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	Electricity $_{P}$
Data unit	kWh
Description	Electricity used for sulphur concrete facility in the project
Equations	11
Source of data	Measurement
Description of measurement methods and procedures to be applied	Metering of electricity may be direct or by a utility provider. Measurement must be continuous, with monthly aggregation.
Frequency of monitoring/recording	Continuously aggregated (totalized) per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Electricity utility standard maintenance and calibration procedures apply. Cross-checking of metered values versus engineering estimates or theoretical electricity usage values ensures accuracy between calibration intervals.
Purpose of data	Calculation of project emission
Calculation method	N/A
`Comment	None

Data / Parameter	Vol $_{vent\ gas}$
Data unit	m^3
Description	Volume of degassing vent gas incinerated
Equations	6
Source of data	Measurement of the volume of vented gas (direct metering), or default value.
Description of measurement methods and procedures to be applied	Direct metering of vent gas to the incinerator, or regional or sector-wide default values (in order of preference).
Frequency of monitoring/recording	Continuously aggregated (totalized) per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration for direct metering method as per requirements of meters ensures quality metering. Intermittently cross reference metered value with theoretical

	volume to periodically confirm accuracy. Minor variations must be immaterial on a quarterly or annual basis.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	Proponents must justify that the default value used for incinerator emissions is conservative.

9.3 Description of the Monitoring Plan

The project proponent must develop a monitoring plan detailing the procedures for data capture, measurement and reporting of the data parameters listed in Section 9.2. In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data must be of sufficient quality to fulfill the quantification requirement and be substantiated by company records for the purpose of verification.

The project proponent must establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be conducted for the project.

The project proponent must ensure that all documents and records are kept in a secure and retrievable manner for at least two years after the end of the project crediting period. Record keeping practices must be established that include:

- Electronic recording of values of logged primary parameters for each measurement interval;
- Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments relevant to the project quantification;
- Retention of copies of logs and all logged data; and
- Keeping all records available for review by a verification body.

The project proponent must also develop a QA/QC plan to add confidence that all measurements and calculations have been made correctly. QA/QC measures that may be implemented include, but are not limited to:

- Protecting monitoring equipment (sealed meters and data loggers);
- Protecting records of monitored data (hard copy and electronic storage);
- Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
- Comparing current estimates with previous estimates as a 'reality check';
- Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;

- Establish minimum experience and requirements for operators in charge of project and monitoring; and
- Performing recalculations to make sure no mathematical errors have been made.

In general, measurement inaccuracies are inherently addressed in this methodology because the inputs into concrete production are measured or metered to ensure that concrete mix specifications are met. Therefore, there is a high degree of certainty in the measurements of associated with sulphur, aggregate, modifier, and volumes of fuel employed. However, the project proponent must address uncertainties in all measured values for all quantification parameters by ensuring that meters or scales are appropriately calibrated as prescribed by the manufacturer.

Parameters relevant to the project quantification for which confidence intervals may possibly be generated include MF_{CO2} and $Mass_{precast}$. If a direct measurement approach is employed (such as sampling the population of finished precast products in the case of $Mass_{precast}$, or trial application sampling in the case of MF_{CO2}) then a confidence interval must be determined. If the 95% confidence limits fall outside of 15% of the calculated value (as per the CDM Methodology Panel guidance), then a confidence deduction must be applied, using conservative factors such as those specified in the CDM Meth Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Annex 14.

In the situation where a computer simulation, mass balance process, or design specifications is used as a source of data (for either MF_{CO2} or $Mass_{precast}$), the uncertainty associated with each input to the simulation, or design process must be determined. If the resulting uncertainty of the simulation output falls outside of 15% of the calculated value, a confidence deduction must be applied, using conservative factors, as above. Similarly, if site-specific factors for $Mass_{clinker}$ / $Mass_{Cement}$ are employed and uncertainty is tracked, and if the resulting uncertainty falls outside of 15% of the calculated value, then a confidence deduction must be applied, using conservative factors, as above.

Parameters relevant to the project quantification for which confidence intervals cannot easily be generated include those listed below. The project proponent must demonstrate the factors or values used in the project are appropriately conservative based on the uncertainty of the actual parameter during the project.

- $Vol_{vent\ gas}$
- $EF_{Portland\ Cement\ Production}$
- $EF_{Fuel\ i}$
- $Mass_{clinker}$ / $Mass_{cement}$
- $EF_{clinker}$
- $EF_{Transport}$

- Ratio of Portland cement in finished product ($\%_{PC}$)
- $Vol_{Fuel\ i,\ DG,\ AH}$
- Mass distance of sulphur transported to the concrete facility
- $M_{modifier}$
- $EF_{modifier}$
- Mass distance of modifier transported to the concrete facility
- $EF_{Electricity}$
- $Electricity_B$
- $Electricity_P$

Methods used by the the project proponent for estimating uncertainty must be based on recognized statistical approaches such as those described in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Where applicable, confidence deductions applied must use conservative factors such as those specified in the CDM Methodology Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Annex 14.

10 REFERENCES AND OTHER INFORMATION

The good practice guidance and best science used to develop the quantification methodology are presented below in Table 2.

Table 2: Good Practice Guidance

Document Title	Publishing Body / Date	Description
General Protocol Guidance		
Canada's National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990-2010	Government of Canada (2012)	On behalf of the Government of Canada, Environment Canada releases a national inventory of greenhouse gases annually in accordance with international UNFCCC reporting standards.
Alberta Offset System Offset Credit Project Guidance Document	Alberta Environment (February 2008)	A draft guidance document outlining how to develop offset projects under the Alberta Offset System.
ISO 14064-2	International Organization for Standardization (ISO)(2006)	Provides guidance at the project level for quantification, monitoring and reporting of

Document Title	Publishing Body / Date	Description
		greenhouse gas emission reductions or removal enhancements.
Protocols Reviewed		
ACM0015 Version 3: Consolidated baseline and monitoring methodology for project activities using alternative raw materials that do not contain carbonates for clinker production in cement kilns	Clean Development Mechanism – Executive Board (March 2010)	Approved baseline and monitoring methodology for alternative raw materials for clinker production in cement kilns.
Quantification Protocol for the Substitution of Bitumen Binder in Hot Mix Asphalt Production and Usage	Alberta Environment (October 2009)	Reference for global warming potential figures.
Draft quantification protocol for the use of Sulphur concrete in precast applications	Alberta Environment (February 2010)	General guidance on selection of SSR, quantification and monitoring.
ACM0005 Version 5: Consolidated Baseline Methodology for Increasing the Blend in Cement Production	Clean Development Mechanism – Executive Board (October 2009)	Approved baseline and monitoring methodology for reducing the amount of clinker per tonne of blended cement.
Cement Reporting Protocol	California Climate Action Registry	Provides guidance on accounting and reporting GHG emissions for cement companies.
CO2 Accounting and Reporting Standard for the Cement Industry	World Business Council for Sustainable Development, Version 2.0 (June 2005)	Provides a methodology for calculating and reporting CO2 emissions.
DRAFT Quantification Protocol for the Use of Fly Ash in Concrete and Other Cement Based Products	Alberta Environment (October 2008)	Early technical work considering selection of SSRs and quantification for alternatives to cement used to produce concrete and other cement based products.

Document Title	Publishing Body / Date	Description
Other Resources		
Submission to the Prime Ministerial Task Group on Emissions Trading	Cement Australia (March 2007)	Comments on the Issues Paper released by the Prime Minister's Task Group on Emissions Trading
A Sulphur Concrete Retaining Wall	University of Alberta (2002)	An evaluation of the technical feasibility of constructing sizer walls using sulphur concrete.
Corrosion and Chemical Resistant Masonry Materials Handbook, Walter Lee Sheppard	Noyes Publications (1986)	
National Pollution Inventory, Hydrogen Sulfide: Environmental Effects	Australian Government	See http://www.npi.gov.au/substances/hydrogen-sulfide/environmental.html for further information.
A blueprint for a climate friendly cement industry	WWF International	
CO2 emissions from cement production	ICF Incorporated / USEPA	Good Practice Guidance and Uncertainty Management in national GHG inventories
Sulfurcrete Sulfur Concrete Technology	Cominco	
Concrete Technology – Third Edition, M L Gambhir	Tata McGraw-Hill (2004)	
Sulphur concrete – a new construction material	PCI Journal/January-February 1974	
Cement Sector greenhouse gas emissions reduction	The Loreti Group (2009)	
Shell, Life cycle assessment of sulphur concrete	2009 (Confidential; some relevant results of the study have been presented to the Technical Working Group)	Dutch consulting firm INTRON examined a number of pathways to market for sulphur concrete products, and estimated the net GHG and other environmental benefits.
Shell – product information on Shell Thiocrete	See www.shell.com for further information.	Shell Thiocrete is a modified sulphur binder specifically designed to replace Portland cement in the production of concrete

Document Title	Publishing Body / Date	Description
		products, such as paving stones and curbs.
General Chemistry, 9th Edition, Ebbing & Gammon	Brooks Cole; 9 edition, January 16, 2008	General chemistry background reference
Cement Industry Energy and CO2 Performance "Getting the Numbers Right"	World Business Council for Sustainable Development	This report provides carbon dioxide and energy performance information based on emissions data from individual cement plants, and it was used as a reference for the information in Appendix A and description of Emission Factor for the production of Portland cement.

APPENDIX A: EMISSIONS FACTORS FOR THE PRODUCTION OF PORTLAND CEMENT

This section discusses the emissions factors for the parameter $EF_{Portland\ Cement\ Production}$.

Specific Displacement

The mass of sulphur cement produced by the project may displace Portland cement from a specific Portland cement production facility. Provided the project proponent can demonstrate and justify specific displacement, site specific factors for kiln emission intensity and clinker to cement ratio must be used based on facility feedstock and fuel records.

In general, the equation for determining an emission factor based on site specific information is provided below:

$$EF_{Clinker} = \frac{\sum_k \left(Vol\ Fuel_k \ \times EF\ Fuel_{k,x} \ \times GWP_x\right)}{Mass_{Clinker}} + 540\ kg_{CO2}\ tonnes^{-1}$$

Where:

$EF_{clinker}$	=	Emission factor per tonne of clinker for the baseline scenario (kg CO_2e/t clinker)
$Vol\ Fuel_k$	=	Volume of each type of fuel combusted for clinker production (L, m^3 or other)
$EF\ Fuel_{k,x}$	=	Emissions factor for fuel combustion for each GHG listed (kg GHG/L, m^3 or other).
GWP_x	=	Global warming potential for each GHG (CO_2, CH_4, N_2O)
$Mass_{Clinker}$	=	Mass of total clinker production in the quantification period (t)
540 kg_{CO2} $tonnes^{-1}$	=	Mass of CO_2 attributable to the calcination of one tonne of clinker.

The amount of CO_2 released due to the calcination of one tonne of clinker has been described as nearly constant by the authors of the World Business Council for Sustainable Development in the report “Cement Industry Energy and CO_2 Performance: Getting the numbers right.” This value is considered nearly constant. However, proponents may propose an alternative method to calculate the amount of CO_2 released due to the calcination of one tonne of clinker with justification.

The clinker to cement ratio (as described in Equation 3) is based on actual measurements of mass of cement produced and mass of clinker produced in the quantification period. It is expressed as a unit-less value (or percent) and applied as described in Equation 3.

Uncertainty related to the source of displaced Portland cement must be low and must be characterized by reviewing regional cement supply. Proponents must demonstrate that the distance/economics/logistics/etc. of secondary supplies of Portland cement would have not been viable.

Regional Displacement

The mass of sulphur cement produced by the project may displace Portland cement on a regional basis, meaning multiple Portland cement production facilities would contribute to the general cement supply in a region. In the absence of evidence for a specific displacement, the project proponent must demonstrate and justify regional estimates for kiln emission intensities and clinker to cement ratios. The project proponent must demonstrate that the factors used are conservative.

Regional factors may be determined by the project proponent and must be justified by citing records / studies / etc. specific to the region relevant to the project. In the absence of actual regional factors, an international report is cited below with reference to international regional kiln emission intensities and clinker to cement ratios.

The emission factor for clinker production and the ratio of clinker in Portland cement are listed below in Tables A1 and A2, respectively and were derived from the World Business Council for Sustainable Development's the Cement Sustainability Initiative report, *Cement Industry Energy and CO_2 Performance "Getting the Numbers Right"*.

The factors in Table A1 include emissions from the chemical process of calcination and emissions from fuel combustion, and consider those facilities that combust a wide range of carbon intensive and biogenic fuel sources.

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

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

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

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

Latin America	74
North America	84
World	78

The project proponent must justify the above factors are conservative to determine the emission factor for production of Portland cement in the absence of justification of site specific or region specific factors. This ensures uncertainty in the estimates is accounted conservatively.

DOCUMENT HISTORY

Version	Date	Comment
v1.0	15 May 2015	Initial version