

***DRAFT QUANTIFICATION
PROTOCOL FOR FLY ASH
SUBSTITUTION IN CEMENT BLENDS***

OCTOBER 2008

Draft Version 1

Disclaimer:

Table of Contents

| | |
|---|-----------|
| Table of Contents | 2 |
| List of Figures | 2 |
| List of Tables | 2 |
| 1.0 Project and Methodology Scope and Description | 3 |
| 1.1 Protocol Scope and Description..... | 3 |
| 1.2 <i>Glossary of New Terms</i> | 12 |
| 2.0 Quantification Development and Justification | 14 |
| 2.1 Identification of Sources and Sinks (SS's) for the Project | 14 |
| 2.2 Identification of Baseline..... | 21 |
| 2.3 Identification of SS's for the Baseline..... | 23 |
| 2.4 Selection of Relevant Project and Baseline SS's..... | 30 |
| 2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's | 34 |
| 2.5.1 Quantification Approaches | 34 |
| 2.5.2 Contingent Data Approaches | 39 |
| 2.6 Management of Data Quality..... | 39 |
| 2.6.1 Record Keeping | 40 |
| 2.6.1 Quality Assurance/Quality Control (QA/QC) | 40 |
| APPENDIX A | 56 |

List of Figures

| | |
|--|----|
| FIGURE 1.1: Process Flow Diagram for Project Condition | 6 |
| FIGURE 1.2: Process Flow Diagram for Baseline Condition..... | 7 |
| FIGURE 1.3: Simplified Process Flow Diagram for Project Condition..... | 8 |
| FIGURE 1.4: Simplified Process Flow Diagram for Baseline Condition | 9 |
| | |
| FIGURE 2.1: Project Element Life Cycle Chart | 16 |
| FIGURE 2.2: Baseline Element Life Cycle Chart..... | 25 |

List of Tables

| | |
|---|----|
| TABLE 2.1: Project SS's..... | 17 |
| TABLE 2.2: Baseline SS's | 26 |
| TABLE 2.3: Comparison of SS's | 31 |
| TABLE 2.4: Quantification Procedures..... | 35 |
| TABLE 2.5: Contingent Data Collection Procedures..... | 41 |
| | |
| TABLE A. 1: Flexibility Mechanism | 46 |
| TABLE A. 2: Flexibility Mechanism - Contingency | 54 |

1.0 Project and Methodology Scope and Description

This quantification protocol is written for those familiar with the production of cement and use of fly ash, a coal combustion product recovered from air pollution control devices at coal power plants or other coal combustion facilities, as a substitute for cement products (e.g. Portland Cement) used to produce concrete and other cement based products.

The opportunity for generating carbon offsets with this protocol arises from the avoidance of process emissions associated with the production of cement clinker from carbonate materials such as limestone and from the avoidance of fossil fuel combustion normally required to process raw materials and to operate cement kilns during the production of clinker and blended cement products. The baseline practice would be the production of an equivalent quantity of cement clinker at the average GHG emissions intensity of cement production plants operating in Alberta to match the quantity of fly ash used at mixing sites in the project condition. The baseline emissions would be defined based on the GHG emissions intensity of cement production in Alberta, which is expressed as the combined GHG emissions from fossil fuel combustion and from process (CO₂) emissions per unit of clinker produced at all cement production plants in the province. Therefore the GHG savings are quantified on the basis of the tonnes of cement displaced by the use of fly ash.

1.1 Protocol Scope and Description

This protocol is applicable to projects that involve the mixing of fly ash with other cement products to decrease the quantity of cement required in concrete applications and therefore reduce GHG emissions associated with the production of cement products from raw materials. GHG emissions from cement production are primarily process CO₂ emissions that occur during the calcination of carbonate materials as well as emissions from the consumption of fossil fuels to provide heat and power for the operation of cement kilns and other material processing equipment.

In the project condition the fly ash may enter the cement product supply chain at a variety of points, which may include transportation to cement production plants, product mixing facilities, intermediate distribution centres or transported directly to the site of concrete application. The fly ash may ultimately be used in many different applications as a cement replacement and therefore the quantification of GHG emissions is focussed on the tonnes of cement product displaced by fly ash.

This protocol is NOT applicable to fly ash that is directly used at cement production plants subject to the Alberta Specified Gas Emitters Regulation or other applicable provincial or federal climate change regulations, where the GHG intensity (tonnes of CO₂ equivalent from direct emissions per unit of cement product output from the plant) of the cement production plant is calculated on an intensity basis that includes the tonnes of fly ash used in the denominator. The project proponent would be responsible for tracking fly ash

distribution to ensure that fly ash used at regulated cement plants is not included, to avoid double counting of GHG emission reductions.

Recognizing that there may be many different uses of fly ash which may have relatively complicated supply chains, the protocol is generic in nature to account for possible distribution and mixing facilities included in the project boundary, as illustrated in FIGURE 1.1. The project boundary is built around the fly ash distribution chain as the cement production processes will not be impacted by the project activity, although these processes constitute most of the upstream sources GHG emissions displaced by the project activity. It is therefore up to the project proponent to define their specific fly ash supply/distribution chain to fully account for all incremental GHG emissions associated with the distribution and mixing of fly ash.

The scope of the protocol does not fully account for GHG emissions associated with raw material processing or other activities in the baseline that occur upstream of cement production plants (ie at quarries), which represents a conservative approach to quantification. The project proponent may choose to add in additional sources and sinks related to upstream material processing and transportation provided that they can justify the selection of appropriate emission factors under the protocol flexibility mechanisms.

FIGURE 1.1 offers a process flow diagram for a typical project.

Protocol Approach

The protocol quantification approach is based on the tonnes of fly ash sold/mixed that results in the substitution of cement in concrete applications. The baseline approach utilizes aggregated GHG emission intensity data from cement production facilities in Alberta to determine the baseline emissions that would have occurred had fly ash not been used as a substitute for cement and continued to be an underutilized coal combustion product (e.g. disposed of in landfill).

To demonstrate that a project is covered by the scope of the protocol, the project developer must demonstrate that the implementation of a marketing/ distribution system for fly ash has resulted in the beneficial use of fly ash in place of conventional cement products and that the fly ash would normally have been managed differently (i.e. landfilled). As evidence, the project developer must provide historical records of fly ash sales and/or utilization/mixing to demonstrate that this baseline condition, illustrated in

FIGURE 1.2, was either the previous practice or most likely practice based on conventional industry practices. Further, they must show that under the project activity the tonnes of fly ash diverted to productive use as a cement substitute has increased relative to a baseline period from 1999 to 2001, which is consistent with the Alberta Offset System eligibility criteria requiring offset project start dates to be after January 1, 2002.

The process flow diagrams for the project and baseline scenarios were simplified in FIGURE 1.3 and FIGURE 1.4, respectively, by aggregating the activities that would occur at cement production plants under a single SS to be consistent with the expected format of the data related to fuel consumption and process emissions in the baseline scenario.

FIGURE 1.1: Process Flow Diagram for Project Condition

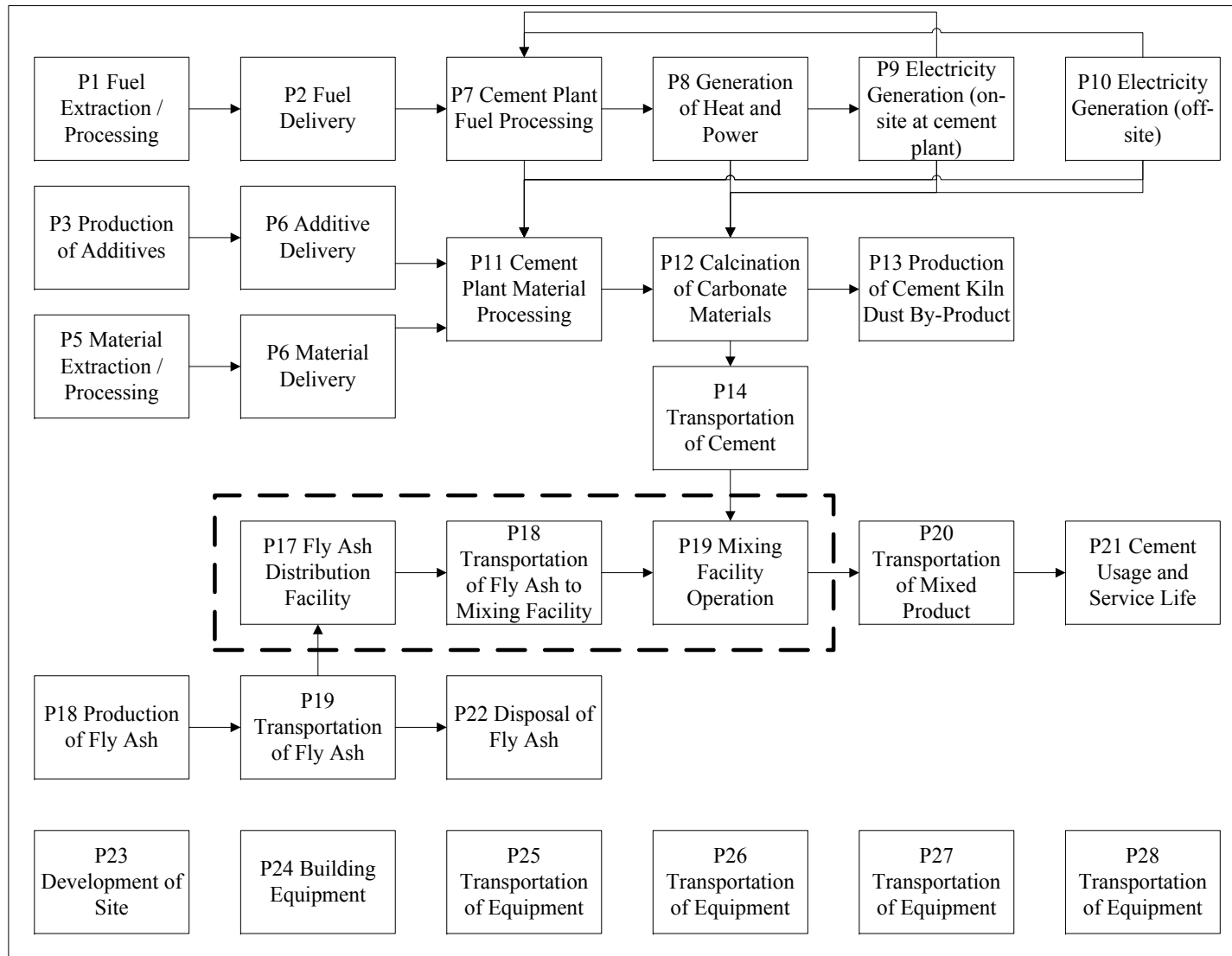


FIGURE 1.2: Process Flow Diagram for Baseline Condition

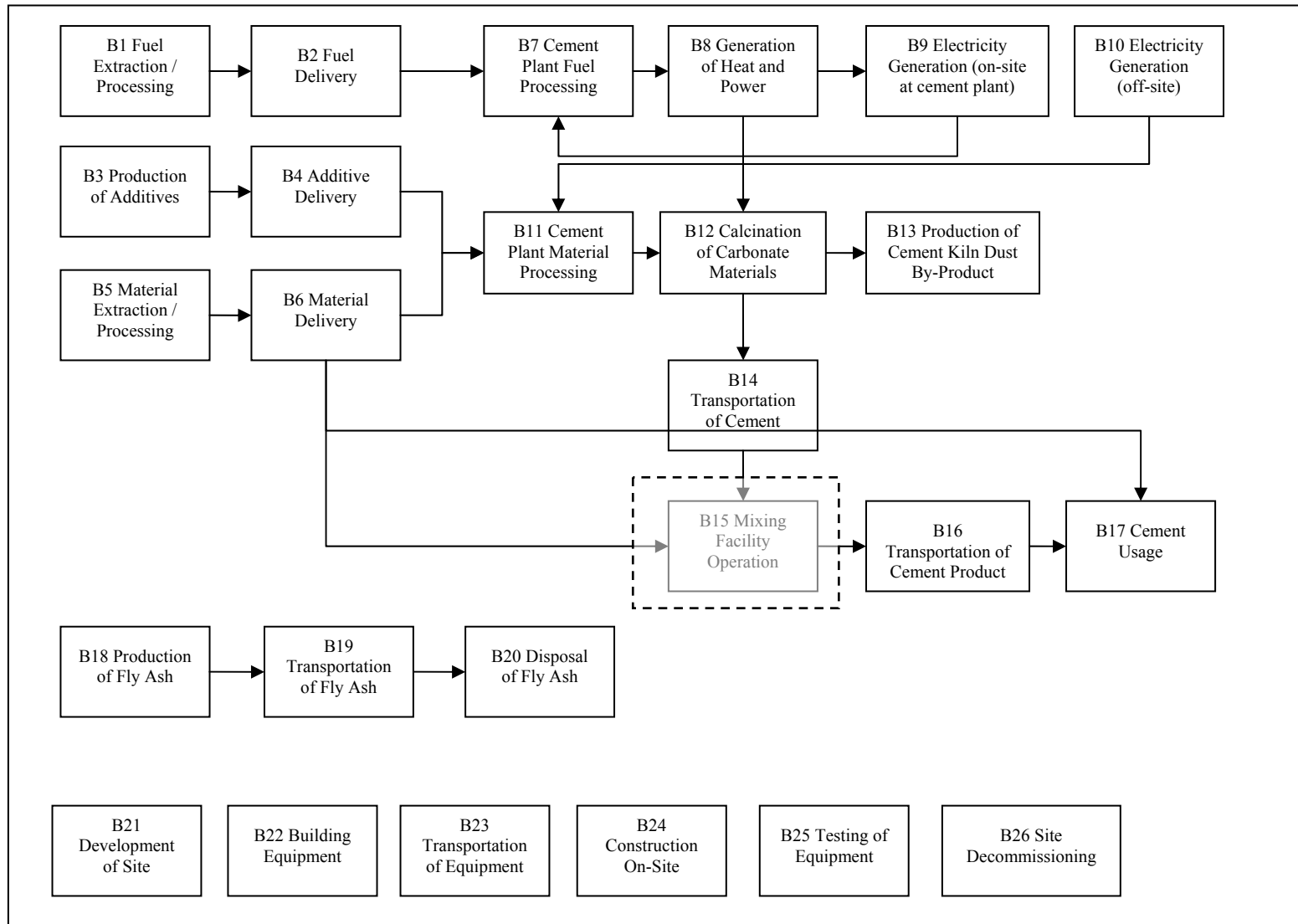


FIGURE 1.3: Simplified Process Flow Diagram for Project Condition

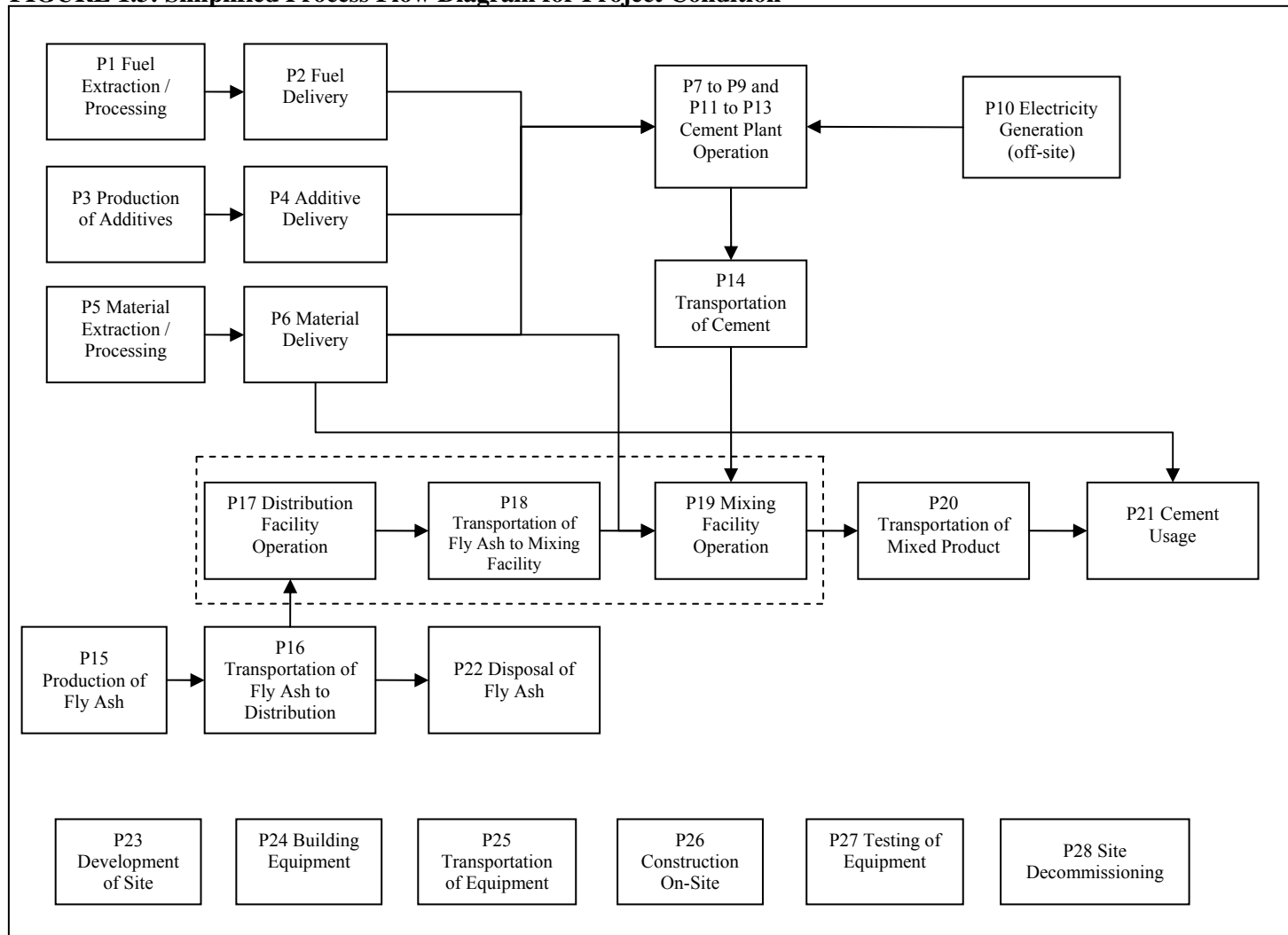
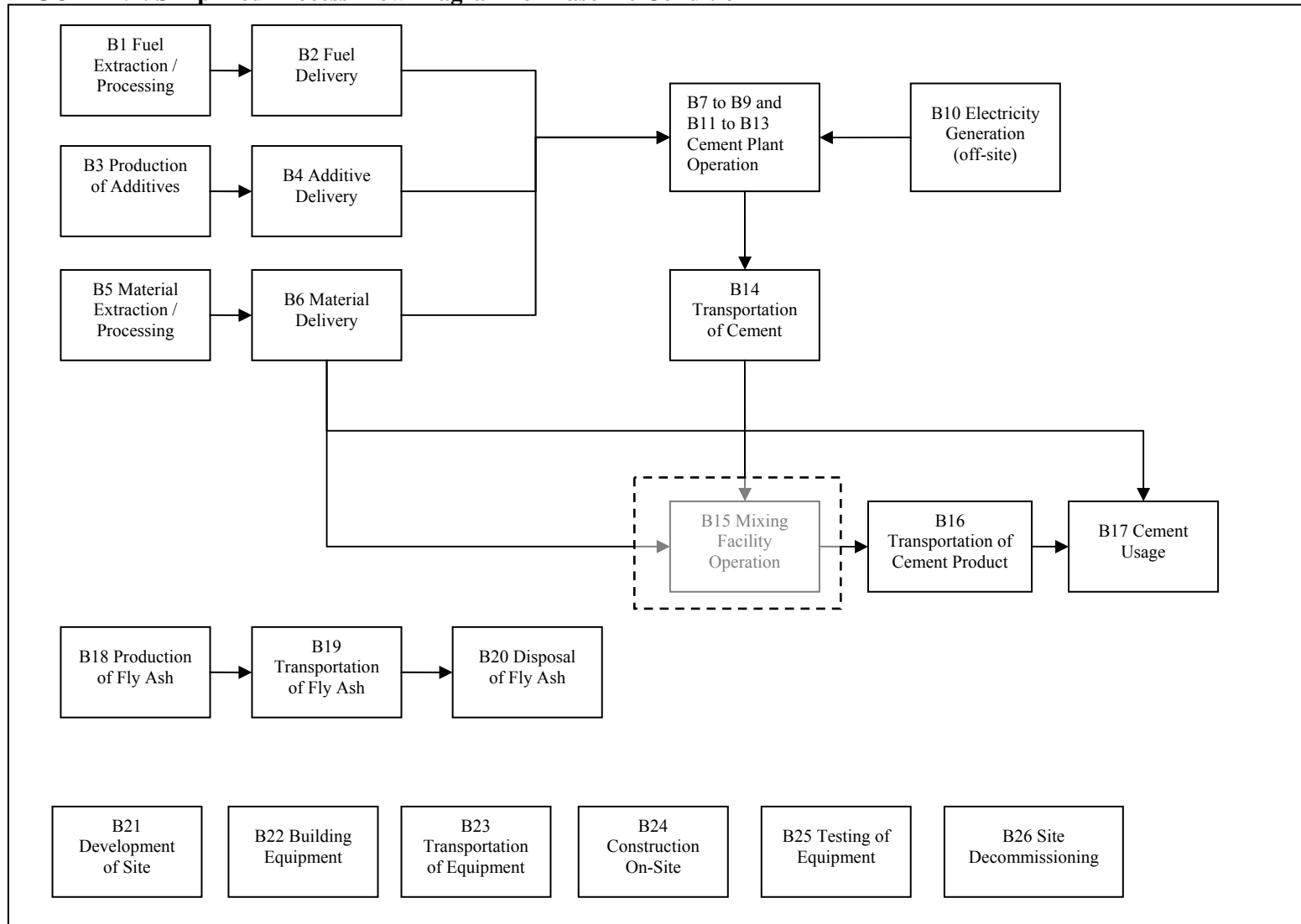


FIGURE 1.4: Simplified Process Flow Diagram for Baseline Condition



Protocol Applicability

To demonstrate that a project meets the requirements under this protocol, the project developer must provide evidence that:

1. The project proponent must define a project specific baseline based on historical fly ash usage or sales during the years 1999-2001. The baseline can be defined as the 3 year average of fly ash tonnes sold/mixed or as the highest value during that period if less than 3 years worth of data are available. Fly ash usage or sales prior to January 1, 2002, would not be considered eligible under the Alberta Offset System and therefore only the incremental quantity of fly ash sold and used in the project condition would be considered eligible for offset crediting;
2. Project proponents should reasonably track the distribution of fly ash up to the point where the fly ash is directly added to concrete as a substitute for other cement products to demonstrate that the fly ash is actually displacing cement products and is being mixed at non-regulated facilities. Any fly ash distributed and blended at cement production plants subject to the Alberta Specified Gas Emitters Regulation (or other relevant provincial/federal climate change regulation) and included in the intensity calculation for that facility is ineligible for offsets. The GHG intensity of cement production plants is expressed as the tonnes of greenhouse gas emissions per unit of product output. The product output would include clinker, blended cement, and/or additives to improve the properties of concrete. Fly ash included in the total production from the cement plants (Large Final Emitter Sites) would be ineligible to generate offsets because the overall GHG intensity for the cement production plant would be decreased by having a larger value for the total facility output. Project proponents must exercise reasonable diligence to ensure that the double counting of GHG emission reductions from fly ash mixing is avoided. If fly ash is handled at a regulated facility but not included in the baseline, records must be available to verify this;
3. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol; and,
4. The project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta Offset System. [Of particular note:
 - a. [The date of equipment installation, operating parameter changes or process reconfiguration are initiated or have effect on the project on or after January 1, 2002 as indicated by facility records;]
 - b. [The project may generate emission reduction offsets for a period of 8 years unless an extension is granted by Alberta Environment, as indicated by facility and offset system records. Additional credit duration periods require a reassessment of the baseline condition; and,]
 - c. [Ownership of the emission reduction offsets must be established as indicated by facility records.]

Protocol Flexibility

Flexibility in applying the quantification protocol is provided to project developers in three ways:

1. The project proponent may choose to develop a baseline GHG emissions intensity factor for cement production using project specific fuel consumption and process emissions data from one or more cement production plants in place of the aggregated values provided in this protocol. The development of the baseline GHG intensity should follow Good Practice Guidance from Alberta Environment and account for all direct GHG emissions at the facility per unit of cement product output from the plant consistent with the quantification approaches outlined in the Alberta SGER Technical Guidance Document for Baseline Emission Intensity Applications. There exists a wide range of other good practice guidance related to the quantification of GHG emissions from cement production including, but not limited to, the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) GHG Protocol Initiative, California Climate Action Registry (CCAR) Cement Reporting Protocol and the Clean Development Mechanism (CDM) Methodology ACM0005. Refer to Appendix A for the detailed quantification approach for this flexibility mechanism;
2. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. Some cement plants may employ Continuous Emissions Monitoring Systems (CEMS) or conduct frequent fuel analyses (energy content and carbon content) which can effectively be used to determine site-specific emission factors that may be more appropriate than the default emission factors in this protocol. The methodology for generation of these emission factors must ensure accuracy; and be robust enough to provide uncertainty ranges in the factors;
3. Measurement and data management procedures may be modified by the project developer to account for the available equipment as long as the specified minimum standards for data quantity, frequency and quality are met. Where these standards cannot be met, the project developer must justify why the method used represents a reasonable deviation to the protocol methodology provided.

The project proponent will have to justify their approach in detail to apply any of these flexibility mechanisms.

1.2 Glossary of New Terms

| | |
|------------------------|--|
| Functional Equivalence | The Project and the Baseline should provide the same function and quality of products or services. This type of comparison requires a common metric or unit of measurement (such as the mass of cement product produced or blended) for comparison between the Project and Baseline activity. |
| Fly Ash: | Fly ash is generated during the combustion of ground or powdered coal at power generation facilities and is collected from the exhaust gas stream. Fly ash is generally finer than cement and is pozzolanic in nature, which means it exhibits cementitious properties. It consists mostly of silicon dioxide, aluminium oxide, calcium oxide, and iron oxide. CSA A3001 identifies three types of fly ash on the basis of calcium content. Two of these types are produced in Canada, Type F (<8% CaO) and Type CI (8 – 20% CaO). A maximum of 5% SO ₃ for all types is permitted for use in cement. |
| Clinker: | Raw materials including minerals containing calcium oxide, silicon oxide, aluminium oxide, ferric oxide, and magnesium oxide are mined and mixed to the proper proportions. This mixture is fed by either wet or dry process into large, heated kilns to drive off unwanted elements. The remaining materials are called clinker. |
| Cement Plant: | A facility that produces clinker and blended cement products. The main components of a cement plant are a high temperature kiln used to remove CO ₂ from carbonate materials to produce clinker and a mill used to grind materials to the appropriate size. |
| Cement: | Cement is used as an ingredient in concrete, mortar, stucco, and grout. The most common type of cement used is called Portland cement, which is made from clay, limestone, sand, and iron. Portland cement does not contain any supplementary cementing materials. |

Blended Cement

Blended cement is cement that contains supplementary cementing materials such as fly ash, blast furnace slag, and silica fume.

2.0 Quantification Development and Justification

The following sections outline the quantification development and justification.

2.1 Identification of Sources and Sinks (SS's) for the Project

SS's were identified for the project by reviewing the relevant process flow diagrams, consulting with stakeholders (i.e. project proponents) and reviewing good practise guidance and other relevant greenhouse gas quantification protocols. This iterative process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagrams provided in FIGURE 1.1 and

FIGURE 1.2, the project SS's were organized into life cycle categories in FIGURE 2.1. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in TABLE 2.1.

FIGURE 2.1: Project Element Life Cycle Chart

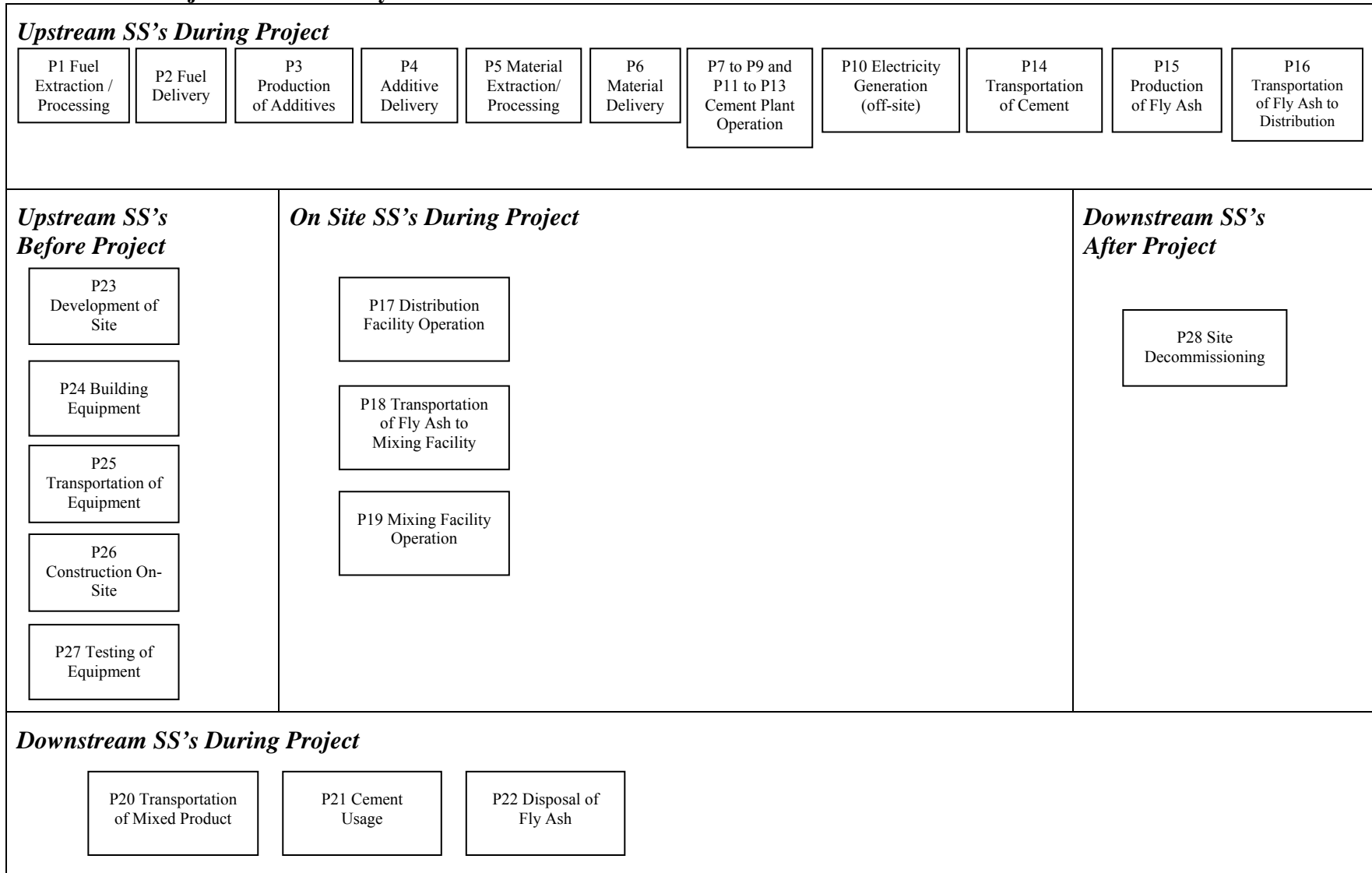


TABLE 2.1: Project SS's

| 1. SS | 2. Description | 3. Controlled, Related or Affected |
|--|--|------------------------------------|
| Upstream SS's during Project Operation | | |
| P1 Fuel Extraction / Processing | Each of the fuels used throughout the project will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are aggregated under this SS to account for GHG emissions associated with their extraction and processing at upstream oil and gas facilities. Volumes and types of fuels are the important characteristics to be tracked. | Related |
| P2 Fuel Delivery | Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. Distance and means of fuel delivery as well as the volumes of fuel delivered are the important characteristics to be tracked. | Related |
| P3 Production of Additives | The additives used in the cement production process of the project will need to be produced off-site. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production of additives. Volumes and types of additives are the important characteristics to be tracked. | Related |
| P4 Additive Delivery | The additives used in the cement production process of the project will need to be transported to the site. This may include shipment by truck or rail, resulting in the emissions of greenhouse gases. Distance and means of additive delivery as well as the tonnes of additives delivered are the important characteristics to be tracked. | Related |
| P5 Material Extraction / Processing | The materials used in the cement production process of the project such as limestone and gypsum will need to be produced off-site. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production of materials. The tonnes of each material are the important characteristic to be tracked. | Related |
| P6 Material Delivery | The materials used in the cement production process of the project will need to be transported to the site. This may include shipment by truck or rail, resulting in the emissions of greenhouse gases. Distance and means of material delivery as well as the volumes of materials delivered are the important characteristics to be tracked. | Related |
| P7 to P9 and P11 to P13 Cement Plant Operation | The fuels used at the cement plant to operate a variety of equipment to produce cement may require additional processing prior to combustion. This is particularly true when alternative fuels such as biomass, refuse or tire derived fuels are used. The processing of these fuels may require the operation of grinding equipment and dryers which would require additional energy inputs that may not be covered by the primary heat and power generation systems at the cement plant, resulting in the emission of greenhouse gases. The types and quantities of fossil fuels consumed are the important characteristics to be tracked. | Related |
| | The generation of heat and/or power at the cement production plant site would be required to operate the mill and kiln as well as other cement production process. The will require combustion of fossil fuels such as coal, petroleum coke, natural gas or alternative fuels, resulting in the emission of greenhouse gases. The quantities and (fossil) carbon contents of each type of fuel are the important quantities to track. | Related |

| | | |
|---------------------------------------|--|---------|
| | The cement plant may generate electricity on-site to provide power for the cement production processes and will result in the combustion of various conventional and possibly alternative fuels, resulting in the emission of greenhouse gases. The type, quantity and (fossil) carbon content of each fuel should be tracked in addition to the total MWh of electricity generated. | Related |
| | The cement plant will require a variety of on-site material processing units such as a mill to grind the raw materials into the appropriate sizes. This equipment may require the consumption of fossil fuels, resulting in greenhouse gas emissions. The type, quantities and (fossil) carbon contents of all fuels not already accounted for under the SS for Heat and Power Generation should be accounted for here. | Related |
| | The calcination of limestone and other carbonate materials to produce clinker involves heating the materials in a kiln at very high temperatures. The chemical decomposition reaction (called calcination) results in the release of CO ₂ for every unit of carbonate contained in the kiln feedstock (mainly limestone) based on the stoichiometry of the reaction. These emissions from calcination are referred to as Industrial Process Emissions and they represent a major source of anthropogenic GHG emissions in the cement industry. Additionally the combustion of fossil fuel is required to operate the kiln. The tonnes of clinker produced as well as the types, quantities and carbon contents of each fuel consumed to operate the kiln are the important characteristics to be tracked. | Related |
| | Cement kiln dust (CKD) may be produced in appreciable quantities as a by-product from the kiln particulate matter control units (baghouses, electrostatic precipitators and cyclones). The CKD may represent the leakage of GHG emissions if it isn't recycled at the plant and blended into the final products. The industrial process emissions from the cement plant may be quantified based on the clinker output of facility (rather than the raw material composition and input to the facility) and therefore if large amounts of CKD are sent to disposal then the process emissions may be somewhat under estimated due to this discrepancy. The important items to track are the total tonnes of CKD produced, the quantity recycled/blended and the tonnes sent for disposal. | Related |
| P10 Electricity Generation (off-site) | Electricity may be required for operating a variety of equipment at the cement production facility in the project. The site may have on-site generation electricity, but may also source electricity from other generators or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. This electricity would have been produced at an emissions intensity as deemed appropriate by the Program Authority. Quantity and source of power are the important characteristics that may need to be tracked as they directly relate to the quantity of greenhouse gas emissions. | Related |
| P14 Transportation of Cement | The cement produced at the cement plant will need to be transported to the blending facility or directly to the end site where the concrete will be poured. This may include shipment by truck or rail, resulting in the emission of greenhouse gases. Distance and means of transportation as well as tonnes of cement transported are the important characteristics to be tracked. | Related |
| P15 Production of Fly Ash | Fly ash is produced from the combustion of coal. The facility that generates the fly ash (typically a coal fired power plant) would have the primary function of producing electricity and would have any number of processes that would require energy inputs and therefore consume fossil fuels as part of those processes. GHG emissions from coal fired electricity generation facilities are not included under the scope of this protocol as they are independent of the project activity (GHG emissions from fly ash blending/usage are not dependent on the | Related |

| | | |
|--|---|------------|
| | operations of the power generation facility) and are already subject to regulation under the Specified Gas Emitters Regulation. | |
| P16 Transportation of Fly Ash to Distribution | The fly ash produced off-site may need to be transported to the distribution facility before it is delivered to mixing facilities or to the end user in the project condition. This may include shipment by truck or rail, resulting in the emission of greenhouse gases. Distance and means of fly ash transportation as well as volumes of fly ash transported are the important characteristics to be tracked. | Related |
| Onsite SS's during Project Operation | | |
| P17 Distribution Facility Operation | The operation of a distribution facility will require the consumption of fossil fuels to operate material handling equipment such as dump trucks and loaders, resulting in the emission of greenhouse gases. Types and quantities of fuels should be tracked to establish functional equivalence between the project and baseline. | Controlled |
| P18 Transportation of Fly Ash to Mixing Facility | The fly ash may need to be transported from any distribution facilities to one or more blending facilities. This may include shipment by truck or rail, resulting in the emission of greenhouse gases. Distance and means of fly ash transportation as well as volumes of fly ash transported are the important characteristics to be tracked. | Controlled |
| P19 Mixing Facility Operation | The operations of the mixing facilities may require fossil fuels for material processing, mixing and for operation of other mobile equipment requiring diesel, gasoline or other fuels, resulting in the emission of greenhouse gases. In the majority of cases the mixing of fly ash in the project is functionally equivalent to the baseline. That said, it would be important to confirm if the project activity resulted in the addition of supplemental equipment in order to mix fly ash. | Controlled |
| Downstream SS's during Project Operation | | |
| P20 Transportation of Mixed Product | The blended product (fly ash and cement) will need to be transported from the blending facility to the final site using concrete. The transportation of this product will require the consumption of fossil fuels. The distance should be evaluated to account for functional equivalence between the baseline and project condition. | Related |
| P21 Cement Usage | The final blended product will be used for any number of uses in the project condition. All of the uses will result in greenhouse gas emissions, but are difficult to quantify due to the number and variety of end-uses and will be functionally equivalent. | Related |
| P22 Disposal of Fly Ash | Not all fly ash is suitable for mixing in cement, thus fly ash disposal occurs in the project condition. Depending in the type of fly ash disposal method, there may be resulting greenhouse gas emissions. The tonnes of fly ash disposed and type of disposal method are important characteristics to be tracked. | Related |
| Other | | |
| P23 Development of Site | Additional development may be required for the addition of a distribution facility in the project condition. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, etc. There will also need to be some construction of structures for the facility such as storage areas, offices, etc. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc. | Related |
| P24 Building Equipment | Additional equipment may need to be built either on-site or off-site to accommodate the blending of fly ash at the blending facility. These may be sourced as pre-made standard equipment or custom built to specification. | Related |

| | | |
|---------------------------------|--|---------|
| | Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly. | |
| P25 Transportation of Equipment | Equipment built off-site and the materials to build equipment on-site will all need to be delivered to the site. Transportation may be completed by truck, barge and/or train. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site. | Related |
| P26 Construction On-Site | The process of construction at the site may require a variety of construction equipment such as heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity. | Related |
| P27 Testing of Equipment | Equipment may need to be tested to ensure that it is operational. This may result in running the equipment in order to ensure that it is operational. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity. | Related |
| P28 Site Decommissioning | Once a distribution facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site. | Related |

2.2 Identification of Baseline

The baseline condition for this protocol is defined as the GHG emissions from the production of an equivalent mass of cement from raw materials that has been displaced by fly ash in the project condition due to the establishment of a marketing and distribution system for fly ash that was previously underutilized. The baseline GHG emissions are quantified based on three main elements: the baseline GHG intensity of cement production in Alberta, the current (project) level of fly ash utilization and the historic level of fly ash utilization.

The baseline condition uses a historic benchmark approach to account for the GHG emissions intensity of cement production in the baseline. Baseline emission factors were developed using aggregated GHG emissions from fossil fuel consumption and industrial process emissions at all cement production plants in Alberta during 2003 to 2006. The total GHG emissions from these plants were divided by the total production output from the cement plants to arrive at a kg CO₂e/tonne of product baseline emission intensity factor. The use of three years of historical GHG emissions data collected after the Alberta Offset System project eligibility start date of January 1, 2002 provides for reasonable certainty as to the actual GHG emissions avoided by projects initiated post 2002. The use of a static baseline emission factor was therefore reasonable at the time of protocol writing and practical given the challenges related to the transfer of potentially sensitive information between proponents in the cement industry and the project proponent(s) distributing and using the fly ash. However, it is expected that as additional Federal GHG regulations come into force in Canada in 2010, there will be opportunities to refine these baseline emission factors with more up to date data at that time.

The baseline emissions from the production of a functionally equivalent quantity of cement are calculated based on the measured tonnes of fly ash mixed with cement in the project condition times the emissions intensity factor for cement production in Alberta. The baseline emissions are quantified on the basis that one tonne of fly ash displaces 0.88 tonnes of blended cement product as per the October 2006 report titled *Materials Technology Laboratory, Estimating GHG Savings from Use of Fly Ash* (N. Bouzoubaa, A. Bilodeau, and B. Fournier). This element of the baseline condition is dynamic in approach as the use of ex post fly ash data accounts for the market forces and other factors in the supply chain that may impact the quantity of cement displaced from year to year.

In order to ensure that the project activity's use of fly ash exceeds business as usual practices, the baseline scenario requires the project proponent to collect historic fly ash sales or usage data to establish the average tonnes of fly ash blended with cement products during the years 1999-2001. By quantifying a project-specific business as usual activity level in the baseline, only the incremental tonnes of fly ash blended in the project condition are credited for offsets.

The use of measured fly ash tonnages and historical GHG emission intensities for cement production in Alberta provides reasonable certainty in the quantification of baseline emissions.

The baseline condition is defined including the relevant SS's and processes as shown in

FIGURE 1.2. More detail on each of these SS's is provided in Section 2.3, below.

2.3 Identification of SS's for the Baseline

Based on the process flow diagrams provided in

FIGURE 1.2, the project SS's were organized into life cycle categories in FIGURE 2.2. Descriptions of each of the SS's and their classification as either 'controlled', 'related' or 'affected' is provided in TABLE 2.2.

FIGURE 2.2: Baseline Element Life Cycle Chart

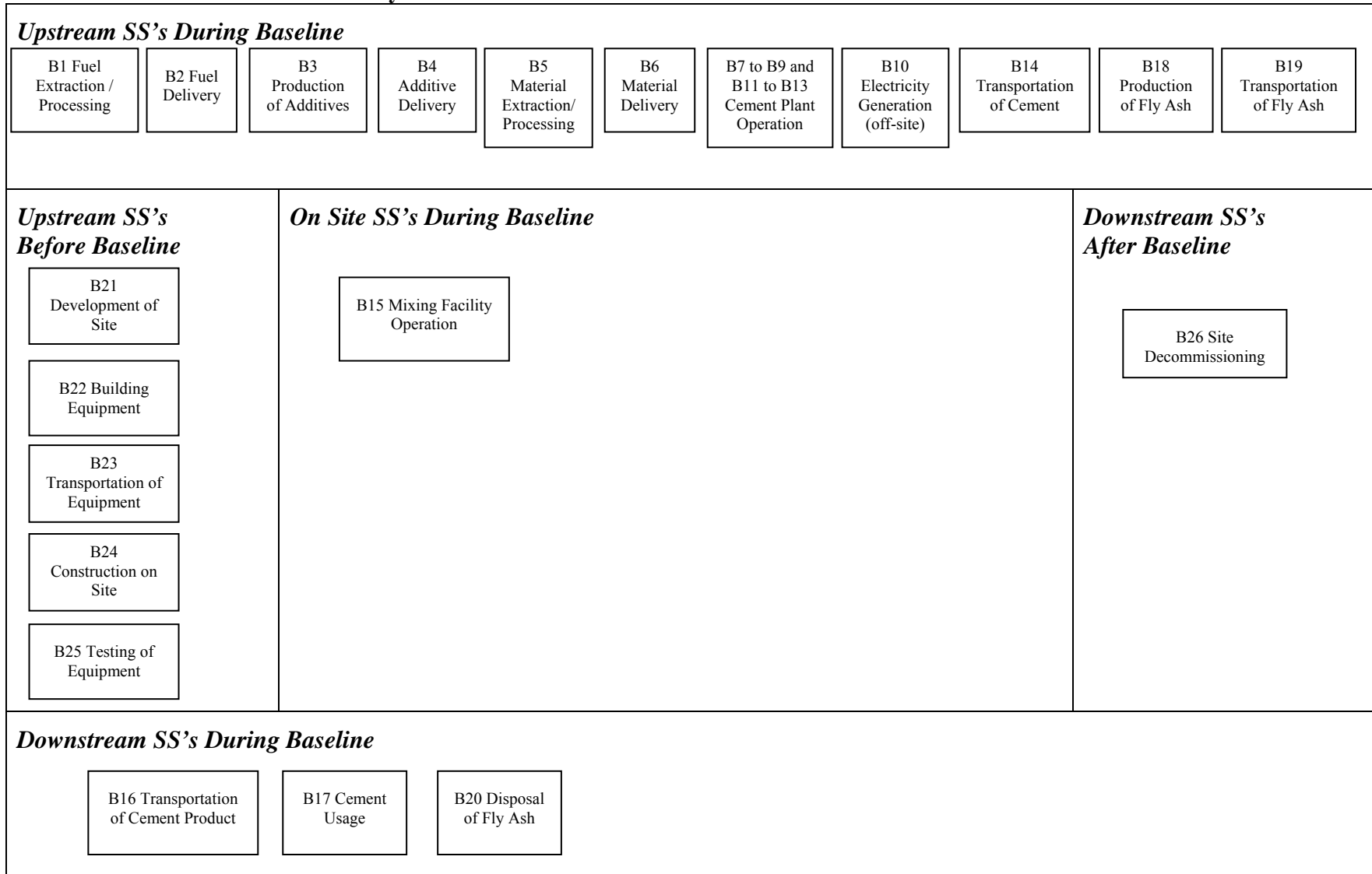


TABLE 2.2: Baseline SS's

| 1. SS | 2. Description | 3. Controlled, Related or Affected |
|--|--|------------------------------------|
| <i>Upstream SS's during Baseline Operation</i> | | |
| B1 Fuel Extraction / Processing | Each of the fuels used at the facility in the baseline will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are aggregated under this SS to account for GHG emissions associated with their extraction and processing at upstream oil and gas facilities. Volumes and types of fuels are the important characteristics to be tracked. | Related |
| B2 Fuel Delivery | Each of the fuels used at the facility in the baseline will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. Distance and means of fuel delivery as well as the volumes of fuel delivered are the important characteristics to be tracked. | Related |
| B3 Production of Additives | The additives used in the cement production process of the baseline will need to be produced offsite. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production of additives. Volumes and types of additives are the important characteristics to be tracked. | Related |
| B4 Additive Delivery | The additives used in the cement production process of the baseline will need to be transported to the site. This may include shipment by truck or rail, resulting in the emissions of greenhouse gases. Distance and means of additive delivery as well as the volumes of additives delivered are the important characteristics to be tracked. | Related |
| B5 Material Extraction / Processing | The materials used in the cement production process of the baseline (including limestone) will need to be produced offsite. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production of materials. Volumes of materials are the important characteristics to be tracked. | Related |
| B6 Material Delivery | Each of the materials used at the cement plant will need to be transported to the site. This may include shipments by truck or rail, resulting in the emissions of greenhouse gases. Distance and means of material delivery as well as the volumes of materials delivered are the important characteristics to be tracked. | Related |
| B7 to B9 and B11 to B 13 Cement Plant Operation | The fuels used at the cement plant to operate a variety of equipment to produce cement may require additional processing prior to combustion. This is particularly true when alternative fuels such as biomass, refuse or tire derived fuels are used. The processing of these fuels may require the operation of grinding equipment and dryers which would require additional energy inputs that may not be covered by the primary heat and power generation systems at the cement plant, resulting in the emission of greenhouse gases. The types and quantities of fossil fuels consumed are the important characteristics to be tracked. | Related |

| | | |
|---------------------------------------|--|---------|
| | The generation of heat and/or power at the cement production plant site would be required to operate the mill and kiln as well as other cement production process. This will require combustion of fossil fuels such as coal, petroleum coke, natural gas or alternative fuels, resulting in the emission of greenhouse gases. The quantities and (fossil) carbon contents of each type of fuel are the important quantities to track. | Related |
| | The cement plant may generate electricity on-site to provide power for the cement production processes and will result in the combustion of various conventional and possibly alternative fuels, resulting in the emission of greenhouse gases. The type, quantity and (fossil) carbon content of each fuel should be tracked in addition to the total MWh of electricity generated. | Related |
| | The cement plant will require a variety of on-site material processing units such as a mill to grind the raw materials into the appropriate sizes. This equipment may require the consumption of fossil fuels, resulting in greenhouse gas emissions. The type, quantities and (fossil) carbon contents of all fuels not already accounted for under the SS for Heat and Power Generation should be accounted for here. | Related |
| | The calcination of limestone and other carbonate materials to produce clinker involves heating the materials in a kiln at very high temperatures. The chemical decomposition reaction (called calcination) results in the release of CO ₂ for every unit of carbonate contained in the kiln feedstock (mainly limestone) based on the stoichiometry of the reaction. These emissions from calcination are referred to as Industrial Process Emissions and they represent a major source of anthropogenic GHG emissions in the cement industry. Additionally the combustion of fossil fuel is required to operate the kiln. The tonnes of clinker produced as well as the types, quantities and carbon contents of each fuel consumed to operate the kiln are the important characteristics to be tracked. | Related |
| | Cement kiln dust (CKD) may be produced in appreciable quantities as a by-product from the kiln particulate matter control units (baghouses, electrostatic precipitators and cyclones). The CKD may represent the leakage of GHG emissions if it isn't recycled at the plant and blended into the final products. The industrial process emissions from the cement plant may be quantified based on the clinker output of facility (rather than the raw material composition and input to the facility) and therefore if large amounts of CKD are sent to disposal then the process emissions may be somewhat under estimated due to this discrepancy. The important items to track are the total tonnes of CKD produced and the quantity recycled/blended. | Related |
| B10 Electricity Generation (off-site) | Electricity may be required for operating a variety of equipment at the cement production facility in the baseline. The site may have on-site generation electricity, but may also source electricity from other generators or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. This electricity would have been produced at an emissions intensity as deemed appropriate by the Program Authority. Quantity and source of power are the important characteristics that may need to be tracked as they directly relate to the quantity of greenhouse gas emissions. | Related |

| | | |
|--|---|------------|
| B14 Transportation of Cement | The cement produced at the cement plant will need to be transported to the mixing facility site. This may include shipment by truck or rail, resulting in the emission of greenhouse gases. Distance and means of transportation as well as volumes of cement transported are the important characteristics to be tracked. | Related |
| B18 Production of Fly Ash | Fly ash is produced from the combustion of coal. The facility that generates the fly ash (typically a coal fired power plant) would have the primary function of producing electricity and would have any number of processes that would require energy inputs and therefore consume fossil fuels as part of those processes. GHG emissions from coal fired electricity generation facilities are not included under the scope of this protocol as they are independent of the project activity (GHG emissions from fly ash mixing/usage are not dependent on the operations of the power generation facility) and are already subject to regulation under the Specified Gas Emitters Regulation. | Related |
| B19 Transportation of Fly Ash | The fly ash produced at the coal combustion facilities will need to be transported to the disposal facility in the baseline condition. This may include shipment by truck or rail, resulting in the emission of greenhouse gases. Distance and means of fly ash transportation as well as volumes of fly ash transported are the important characteristics to be tracked in order to evaluate functional equivalence between the baseline and project scenarios. | Related |
| Onsite SS's during Project Operation | | |
| B15 Mixing Facility Operation | The cement output from the cement production plant may require the addition of other materials in order to achieve the desired properties in the final product and as such cement may be distributed to any number of mixing facilities. The operation of the mixing facilities would result in greenhouse gas emissions due to fossil fuel combustion for on-site transportation, material handling and mixer operations. The tonnes of cement processed are the important characteristic to be tracked. | Controlled |
| Downstream SS's during Baseline Operation | | |
| B16 Transportation of Cement Product | The mixed cement product will need to be transported from the mixing facility to the final site using concrete. The transportation of this product will require the consumption of fossil fuels. The distance should be evaluated to account for functional equivalence between the baseline and project condition. | Related |
| B17 Cement Usage | The final cement product will be used for any number of uses in the project condition. All of the uses will result in greenhouse gas emissions, but are difficult to quantify due to the number and variety of end-uses and will be functionally equivalent. | Related |
| B20 Disposal of Fly Ash | Depending in the type of fly ash disposal method, there may be resulting greenhouse gas emissions. The tonnes of fly ash disposed and type of disposal method are important characteristics to be tracked. | Related |
| Others | | |

| | | |
|---------------------------------|--|---------|
| B21 Development of Site | The mixing site may need to be developed under the baseline condition. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, etc. There will also need to be some construction of buildings for the facility such as storage areas, offices, etc. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc. | Related |
| B22 Building Equipment | Equipment may need to be built either on-site or off-site. This can include the baseline components for the storage, handling and processing of the cement and mixing materials. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly. | Related |
| B23 Transportation of Equipment | Equipment built off-site and the materials to build equipment on-site will all need to be delivered to the site. Transportation may be completed by truck, barge and/or rail. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site. | Related |
| B24 Construction on Site | The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity. | Related |
| B25 Testing of Equipment | Equipment may need to be tested to ensure that it is operational. This may result in running the equipment in order to ensure that it is operational. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity. | Related |
| B26 Site Decommissioning | Once a mixing facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site. | Related |

2.4 Selection of Relevant Project and Baseline SS's

Each of the SS's from the project and baseline conditions were compared and evaluated as to their relevancy using the guidance provided in Annex D of the "Guide for Protocol Developers: Draft for Consultation", dated August 2008 (Environment Canada). The justification for the exclusion or conditions upon which SS's may be excluded is provided in TABLE 2.3 below. All other SS's listed previously are included.

TABLE 2.3: Comparison of SS's

| 1. Baseline Options | 2. Baseline (C, R, A) | 2. Project (C, R, A) | 4. Include or Exclude from Quantification | 5. Justification for Exclusion |
|--|-----------------------|----------------------|---|---|
| Upstream SS's | | | | |
| P1 Fuel Extraction / Processing | N/A | Related | Exclude | Excluded since the emissions from fuel extraction and processing would have been higher in the baseline since a greater amount of cement would have had to be produced and would therefore have required a greater amount of fossil fuels, which would have had to have been extracted and processed. |
| B1 Fuel Extraction / Processing | Related | N/A | Exclude | Excluded as the data needed to quantify this SS are not directly controlled by the project proponent and therefore it is unlikely that the project proponent would have access to fuel consumption records from the cement production plant. Since the protocol approach relies on aggregated emissions intensity data per unit of cement production, it would likely not be possible for the project proponent to disaggregate specific fuel consumption data per unit of cement displaced by his/her project activity. Additionally it would be conservative to exclude these emissions in the baseline scenario. |
| P2 Fuel Delivery | N/A | Related | Exclude | Excluded as these SS's are likely lower in the project condition and therefore it is conservative to exclude them. |
| B2 Fuel Delivery | Related | N/A | Exclude | |
| P3 Production of Additives | N/A | Related | Exclude | Excluded as these SS's are likely lower in the project condition and therefore it is conservative to exclude them. |
| B3 Production of Additives | Related | N/A | Exclude | |
| P4 Additive Delivery | N/A | Related | Exclude | Excluded as these SS's are likely lower in the project condition and therefore it is conservative to exclude them. |
| B4 Additive Delivery | Related | N/A | Exclude | |
| P5 Material Extraction / Processing | N/A | Related | Exclude | Excluded as these SS's are likely lower in the project condition and therefore it is conservative to exclude them. |
| B5 Material Extraction / Processing | Related | N/A | Exclude | |
| P6 Material Delivery | N/A | Related | Exclude | Excluded as these SS's are likely lower in the project condition and therefore it is conservative to exclude them. |
| B6 Material Delivery | Related | N/A | Exclude | |
| P7 to P9 and P11 to P13 Cement Plant Operation | N/A | Related | Include | N/A |
| B7 to B9 and B11 to B13 Cement Plant Operation | Related | N/A | Include | |
| P10 Electricity Generation (Off-Site) | N/A | Related | Exclude | Excluded as these SS's are likely lower in the project condition because the replacement of cement with fly ash would indirectly reduce electricity usage |

| | | | | |
|---|------------|------------|---------|--|
| B10 Electricity Generation (Off-Site) | Related | N/A | Exclude | for material processing at cement plants as less material would be required to produce cement products and therefore it is conservative to exclude them. |
| P14 Transportation of Cement | N/A | Related | Exclude | Excluded as the replacement of cement with fly ash in the project would reduce transportation requirements for cement compared to the baseline and it is therefore conservative to exclude these SS's. |
| B14 Transportation of Cement | Related | N/A | Exclude | |
| P16 Transportation of Fly Ash to Distribution | N/A | Related | Exclude | Excluded as in the majority of project configurations the total transportation distance included in the project fly ash distribution chain (P16, P18 and P20) would be less than or equal to the total distance required to transport an equivalent amount of cement to mixing facilities and end users in the baseline (B14 and B16) had fly ash not been utilized in the project activity. |
| B19 Transportation of Fly Ash | Related | N/A | Exclude | |
| P15 Production of Fly Ash | N/A | Related | Exclude | Excluded as the fly ash is a waste by-product from coal power plants and all GHG emissions from these facilities are already regulated under the Specific Gas Emitters Regulation. |
| B18 Production of Fly Ash | Related | N/A | Exclude | |
| Onsite SS's | | | | |
| P17 Distribution Facility Operation | N/A | Controlled | Include | N/A |
| P18 Transportation of Fly Ash to Mixing | N/A | Controlled | Exclude | Excluded as in the majority of project configurations the total transportation distance included in the project fly ash distribution chain (P16, P18 and P20) would be less than or equal to the total distance required to transport an equivalent amount of cement to mixing facilities and end users in the baseline (B14 and B16) had fly ash not been utilized in the project activity. |
| P19 Mixing Facilities Operation | N/A | Controlled | Exclude | Excluded as the mixing facilities will continue to process the same volume of materials (cement plus fly ash) using the same types of equipment and mixing operations will likely not be impacted by the project activity and will therefore be functionally equivalent in the baseline and project conditions |
| B15 Mixing Facilities Operation | Controlled | N/A | | |
| Downstream SS's | | | | |
| P20 Transportation of Blended Product | N/A | Related | Exclude | Excluded as in the majority of project configurations there will be no change in product transportation practices and therefore no change in fossil fuel consumption for mixed product transportation, making the baseline and project scenarios functionally equivalent. |
| B16 Transportation of Blended Product | Related | N/A | | |
| P21 Cement Usage | N/A | Related | Exclude | Excluded as in the majority of project configurations there will be no change in downstream cement usage, making the baseline and project scenarios functionally equivalent. |
| B17 Cement Usage | Related | N/A | | |
| P22 Disposal of Fly Ash | N/A | Related | Exclude | Excluded as in the majority of disposal scenarios greenhouse gas emissions at the disposal site are minimal and it is conservative to exclude them. |
| B20 Disposal of Fly Ash | Related | N/A | Exclude | |

| Other | | | | |
|---------------------------------|---------|---------|---------|---|
| P23 Development of Site | N/A | Related | Exclude | Emissions from the distribution and blending facilities site development are not material given the long project life, and the minimal site development typically required. |
| B20 Development of Site | Related | N/A | Exclude | Emissions from blending facility site development are not material for the baseline condition given the minimal site development typically required. |
| P24 Building Equipment | N/A | Related | Exclude | Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required. |
| B21 Building Equipment | Related | N/A | Exclude | Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required. |
| P25 Transportation of Equipment | N/A | Related | Exclude | Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required. |
| B22 Transportation of Equipment | Related | N/A | Exclude | Emissions from transportation of equipment are not material for the baseline condition given the minimal transportation of equipment typically required. |
| P26 Construction on Site | N/A | Related | Exclude | Emissions from construction on site are not material given the long project life, and the minimal construction on site typically required. |
| B23 Construction on Site | Related | N/A | Exclude | Emissions from construction on site are not material for the baseline condition given the minimal construction on site typically required. |
| P27 Testing of Equipment | N/A | Related | Exclude | Emissions from testing of equipment are not material given the long project life and the minimal testing of equipment typically required. |
| B24 Testing of Equipment | Related | N/A | Exclude | Emissions from testing of equipment are not material for the baseline condition given the minimal testing of equipment typically required. |
| P28 Site Decommissioning | N/A | Related | Exclude | Emissions from decommissioning are not material given the long project life, and the minimal decommissioning typically required. |
| B25 Site Decommissioning | Related | N/A | Exclude | Emissions from decommissioning are not material for the baseline condition given the minimal decommissioning typically required. |

2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's

2.5.1 Quantification Approaches

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined in TABLE 2.4, below. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

$$\text{Emission Reduction} = \text{Emissions}_{\text{Baseline}} - \text{Emissions}_{\text{Project}}$$

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Cement Plant Operation}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Cement Plant Operation}} + \text{Emissions}_{\text{Distribution Facility Operation}}$$

Where:

$\text{Emissions}_{\text{Baseline}}$ = sum of the emissions under the baseline condition.

$\text{Emissions}_{\text{Cement Plant Operation}}$ (SS B7 to B9 and B11 to B13)

$\text{Emissions}_{\text{Project}}$ = sum of the emissions under the project condition.

$\text{Emissions}_{\text{Cement Plant Operation}}$ (SS P7 to P9 and P11 to P13)

$\text{Emissions}_{\text{Distribution Facility Operation}}$ (SS P17)

TABLE 2.4: Quantification Procedures

| 1.0 Project/ Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|--|--|--|----------------------------|---|---|--|
| Project SS's | | | | | | |
| P7 to P9 and P11 to P13 Cement Plant Operation | This SS is accounted for under the baseline scenario as only the incremental change in tonnes of cement displaced by fly ash are quantified. Refer to the SS's for B7 to B9 and B11 to B13, collectively referred to under 'Cement Plant Operation.' | | | | | |
| P17 Distribution Facility Operation | $\text{Emissions}_{\text{Distribution Facility Operation}} = \sum (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{CO}_2}) ; \sum (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{CH}_4}) ; \sum (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{N}_2\text{O}})$ | | | | | |
| | Emissions _{Distribution Facility Operation} | kg of CO ₂ ; kg of CH ₄ ; kg of N ₂ O | N/A | N/A | N/A | Quantity being calculated. |
| | Volume of Fuel Consumed for the operation of the Distribution Facility / Vol. Fuel _i | L / m ³ / other | Measured | Direct metering or reconciliation of volume in storage (including volumes received). | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |
| | CO ₂ Emissions Factor for Each Type of Fuel / EF Fuel _{iCO2} | kg CO ₂ per L / m ³ / other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | CH ₄ Emissions Factor for Each Type of Fuel / EF Fuel _{iCH4} | kg CH ₄ per L / m ³ / other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | N ₂ O Emissions Factor for Each Type of Fuel / EF Fuel _{iN2O} | kg N ₂ O per L / m ³ / other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| Baseline SS's | | | | | | |

| 1.0 Project/ Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|--|--|----------------------------|----------------------------|---|----------------------------------|--|
| B7 to B9 and B11 to B13 Cement Plant Operation | $\text{Emissions}_{\text{Cement Plant Operation}} = (\text{Mass of Cement}_{\text{Displaced Project}} - \text{Mass of Cement}_{\text{Displaced Business as Usual}}) * \text{EF}_{\text{Cement Production Intensity}}$ $\text{Mass of Cement}_{\text{Displaced Project}} = \text{Mass of Fly Ash Mixed}_{\text{Project}} * \text{Equivalence Factor}$ $\text{Mass of Cement}_{\text{Displaced Business as Usual}} = \text{Average Mass of Fly Ash Mixed}_{1999-2001} * \text{Equivalence Factor}$ | | | | | |
| | Emissions _{Cement Plant Operation} | kg of CO ₂ e | N/A | N/A | N/A | Quantity being calculated. |
| | Incremental Mass of Cement Product Displaced by Fly Ash / Mass of Cement <small>Displaced Project</small> | Tonnes | Calculated | Calculated based on the mass of fly ash mixed at eligible (non-regulated) facilities in the project condition times the equivalence factor to determine the mass of cement displaced per mass of fly ash mixed. | Reconciliation of Monthly Totals | It is reasonable to determine the equivalent amount of cement displaced on a monthly basis as this value is calculated from fly ash data that is measured on a per load basis. |
| | Average Mass of Cement Product Displaced by Fly Ash in the Baseline/ Mass of Cement <small>Displaced Business as Usual</small> | Tonnes | Calculated | Calculated based on the average mass of fly ash mixed at eligible (non-regulated) facilities from 1999-2001 times the equivalence factor to determine the mass of cement displaced per mass of fly ash mixed. | Reconciliation of Monthly Totals | It is reasonable to determine the equivalent amount of cement displaced on a monthly basis as this value is calculated from fly ash data that is measured on a per load basis. |
| | Mass of Fly Ash Mixed With Cement Products in the Project Condition/ Average Mass of Fly Ash Mixed <small>Project</small> | Tonnes | Measured | The mass of fly ash mixed is the weight of fly ash received by eligible mixing facilities or end users as measured using conventional truck scales or other applicable weigh scales that are regularly maintained and calibrated. | Each load | Measurement on a per load basis represents the highest level of diligence to account for variations in moisture content and bulk density. |

| 1.0 Project/ Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|-----------------------------|---|-----------------------------|----------------------------|--|--------------|---|
| | Average Mass of Fly Ash Mixed With Cement Products Over the 3 years Preceding 2002 / Average Mass of Fly Ash Mixed <small>1999-2001</small> | Tonnes | Estimated | Average mass of fly ash used or delivered to mixing facilities or end users during the years 1999 – 2001 (the 3 years preceding the Alberta Offset System project start date eligibility criteria). This quantity represents the business as usual rate of fly ash substitution. | N/A | Measurement will be based on historical fly ash utilization or delivery records available to the project proponent. The use of three years of historical data provides sufficient diligence to establish business as usual fly ash usage and determine the incremental fly ash usage that has occurred as a result of the project activity. |
| | Equivalence Factor to Convert from Mass of Fly Ash Used to Mass of Cement Displaced/ Equivalence Factor | Tonne fly ash/ tonne cement | Estimated | The equivalence factor is used to account for the fact that one tonne of fly ash does not displace exactly one tonne of cement. The default equivalence factor is 0.88 as per <i>Materials Technology Laboratory, Estimating GHG Savings from Use of Fly Ash</i> (N. Bouzoubaa, A. Bilodeau, and B. Fournier). | Once | The use of an equivalence factor represents a conservative method to determine the actual displacement of cement per unit of fly ash used based on the physical properties of the two materials (binding strength, pozzolanic properties etc.). |

| 1.0 Project/ Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|-----------------------------|---|---|----------------------------|--|--------------|--|
| | Emissions Intensity Factor for Cement Production / Cement Production Intensity | kg of CO ₂ e per tonne of cement displaced | Estimated | This represents an aggregate emission factor for fossil fuel consumption and industrial process (CO ₂) emissions per unit of cement product output at all relevant Alberta cement production plants. GHG emissions intensities have been averaged from 3 years of data at the relevant cement production plants that was submitted to Alberta Environment under the Specified Gas Emitters Regulation (SGER) during 2003-2006. | Annual | The Alberta SGER submissions represent best available cement industry data that has been verified by a 3 rd party auditor and reviewed by Alberta Environment. The facility GHG emission intensity data has been collected for all cement production plants in Alberta. In the event that SGER data is unavailable to the project proponent, guidance is given in Appendix A on the required data needed to establish a baseline GHG intensity per unit of cement displaced by fly ash. |

2.5.2. Contingent Data Approaches

Contingent means for calculating or estimating the required data for the equations outlined in section 2.5.1 are summarized in TABLE 2.5, below.

2.6 Management of Data Quality

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 should be of sufficient quality to fulfill the quantification requirements in Table 2.4 and be substantiated by company records for the purpose of verification.

Since this protocol relies on existing audited GHG intensity data from cement production plants in Alberta, the main data management requirements are focussed on the tonnes of fly ash utilized in the project condition as well as in the business as usual case, defined to be the three years preceding the Alberta Offset System start date eligibility requirement (2002). The fly ash distribution chain from the coal combustion facility through to the end user may involve a number of different parties and diligent record keeping is important to ensure accurate determination of the mass of fly ash that has displaced cement. The project proponent would be expected to retain hard copies of measured data from weigh scales and/or soft copies from databases or spreadsheets tracking sales and distribution records.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures should 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 to conduct for the project.

Due to the broad nature of this protocol it is possible that project proponents could be from one of many different positions in the fly ash supply chain. Each project proponent will have access to select information and data based on that position. It is recognized that many fly ash utilization projects will employ different marketing and supply chains from producer to end user and as such the project proponent should analyze the information flow available to them to ensure that data quality is high.

For projects applying the flexibility mechanism in Appendix A, instead of relying on data that has been audited by a third party for completeness and accuracy and reviewed by Alberta Environment, a higher level of data management is expected in order to substantiate the accuracy of records related to fossil fuel consumption and process emissions required to develop the baseline GHG intensity per unit of cement output from a relevant cement plant. Rigorous data management systems at the cement plant would be important to track the required three years of fuel consumption records, process CO₂

emissions data and production output from the cement plant to establish the baseline GHG intensity.

2.6.1 Record Keeping

Record keeping practises should include:

- a. Electronic recording of values of logged primary parameters for each measurement interval;
- b. Printing of monthly back-up hard copies of all logged data;
- c. Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
- d. Retention of copies of logs and all logged data for a period of 7 years; and
- e. Keeping all records available for review by a verification body.

2.6.1 Quality Assurance/Quality Control (QA/QC)

QA/QC can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

- a Protecting monitoring equipment (sealed meters and data loggers);
- b Protecting records of monitored data (hard copy and electronic storage);
- c Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
- d Comparing current estimates with previous estimates as a ‘reality check’;
- e Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;
- f Establish minimum experience and requirements for operators in charge of project and monitoring; and
- g Performing recalculations to make sure no mathematical errors have been made.

TABLE 2.5: Contingent Data Collection Procedures

| 1. Project / Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Contingency Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|--|---|----------------------------|-------------------------|---|----------------------------------|--|
| Project SS's | | | | | | |
| P17 Distribution Facility Operation | Volume of Each Type of Fuel / Volume of Fuel; | L / m ³ / other | Estimated | Reconciliation of volume of fuel purchased by the distribution facility operator within a given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used |
| Baseline SS's | | | | | | |
| B7 to B9 and B11 to B13 Cement Plant Operation | Mass of Fly Ash Mixed With Cement Products in the Project Condition/ Average Mass of Fly Ash Mixed _{Project} | Tonnes | Estimated | Reconciliation of mass of fly ash sold each month in the project condition. The project proponent must demonstrate that the tonnes of fly ash sold do not include any fly ash sold to facilities regulated under the SGER or equivalent GHG regulation as specified in the protocol applicability criteria. | Reconciliation of Monthly Totals | Records of sales to eligible facilities provides a reasonable estimate of the parameter when the more accurate and precise method cannot be used. The project proponent must |
| | Average Mass of Fly Ash Mixed With Cement Products Over the 3 years Preceding 2002 / Average Mass of Fly Ash Mixed ₁₉₉₉₋₂₀₀₁ | Tonnes | Estimated | Reconciliation of mass of fly ash sold during the years 1999-2001. | Reconciliation of Monthly Totals | Frequency of reconciliation provides for reasonable diligence. Use of historic sales data is reasonable given the wide range of potential end users of fly ash. |

APPENDIX A

Quantification of Flexibility Mechanisms

Flexibility Mechanism

Introduction: This flexibility mechanism is intended to allow the project proponent to quantify GHG emissions from individual SSRs that, when combined, represent the entire operations within the boundary of one or more cement production plants, in the event that aggregated GHG emissions data per unit of cement product output from the plant(s) is not available through other reporting systems (e.g. Alberta SGER). The project proponent must define which activities are considered to be part of the “Cement Plant Site” as each site will differ in its configuration. Project proponents may refer to the Alberta Specified Gas Emitters Regulation Guidance Document, Environment Canada Section 71 and the World Resources Institute Cement Protocol, Clean Development Mechanism protocol, or California Climate Action Registry protocol for further guidance.

The main activities that result in GHG emissions at the Cement Plant Site can be separated into direct emissions from fuel consumption and from process CO₂ emissions, as discussed below. Indirect emissions from the consumption of electricity produced off-site (e.g. grid electricity) are not included in the quantification approach as these emissions would occur upstream of the cement plant. Since this flexibility mechanism is used for the determination of baseline emissions, it is conservative to exclude the indirect emissions from electricity generation (imported from the grid or other direct connected facilities) as the resulting baseline GHG emission intensity per unit output will be lower.

Fuel Consumption:

Fossil fuel consumption is broken down into two streams: The fossil fuels, alternative fuels or biomass fuels consumed to generate high temperatures in the cement kiln and pre-calciner (kiln fuels) and the fossil fuels consumed to operate various other equipment at the cement plant (non-kiln fuels). Non-kiln fossil fuels may be consumed to operate thermal process equipment (e.g. dryers), power generation systems, on-site and quarry vehicles, and for room heating. The SSRs in Figure 1.2 that represent the operations of the cement plant (B7, B8, B9 and B11) are aggregated in terms of non-kiln fuels and kiln fuels, however project proponents may account for fuel consumption based on individual site activities or aggregated activities as appropriate. The project proponent should justify the boundary of the cement plant to account for fossil fuel consumption for material handling and on-site transportation as individual cement plants may differ in their configuration. It is assumed for simplicity that any alternative or biomass fuels are consumed as kiln fuels.

Process CO₂ Emissions:

Process CO₂ emissions result from the calcination of carbonate materials (e.g. calcium carbonate and magnesium carbonate) and can be quantified based on a material balance into and out of the cement kiln. The SS’s B12 Calcination of Carbonate Materials and B13 Production of Cement Kiln Dust By-Product represent the potential sources of process emissions from cement plant operations. Quantification of process emissions can be done on a raw material input basis that considers the carbonate materials input into the kiln and their compositions (IPCC) or on a product output basis considering the tonnes of

clinker and cement kiln dust produced (WRI and CCAR). The approach used in this flexibility mechanism is consistent with the WRI and CCAR approaches that rely primarily on facility clinker production. Additionally, for conservativeness, GHG emissions from cement kiln dust were not included in the baseline GHG intensity.

Unit of Production:

The GHG emission quantification approach used in this protocol requires that all emissions are quantified on an intensity basis, per unit of cement produced in order to determine the GHG benefit from the replacement of cement with fly ash. The denominator of the GHG intensity term must therefore account for the total product output from the cement plant, which would include total clinker production at the plant and all mineral components added either as clinker substitutes (gypsum, fly ash, puzzolana, limestone, slag, CKD) or as direct cement substitutes (mineral additives that are mixed on-site and shipped as blended cement products). The total production should be representative of the end products shipped from the cement plant site and be inclusive of additives, including any fly ash that has been mixed at the cement plant or input into the kiln with raw materials.

Flexibility Quantification Approach

The quantification approach for the development of a baseline GHG intensity for cement production includes an aggregation of the relevant baseline SS's defined in Figure 1.2 for cement plant operation. These calculation methodologies serve to complete the following three equations for calculating the baseline GHG intensity per tonne of output from a cement plant.

$$\text{Annual GHG Emissions Intensity} = \text{Emissions}_{\text{Cement Plant Operation}} / \text{Total Production}$$

$$\text{GHG Emissions}_{\text{Cement Plant Operation}} = \text{Emissions}_{\text{Fuel Consumption for Kiln Operation}} + \text{Emissions}_{\text{Fuel Consumption for Other}} + \text{Emissions}_{\text{Industrial Process}}$$

$$\text{Total Production} = \text{Tonnes}_{\text{Clinker}} + \text{Tonnes}_{\text{Mineral Components Added as Clinker Substitutes}} + \text{Tonnes}_{\text{Mineral Components Used On-Site as Cement Substitutes}}$$

Where:

$\text{Emissions}_{\text{Cement Plant Operation}}$ = sum of the direct GHG emissions at the cement plant site.

$\text{Emissions}_{\text{Fuel Consumption for Kiln Operation}}$ = Sum of emissions from fossil fuels, alternative fuels and biomass fuels consumed to generate heat and/or power to operate the cement kiln (F1)

$\text{Emissions}_{\text{Fuel Consumption for Other}}$ = Sum of emissions from fossil fuels consumed for non-kiln activities including other on-site heat, power generation and the operation of on-site mobile equipment (F2)

$\text{Emissions}_{\text{Industrial Process}}$ = Sum of industrial process CO₂ emissions from calcination of carbonate materials (F3)

Total Production = sum of the total annual product output from the cement plant. (P)

$\text{Tonnes}_{\text{Clinker}}$ = Total facility clinker output in tonnes

$\text{Tonnes}_{\text{Mineral Components Added as Clinker Substitutes}}$ = Tonnes of mineral components consumed in clinker and cement production, including gypsum, limestone, slag, fly ash, puzzolana, cement kiln dust and other materials

$\text{Tonnes}_{\text{Mineral Components Used On-Site as Cement Substitutes}}$ = tonnes of pure mineral components added as direct cement substitutes at the cement plant site before shipment of cement products off-site

TABLE A. 1: Flexibility Mechanism

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|---|--|--|-------------------------|--|------------------------|--|
| Aggregated SS's for Cement Plant Operation | | | | | | |
| Baseline Cement Plant GHG Intensity | Cement Plant GHG Intensity = $\sum (\text{Emissions}_{F1, F2 \text{ and } F3}) / (\text{Total Production})$ | | | | | |
| | Emissions $F1, F2 \text{ and } F3$ | kg of CO ₂ ; kg of CH ₄ ; kg of N ₂ O | N/A | N/A | N/A | Quantity being calculated. The baseline cement plant intensity should be calculated as the average from 3 years worth of data. The use of 3 years of data provides consistent representation of facility fuel mix and production levels. |
| | Total Cement Plant Output Including Additives/ Total Production | Tonnes | Measured | Reconciliation of facility clinker production records and facility cement production records. Total production includes all mineral additives that are blended into cement | Monthly Reconciliation | Monthly reconciliation is reasonable since facilities keep detailed production and accounting records. |
| F1 Fuel Consumption for Kiln Operation | $\text{Emissions } F1_{\text{Fuel Consumption for Kiln Operation}} =$ $\sum (\text{Vol. Fossil Fuel} * \text{HHV}_{FF} * \text{EF Fossil Fuel}_{iCO_2}); \sum (\text{Vol. Fossil Fuel} * \text{HHV}_{FF} * \text{EF Fossil Fuel}_{iCH_4}); \sum (\text{Vol. Fossil Fuel} * \text{HHV}_{FF} * \text{EF Fossil Fuel}_{iN_2O});$ $\sum (\text{Mass Alt. Fuel} * \text{HHV}_{AF} * \text{EF Alt. Fuel}_{iCO_2}); \sum (\text{Mass Alt. Fuel} * \text{HHV}_{AF} * \text{EF Alt. Fuel}_{iCH_4}); \sum (\text{Mass Alt. Fuel} * \text{HHV}_{AF} * \text{EF Alternative Fuel}_{iN_2O})$ $\sum (\text{Mass Biomass} * \text{HHV}_{Biomass} * \text{EF Biomass}_{CH_4}); \sum (\text{Mass Biomass} * \text{HHV}_{Biomass} * \text{EF Biomass}_{N_2O})$ | | | | | |
| | Emissions $F_{\text{Fuel Consumption for Kiln Operation}}$ | kg of CO ₂ ; kg of CH ₄ ; kg of N ₂ O | N/A | N/A | N/A | Quantity being calculated. |

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|-----------------|---|---------------------------------|-------------------------|---|--|--|
| | Quantity of Fossil Fuel Consumed for Kiln Operation / Vol. Fuel _i | m ³ , tonne or other | Measured | Direct metering or reconciliation of volume in storage (including volumes received). | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |
| | Higher Heating Value of Fossil Fuel / HHV _{FF} | GJ/ m3 or GJ/tonne | Measured | Annual fuel analysis or use of reference values from Environment Canada or WRI/WBCSD GHG Protocol Initiative. | Annual | The use of higher heating values is consistent with Environment Canada's National GHG Inventory. Annual fuel analysis or the use of reference values is reasonable since most fossil fuels used will have consistent heating values. |
| | CO ₂ Emissions Factor for Each Type of Fuel / EF Fuel _{i CO2} | kg CO ₂ per GJ | Estimated | Site specific emission factors (e.g. from continuous emissions monitoring systems or fuel carbon content analyses) should be used where available, otherwise Environment Canada default values may be used. | Annual | Site specific emission factors represent best available data for the fuels consumed to operate the kiln. Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | CH ₄ Emissions Factor for Each Type of Fuel / EF Fuel _{i CH4} | kg CH ₄ per GJ | Estimated | From Environment Canada reference documents. Project proponents may also choose to ignore methane emissions due to the high temperatures in the kiln or for conservativeness. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|-----------------|--|--------------------------------|-------------------------|--|--|--|
| | N ₂ O Emissions Factor for Each Type of Fuel / EF Fuel _i N ₂ O | kg N ₂ O per GJ | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | Quantity of Alternative Fuel Consumed for Kiln Operation / Mass Alt. Fuel | Tonne / other | Measured | Direct metering or reconciliation of volume in storage (including volumes received). | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |
| | Higher Heating Value of Alternative Fuel / HHV _{AF} | GJ/tonne or GJ/ m ³ | Measured | Annual fuel testing or use of reference values from Environment Canada. | Annual | The use of higher heating values is consistent with Environment Canada's National GHG Inventory. Annual fuel analysis or the use of reference values is reasonable since most fossil fuels used will have consistent heating values. |
| | CO ₂ Emissions Factor for Each Type of Alternative Fuel / EF Alt. Fuel _i CO ₂ | kg CO ₂ per GJ | Estimated | Site specific emission factors (e.g. from continuous emissions monitoring systems or fuel carbon content analyses) should be used where available, otherwise default values from the WRI/ WBCSD GHG Protocol Initiative may be used. | Annual | Site specific emission factors represent best available data for the fuels consumed to operate the kiln. Reference values adjusted periodically as part of the GHG Protocol Initiative. |

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|-----------------|---|----------------------------|-------------------------|--|--|---|
| | CH ₄ Emissions Factor for Each Type of Alternative Fuel / EF Alt. Fuel _i CH ₄ | kg CH ₄ per GJ | Estimated | Site specific emission factors (e.g. from continuous emissions monitoring systems) should if available, otherwise default values from the WRI/ WBCSD GHG Protocol Initiative may be used. Project proponents may also choose to ignore methane emissions due to the high temperatures in the kiln or for conservativeness. | Annual | Site specific emission factors represent best available data for the fuels consumed to operate the kiln. Reference values adjusted periodically as part of the GHG Protocol Initiative. |
| | N ₂ O Emissions Factor for Each Type of Alternative Fuel / EF Alt. Fuel _i N ₂ O | kg N ₂ O per GJ | Estimated | Site specific emission factors (e.g. from continuous emissions monitoring systems) should be used where available, otherwise default values from the WRI/ WBCSD GHG Protocol Initiative may be used. | Annual | Site specific emission factors represent best available data for the fuels consumed to operate the kiln. Reference values adjusted periodically as part of the GHG Protocol Initiative. |
| | Quantity of Biomass Consumed for Kiln Operation / Mass Alt. Fuel | Tonnes | Measured | Reconciliation of masses purchased and in storage. | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|--------------------------------------|--|--|-------------------------|--|--|---|
| | CH ₄ Emissions Factor Biomass / EF Biomass _{CH4} | kg CH ₄ per GJ | Estimated | Site specific emission factors (e.g. from continuous emissions monitoring systems) should be used where available, otherwise default values from the WRI/ WBCSD GHG Protocol Initiative may be used. | Annual | Site specific emission factors represent best available data for the fuels consumed to operate the kiln. Reference values adjusted periodically as part of the GHG Protocol Initiative. |
| | N ₂ O Emissions Factor for Biomass / EF Biomass _{N2O} | kg N ₂ O per GJ | Estimated | Site specific emission factors (e.g. from continuous emissions monitoring systems) should be used where available, otherwise default values from the WRI/ WBCSD GHG Protocol Initiative may be used. | Annual | Site specific emission factors represent best available data for the fuels consumed to operate the kiln. Reference values adjusted periodically as part of the GHG Protocol Initiative. |
| F2 Fossil Fuel Consumption for Other | Emissions F2 _{Fuel Consumption for Other} = $\sum (\text{Vol. Fossil Fuel} * \text{HHV}_{\text{FF}} * \text{EF Fossil Fuel}_{\text{iCO}_2}); \sum (\text{Vol. Fossil Fuel} * \text{HHV}_{\text{FF}} * \text{EF Fossil Fuel}_{\text{iCH}_4}); \sum (\text{Vol. Fossil Fuel} * \text{HHV}_{\text{FF}} * \text{EF Fossil Fuel}_{\text{iN}_2\text{O}});$ | | | | | |
| | Emissions _{Distribution Facility Operation} | kg of CO ₂ ; kg of CH ₄ ; kg of N ₂ O | N/A | N/A | N/A | Quantity being calculated. |
| | Volume of Fuel Consumed for Other Non-Kiln Operations at Cement Plant Site/ Vol. Fuel _i | L , m ³ , tonne, other | Measured | Direct metering or reconciliation of volume in storage (including volumes received). | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|-----------------------|--|----------------------------|-------------------------|--|------------------------|--|
| | Higher Heating Value of Fossil Fuel / HHV _{FF} | GJ/ m3, GJ/ L or GJ/tonne | Measured | Annual fuel analysis or use of reference values from Environment Canada or WRI/ WBCSD GHG Protocol Initiative. | Annual | The use of higher heating values is consistent with Environment Canada’s National GHG Inventory. Annual fuel analysis or the use of reference values is reasonable since most fossil fuels used will have consistent heating values. |
| | CO ₂ Emissions Factor for Each Type of Fuel / EF Fuel _{i CO2} | kg CO ₂ per GJ | Estimated | From Environment Canada or WRI/ WBCSD GHG Protocol Initiative reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | CH ₄ Emissions Factor for Each Type of Fuel / EF Fuel _{i CH4} | kg CH ₄ per GJ | Estimated | From Environment Canada or WRI/ WBCSD GHG Protocol Initiative reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | N ₂ O Emissions Factor for Each Type of Fuel / EF Fuel _{i N2O} | kg N ₂ O per GJ | Estimated | From Environment Canada or WRI/ WBCSD GHG Protocol Initiative reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| F3 Industrial Process | Emissions F3 _{Industrial Process} = ∑ (Mass Clinker * EF Clinker _{CO2}) | | | | | |
| | EF Clinker _{CO2} = [(%CaO _{clinker} - CaO _{imported})*(44/56) +%MgO _{clinker} *(44/40)] | | | | | |
| | Emissions _{Industrial Process} | kg of CO ₂ | N/A | N/A | N/A | Quantity being calculated. |
| | Mass of Clinker produced in Each Month / Mass Clinker | tonnes | Measured | Reconciliation of historical facility clinker output records based on facility weigh scales. | Monthly Reconciliation | Frequency of reconciliation provides for reasonable diligence given that these records will be historical. |

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|-----------------|--|---------------------------------------|-------------------------|---|--------------|--|
| | CO ₂ Emissions Factor for Industrial Process Emissions from Clinker Production / EF Clinker _{CO2} | kg of CO ₂ / tonne clinker | N/A | N/A | N/A | Quantity being calculated. |
| | Mass Percent Calcium Oxide in Clinker Produced / %CaO _{clinker} | Tonne CaO / tonne clinker | Measured | Reconciliation of clinker compositions from testing or material specifications. | Quarterly | Frequency of testing provides for reasonable diligence as clinker compositions will likely remain fairly constant for most operations. |
| | Tonnes of Non-Carbon Bound Calcium Oxide Contained in Raw Materials Fed to the Kiln per Unit of Clinker Output / CaO _{imported} | Tonne CaO / tonne clinker | Measured | Reconciliation of composition of raw material mix input into the kiln based on material testing or product/kiln operating specifications. | Quarterly | Frequency of testing provides for reasonable diligence as raw material compositions will likely be consistent for most operations. |
| | Stoichiometric Conversion Factor from mass of CaO to mass of CO ₂ / 44/56 | - | N/A | Reference value based on molecular weights of carbon dioxide and calcium oxide, which are 44 g/mol and 56 g/mol, respectively. | N/A | Molecular weights are standard values. |
| | Mass Percent Magnesium Oxide in Clinker Produced / %MgO _{clinker} | Tonne CaO / tonne clinker | Measured | Reconciliation of clinker compositions from testing or material specifications. | Quarterly | Frequency of testing provides for reasonable diligence as clinker compositions will likely remain fairly constant for most operations. |

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|-----------------|--|---------|-------------------------|--|--------------|--|
| | Stoichiometric Conversion Factor from mass of MgO to mass of CO ₂ / 44/40 | - | N/A | Reference value based on molecular weights of carbon dioxide and magnesium oxide, which are 44 g/mol and 40 g/mol, respectively. | N/A | Molecular weights are standard values. |

TABLE A. 2: Flexibility Mechanism - Contingency

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|---|--|---------------------------------|-------------------------|--|-------------------------|---|
| Aggregated SS's for Cement Plant Operation | | | | | | |
| F1 Fuel Consumption for Kiln Operation | Quantity of Fossil Fuel Consumed for Kiln Operation / Vol. Fuel _i | m ³ , tonne or other | Estimated | Reconciliation of volume of fuel purchased by the cement plant facility operator within a given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| | Quantity of Alternative Fuel Consumed for Kiln Operation / Mass Alt. Fuel | Tonne / other | Estimated | Reconciliation of mass of fuel purchased by the cement production plant operator within a given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| | Quantity of Biomass Consumed for Kiln Operation / Mass Alt. Fuel | Tonnes | Estimated | Reconciliation of masses purchased and in storage. | Monthly Reconciliation. | Frequency of reconciliation provides for reasonable diligence. |
| F2 Fossil Fuel Consumption for Other | Volume of Fuel Consumed for Other Non-Kiln Operations at Cement Plant Site/ Vol. Fuel _i | L / m ³ / other | Estimated | Reconciliation of volume of fuel purchased by the cement plant facility operator within a given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| F3 Industrial Process | Mass of Clinker produced in Each Month / Mass Clinker | tonnes | Estimated | Reconciliation of historical facility clinker sales and input records (into other processes) based on facility weigh scales. | Monthly Reconciliation | Frequency of reconciliation provides for reasonable diligence given that these records will be historical. |
| | Mass Percent Calcium Oxide in Clinker Produced/ %CaO _{clinker} | Tonne CaO / tonne clinker | Estimated | Reconciliation of clinker compositions from previous years data. | Annual | Frequency of reconciliation provides for reasonable diligence as clinker compositions will likely remain fairly constant for most operations. |

| 1.0 Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|-----------------|--|---------------------------|-------------------------|---|--------------|--|
| | Tonnes of Non-Carbon Bound Calcium Oxide Contained in Raw Materials Fed to the Kiln per Unit of Clinker Output/ CaO _{imported} | Tonne CaO / tonne clinker | Estimated | Use of industry standard composition of raw material mix in the relevant geographic region. | Annual | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| | Mass Percent Magnesium Oxide in Clinker Produced / %MgO _{clinker} | Tonne CaO / tonne clinker | Estimated | Use of industry standard composition of raw material mix in the relevant geographic region | Annual | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |

APPENDIX B

Relevant Emission Factors

All values interpreted from volume 1 of the technical report: A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H₂S) Emissions by the Upstream Oil and Gas Industry dated September 2004 completed by Clearstone Engineering Ltd. on behalf of the Canadian Association of Petroleum Producers (CAPP).

Table A1: Emission Intensity of Fuel Extraction and Production (Diesel, Natural Gas, and Gasoline)

| Diesel | | |
|-------------------------------------|----------|--|
| Production | | |
| Emissions Factor (CO ₂) | 0.138 | kg CO ₂ per Litre |
| Emissions Factor (CH ₄) | 0.0109 | kg CH ₄ per Litre |
| Emissions Factor (N ₂ O) | 0.000004 | kg N ₂ O per Litre |
| Natural Gas | | |
| Extraction | | |
| Emissions Factor (CO ₂) | 0.043 | kg CO ₂ per m ³ |
| Emissions Factor (CH ₄) | 0.0023 | kg CH ₄ per m ³ |
| Emissions Factor (N ₂ O) | 0.000004 | kg N ₂ O per m ³ |
| Processing | | |
| Emissions Factor (CO ₂) | 0.090 | kg CO ₂ per m ³ |
| Emissions Factor (CH ₄) | 0.0003 | kg CH ₄ per m ³ |
| Emissions Factor (N ₂ O) | 0.000003 | kg N ₂ O per m ³ |
| Gasoline | | |
| Production | | |
| Emissions Factor (CO ₂) | 0.138 | kg CO ₂ per Litre |
| Emissions Factor (CH ₄) | 0.0109 | kg CH ₄ per Litre |
| Emissions Factor (N ₂ O) | 0.000004 | kg N ₂ O per Litre |

Table A2: Emission Intensity of Combustion (Diesel, Natural Gas and Gasoline)

| Diesel | | |
|--|----------|--|
| Emissions Factor (CO ₂) | 2.730 | kg CO ₂ per Litre |
| Emissions Factor (CH ₄) | 0.000133 | kg CH ₄ per Litre |
| Emissions Factor (N ₂ O) | 0.0004 | kg N ₂ O per Litre |
| Natural Gas | | |
| Electric Utilities | | |
| Emissions Factor (CO ₂) | 1.891 | kg CO ₂ per m ³ |
| Emissions Factor (CH ₄) | 0.00049 | kg CH ₄ per m ³ |
| Emissions Factor (N ₂ O) | 0.000049 | kg N ₂ O per m ³ |
| Gasoline | | |
| Heavy-Duty Gasoline Vehicles (3-way catalyst) | | |
| Emissions Factor (CO ₂) | 2.360 | kg CO ₂ per Litre |
| Emissions Factor (CH ₄) | 0.000068 | kg CH ₄ per Litre |
| Emissions Factor (N ₂ O) | 0.0002 | kg N ₂ O per Litre |