Specified Gas Emitters Regulation

Quantification Protocol for the Substitution of Bitumen Binder in Hot Mix Asphalt Production and Usage

October 2009

Version 1.0

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All Quantification Protocols approved under the *Specified Gas Emitters Regulation* are subject to periodic review as deemed necessary by the Department, and will be re-examined at a minimum of every 5 years from the original publication date to ensure methodologies and science continue to reflect best-available knowledge and best practices. This 5-year review will not impact the credit duration stream of projects that have been initiated under previous versions of the protocol. Any updates to protocols occurring as a result of the 5-year and/or other reviews will apply at the end of the first credit duration period for applicable project extensions.

Any comments, questions, or suggestions regarding the content of this document may be directed to:

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1.0 Project and Methodology Scope and Description

This quantification protocol is written for those familiar with the production and usage of hot mix asphalt. Some familiarity with, or general understanding of the operation of these projects is expected.

It should be noted that this protocol in no way indicates that the use of a sulphur extender is an accepted alternative to the use of conventional bitumen binder for paving projects in Alberta. As such, approval from the relevant government authority is required prior to the use of such products.

The opportunity for generating carbon offsets with this protocol arises primarily from the substitution of a proportion of the bitumen binder used in conventional hot mix asphalt for a sulphur extender product resulting in the avoided production of a proportion of the bitumen binder used in conventional hot mix asphalt and reduced consumption of fossil fuels due to lower mix production temperatures. There is also the opportunity for greenhouse gas (GHG) emission reductions from avoided fugitive emissions of methane associated with the handling and storage of bitumen, which would have been emitted from hot mix facilities where the baseline practice was the use of conventional hot mix asphalt.

1.1 Protocol Scope and Description

This protocol is applicable to projects that involve the substitution of a proportion of the bitumen binder used in conventional hot mix asphalt for a sulphur product that reduces required quantities of aggregate and bitumen, fuel usage due to reduced mix production temperatures and reduces emissions from the hot mix plant stack and paving application. The baseline configuration would be the use of conventional hot mix asphalt, whose composition of aggregate versus bitumen binder will vary depending on the type of road paved (i.e. low, medium or high volume road) produced at a temperature ranging from 130 to a maximum of 155 degrees Celsius. The project activity could be implemented at existing hot mix facilities or implemented at new facilities as a best practice technology.

This protocol is intended to be applied to hot mix facilities in the hot mix asphalt industry. The sulphur product being substituted for bitumen must be either a sulphur extender in the form of pellets or a similar solid sulphur product composed of carbon black, sulphur, and small quantities of plasticizer and H_2S scavenger additives. The product may also contain wax additives, used to further reduce hot mix asphalt production and compaction temperatures. Note however that reduced hot mix asphalt production and compaction temperatures are anticipated for hot mix facilities using a sulphur extender without wax additives, and this protocol applies to hot mix facilities using either formulation of sulphur extender.

It should be noted that while this protocol is targeted at projects that involve the use of a solid sulphur product composed of carbon black, sulphur, and potentially wax additives, some procedures in this protocol may be transferable to other types of binder products substituted for conventional bitumen binder. However, there could be considerable differences between these types of products given the potential differences in sourcing of components, composition and GHG emissions, which could lead to inaccuracy in the quantification of the GHG emission reductions.

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

Protocol Approach

To demonstrate that a project is covered by the scope of the protocol, the project developer must demonstrate that they are substituting a proportion of the bitumen binder used in conventional hot mix asphalt for a solid sulphur product, herein referred to as a sulphur extender. This protocol is also applicable to project developers using a sulphur extender product with a wax additive to further lower mix and compaction temperatures.

The project developer must demonstrate that the baseline condition, illustrated in **FIGURE 1.2**, was either the previous practise or most likely practise based on conventional industry practices. Further, they must show that the quantity of bitumen binder used per unit of hot mix asphalt produced under the project activity has been reduced by the use of a sulphur extender. This is accomplished by tracking the mass of hot mix asphalt produced, and the mass of aggregate, bitumen and sulphur extender consumed. The quantification of offsets from the utilization of a sulphur extender is accomplished by using current fuel usage data and the quantities of each component consumed to produce the hot mix asphalt. Project proponents would be responsible for metering of relevant inputs and outputs to the hot mix facility.

Protocol Applicability

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

1. Industry best practices for appropriate handling, mix production temperatures and disposal of any mix produced at temperatures exceeding 155°C are followed. This will require strict adherence to the procedures contained in the sulphur extender product's manufacturer documentation for handling and storage of solid sulphur, handling and use of the sulphur extender product, construction specifications, mix design, etc.;
2. Hot mix asphalt production temperatures are monitored at the plant outlet to ensure production within the appropriate temperature range;
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.

FIGURE 1.1: Process Flow Diagram for Project Condition

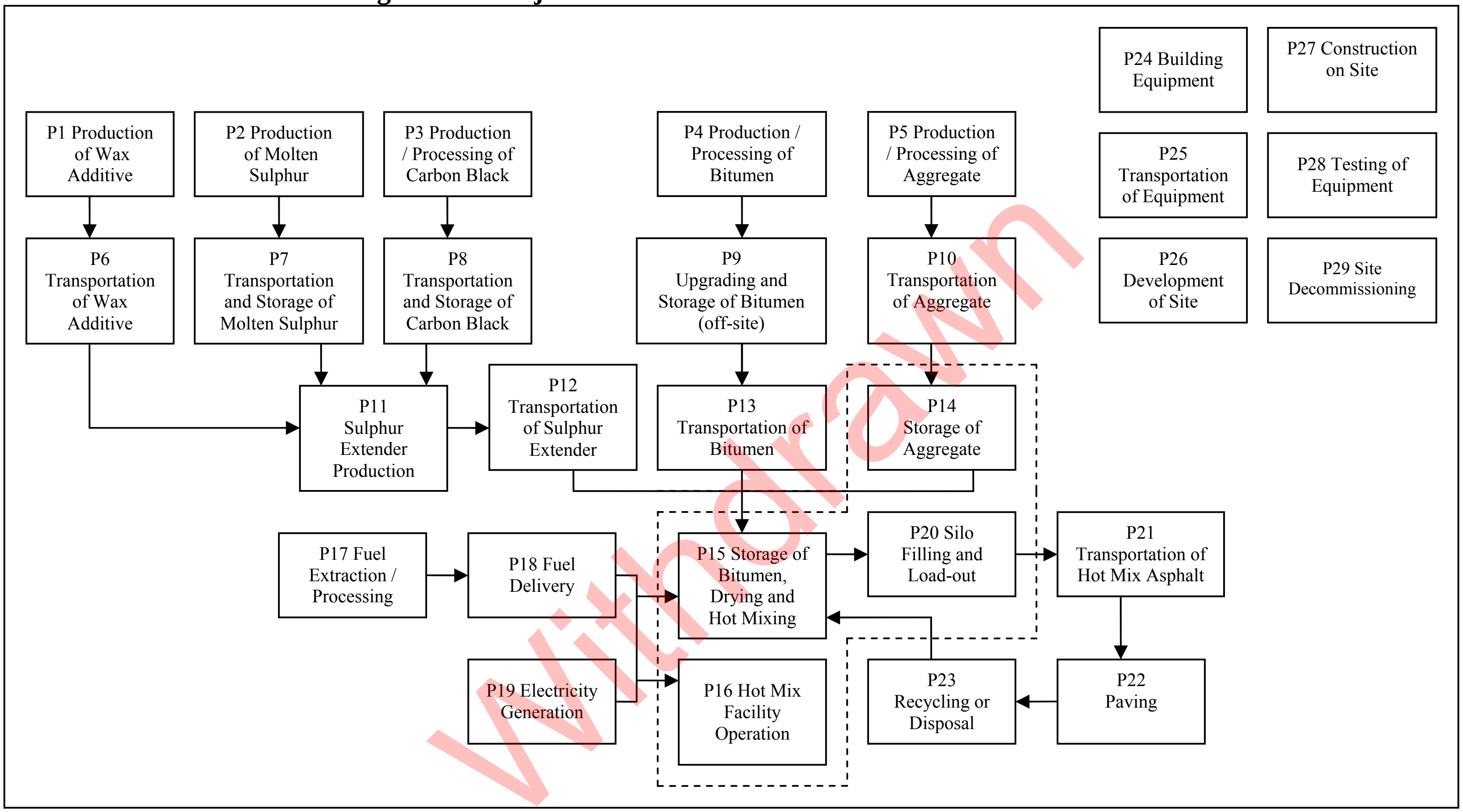
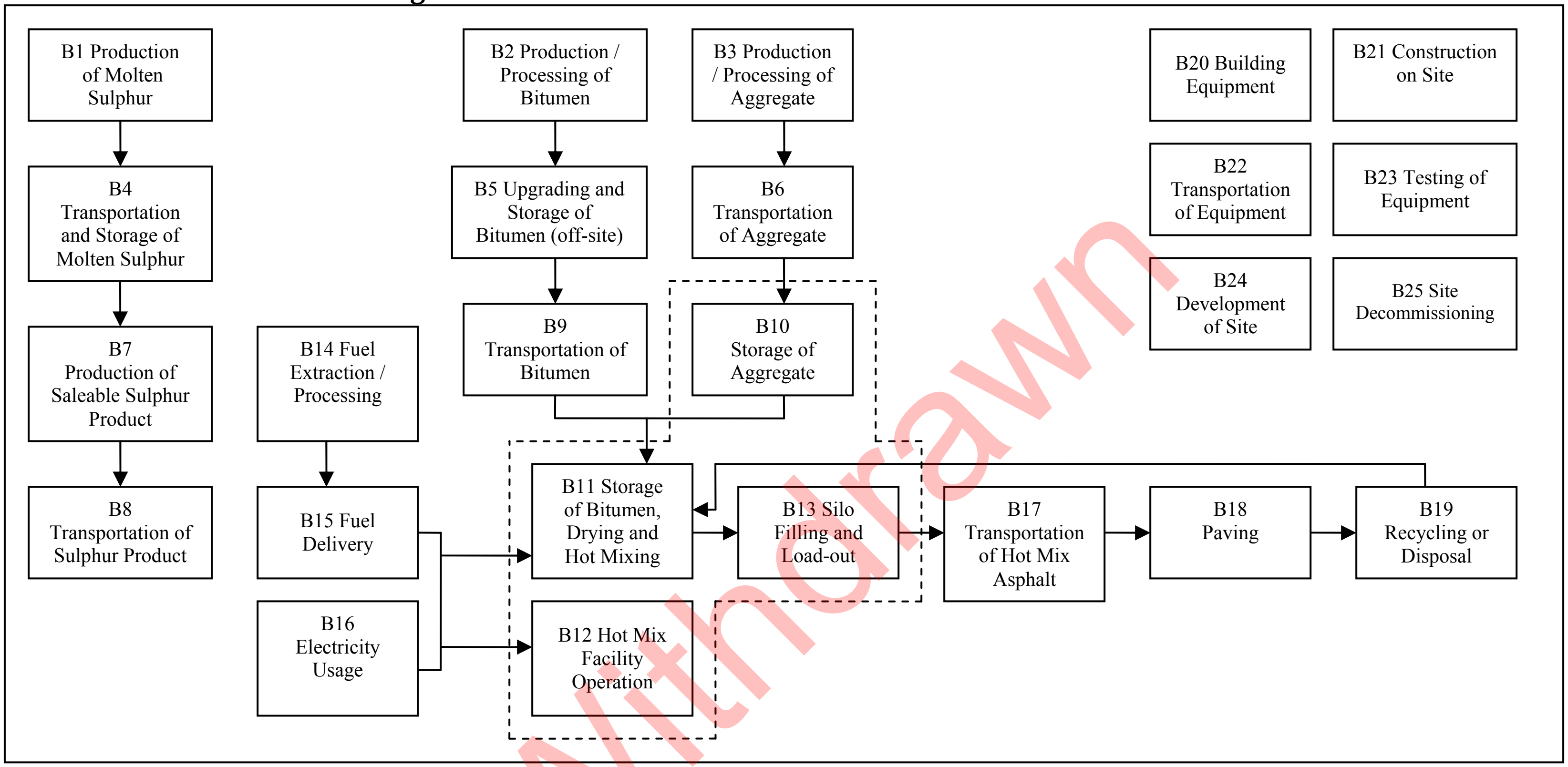


FIGURE 1.2: Process Flow Diagram for Baseline Condition



Protocol Flexibility

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

1. If the project developer has records of historical mix formulation data (i.e. weight percent of bitumen binder and aggregate used per tonne of hot mix asphalt) prior to sulphur extender use, this value may be substituted for the default values of bitumen and aggregate content included in APPENDIX B. Note that values must be applicable to the type of road being paved in the Project condition.
    a. Note that three years of consecutive historical data is not required given that mix formulation will vary depending on application and mixing facilities are commonly mobile in Alberta and produce multiple mixes in any given time period. However, historical data from representative projects conducted over a three year period with mix formulations applicable to the type of road being paved by the project should be used;
2. If hot mix stack emission testing has been conducted at the facility that allows for the characterization of methane emissions from conventional and sulphur extender hot mix asphalt, this data may be used to quantity the $\text{Emissions}_{\text{Hot Mix Stack}}$ under SS's P15 and B11. The methodology for calculating site-specific emission factors is included in APPENDIX C;
    a. This quantification method is included as a flexibility mechanism as hot mix facilities in Alberta are not required to conduct annual sampling or report emissions of CO_2 or total organics. However for the use of site-specific emission factors, a minimum of three hot mix stack tests conducted on different days and in different conditions is required; and
    b. Further, note that stack sampling of emissions from the hot mix stack should include only mixing process emissions. As such, this parameter would not be calculated for CH_4 at facilities where stack emission monitoring is conducted at a point that includes both process emissions from mixing and ducted emissions from fuel combustion. In this case these emissions would already have been accounted for under the fuel usage variable also included in the SS's P15 and B11;
3. The sources and sinks (SS's) B18 and P22 may be added back into the protocol if further sampling and characterization of emissions is conducted and / or appropriate data, calculation methodologies, etc. become available;
4. If the project developer is substituting the bitumen binder used in conventional hot mix asphalt with a comparable product to a sulphur based extender, this protocol may be applied. The emissions associated with the production and usage of the product and each component must be considered. This will likely require the generation of applicable emission factors. The methodology for calculation of baseline and project emissions and generation of emission factors must ensure accuracy and be robust enough to provide uncertainty ranges in the factors. Further, justification must be provided by the project proponent to demonstrate that the quantification approach is conservative and appropriate; and

5. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must ensure accuracy and be robust enough to provide uncertainty ranges in the factors.

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 food processed, units of output per month) for comparison between the Project and Baseline activity.
Bitumen Handling Emissions:	Intentional and unintentional releases of GHGs during bitumen handling and storage from joints, seals, etc. in processing, piping and treatment equipment.
Aggregate:	Aggregate is composed of coarse particulate material including sand, gravel, crushed stone, slag, and recycled concrete. It may be sourced from gravel pits, quarries and other local areas surrounding the hot mix facility.
Binder:	Hot mix asphalt binder serves as a waterproof adhesive that binds the aggregate together and includes the sum of the quantities of bitumen and sulphur extender consumed.
Bitumen:	Bitumen is a petroleum based liquid asphalt product, produced from the heavy crude oil refining process. Crude oil at the refinery is first subjected to atmospheric distillation and the short residue is processed in a vacuum tower (i.e. vacuum distillation). Paving grade bitumen is the residue left after distilling off all of the lighter fuels. After refining, bitumen is stored at the refinery at temperatures of approximately 170°C until transportation and delivery to the hot mix facility.
Hot Mix Asphalt	Refers to the mixture of binder and aggregate delivered from the hot mix facility to the silo / truck for load-out and delivery to the paving site. The

aggregate to binder mix ratio will depend on desired performance properties for paving and may vary at each hot mix facility and for each project.

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

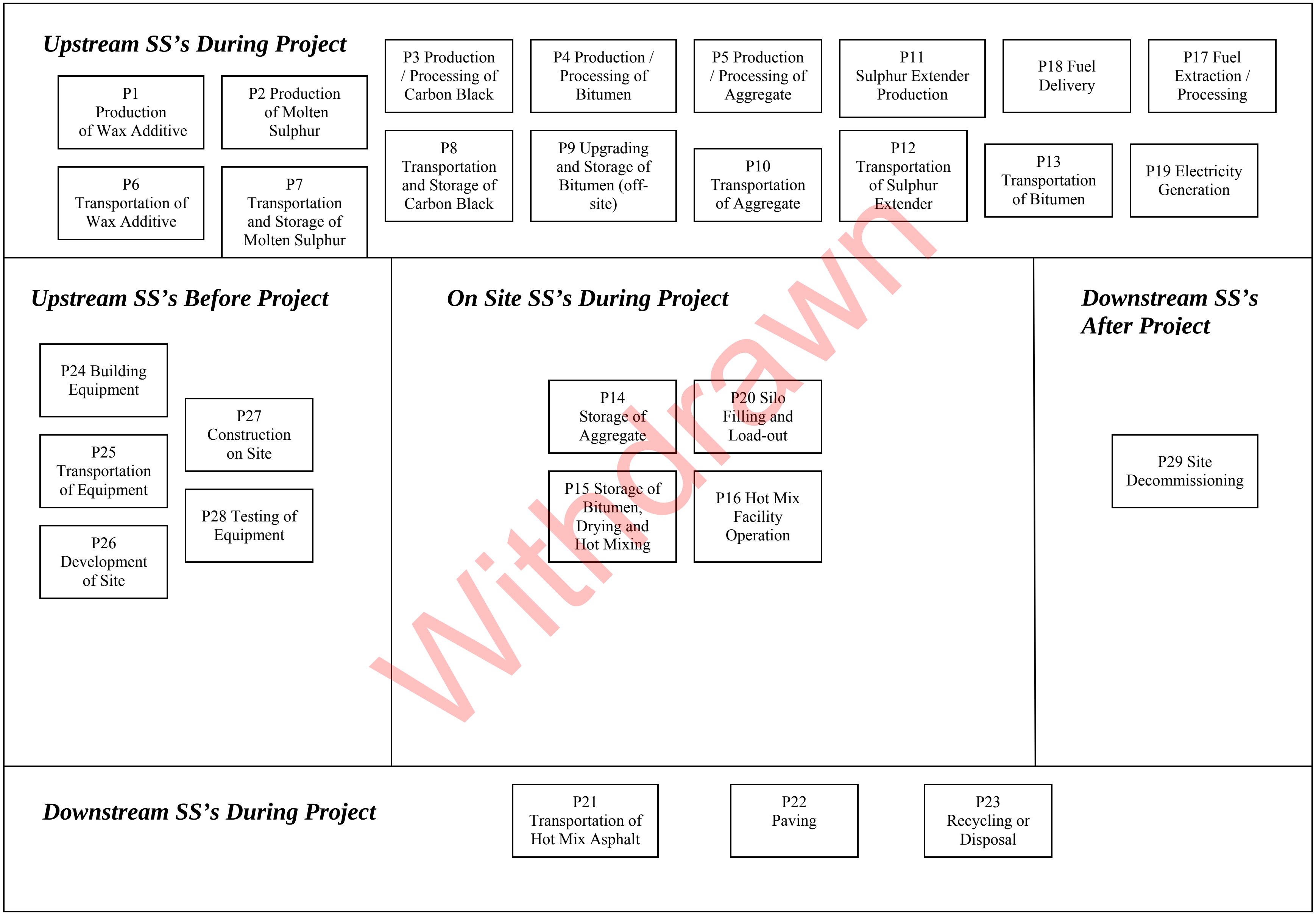


TABLE 2.1: Project SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
P1 Production of Wax Additive	A paraffin wax additive, produced by the Fischer Tropsch (FT) coal or natural gas based production process may be included as an additive in the sulphur extender product to lower compaction and mix temperatures. Production involves the production of a synthetic petroleum substitute via a catalyzed chemical reaction. The feedstock is synthesis gas produced from the gasification of coal, natural gas or biomass. Synthesis gas is converted to wax, which is further treated to produce mid-weight distillate products and lubricants. Each of the fuels used and emissions throughout the production process 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 this product. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
P2 Production of Molten Sulphur	Molten sulphur is produced as a by-product of fossil fuel production and processing. In particular, it is an output from sulphur recovery units installed by facilities to meet the increasingly stringent SO_2 emission regulations being implemented in many jurisdictions. Each of the energy inputs and fugitive emissions throughout the production process 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 molten sulphur. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
P3 Production / Processing of Carbon Black	Carbon black may be produced by either a furnace black or a thermal production process. Emissions from carbon black production are attributed to production of the primary feedstock (a heavy oil by-product of the refining or coke production process), and those attributed to the secondary feedstock (the fossil fuels used in the process). Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
P4 Production / Processing of Bitumen	Emissions associated with bitumen production are associated with flaring, fugitive equipment leaks, loading / unloading and reported / unreported venting from production, cleaning and transportation of heavy crude oil for upgrading or refining. Bitumen is produced from vacuum distillation following the fractional distillation process, and may be stored on site at high temperatures prior to transportation to the hot mix facility. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
P5 Production / Processing of Aggregate	Aggregate may be sourced from gravel pits, quarries and other local areas surrounding the hot mix facility. While the volumes of binder and aggregate used in the project and baseline are the same, on a weight basis	Related

	more aggregate is used in the baseline, because sulphur has a higher specific gravity than bitumen. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	
P6 Transportation of Wax Additive	The wax additive used at the project facility may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P7 Transportation and Storage of Molten Sulphur	The molten sulphur used to produce the sulphur extender may be transported to the project site in insulated trucks and/or by train from the gas processing facility from which it is sourced. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P8 Transportation and Storage of Carbon Black	The carbon black used at the project facility may be transported to the project site by truck and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P9 Upgrading and Storage of Bitumen (Off-site)	There may be fuel usage and fugitive / venting emissions associated with storage of liquid asphalt at high temperatures following the vacuum distillation upgrading process prior to transportation. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
P10 Transportation of Aggregate	The aggregate used at the project facility may be transported to the project site by truck and/or train from the local area from which it is sourced. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P11 Sulphur Extender Production	The sulphur extender is produced by pumping molten sulphur into an insulated mixing tank to be mixed with carbon black at approximately 130°C to 135°C. The product is then pumped to either a pastillation unit or to a wet process pelletizing unit where the pastilles and pellets are cooled by water. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
P12 Transportation of Sulphur Extender	The sulphur extender product used at the project facility may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P13 Transportation of Bitumen	The bitumen used at the project facility may be transported to the project site by truck, barge and/or train from the refinery where it is produced. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P17 Fuel Extraction / Processing	Each of the fuels used throughout the on-site component of 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	Related

	production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	
P18 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. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there are no other delivery emissions as the fuel is already going to the commercial fuelling station. Distance and means of fuel delivery as well as the volumes of fuel delivered are the important characteristics to be tracked.	Related
P19 Electricity Generation	Electricity may be required for operating the hot mix facility (dryers, mixers, facility operation, etc.) and associated equipment. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid if the project activity includes the installation of an electricity generator. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Related
Onsite SS's during Project Operation		
P14 Storage of Aggregate	Aggregate may be stored on-site in open piles or bins prior to drying and hot mixing. There may be fugitive emissions associated with its storage. Quantities of aggregate stored are the important characteristics to be tracked.	Controlled
P15 Storage of Bitumen, Drying and Hot Mixing	Fossil fuels are required to fuel the burners used to dry and heat the aggregate, bitumen and sulphur extender to required temperatures for mixing and paving. There may also be emissions associated with the bitumen storage, aggregate drying and hot mixing processes. Sampling of stack emissions and total volumes fossil fuels consumed are the important characteristics to be tracked.	Controlled
P16 Hot Mix Facility Operation	This SS relates to the greenhouse gas emissions associated with fossil fuel consumption for the operation and maintenance of the hot mix facility, excluding any operation associated with aggregate drying, hot mixing or bitumen storage. Facility operation may require any number of energy inputs and mechanical processes excluding those related to processing inputs and generating the hot mix asphalt for downstream use. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Controlled
P20 Silo Filling and Load out	There may be fugitive emissions associated with bitumen handling including silo filling and load-out due to bitumen temperatures and loss on heating. The emissions would primarily be associated with the quantity of bitumen consumed. Quantities of bitumen binder consumed will be the important characteristics to be tracked.	Controlled
Downstream SS's during Project Operation		
P21 Transportation of Hot Mix Asphalt	The hot mix asphalt produced at the project facility may be transported to the project site by truck and/or train to the paving site. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P22 Paving	Hot mix asphalt will be applied using a paver and compacted using rollers. There may be fugitive emissions	Controlled

	during the application and curing of the hot mix asphalt. Emissions may be dependant on the temperature and rate of diluent evaporation. Temperature, composition and quantities of hot mix asphalt applied are the important characteristics to be tracked.	
P23 Recycling and Disposal	Paving max be recycled 10 to 20 years after application. This will involve milling and grinding the paving and returning it to the hot mix facility. Recycled asphalt pavement (RAP) will then be mixed with new hot mix asphalt at a given proportion and re-used. There may be fuel inputs and fugitive emissions associated with the recycling process. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
Other		
P24 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. 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
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 Development of Site	Site development could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. 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
P27 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
P28 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of	Related

	electricity.	
P29 Site Decommissioning	Once the 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

2.2.1 Identification of Possible Baseline Scenarios

The development of quantification approaches for the emissions associated with conventional hot mix asphalt production and usage required the examination of a variety of baseline scenarios as described in **TABLE 2.2**. The main criteria used to evaluate each scenario included data availability, environmental integrity, accuracy, ease of application (e.g. through monitoring requirements), and the impact of existing or anticipated regulatory requirements. These approaches include site-specific scenarios and more generalized scenarios that included regional or industry average factors.

TABLE 2.2: Assessment of Possible Baseline Scenarios

1. Baseline Options	2. Description	3. Static / Dynamic Baseline	4. Accept or Reject and Justify
Projection Based	Projection of the baseline scenario based on modeling the future emissions from road resurfacing projects	Dynamic.	Reject. This method would require modeling emissions as a function of historical and forecasted future paving mix production, stack emissions and fuel consumption. This approach relies on the use of an appropriate model and measured facility data. Given the potential for emissions and fuel usage to change significantly depending on weather conditions, mix formulation, aggregate source and other conditions Modelling would not provide a reasonable representation of baseline emissions. This approach is not applicable.
Historic Benchmark	Assessment of the baseline scenario based on data from the operation of the site prior to project implementation.	Static.	Reject. A historic benchmark approach would use historical fuel usage and emissions data to quantify the baseline. Data would be adjusted for the quantity of paving mix produced in the project. This approach is not recommended as fuel consumption and emissions have the potential to change significantly for each project depending on the mix formulation, source of aggregate, etc. As such, under most circumstances historic data would not be an accurate representation of emissions from a project. However, in some instances, the project developer may have representative baseline data for a given mix formulation and road type. As such, this baseline

			alternative is included as a flexibility mechanism, provided justification can be provided to ensure that the historic data is applicable.
Performance Standard	Assessment of the baseline scenario based on the emissions profile of a typical hot mix facility in terms of fuel consumption and the typical emissions profile for fugitive emissions.	Dynamic.	Accept. The performance standard approach would assess the emissions from the emission profile of a typical hot mix facility. While emissions will vary depending on efficiency, age and other characteristics at the site, this approach represents the most accurate values available. Data is available to allow for the modeling of emissions using emissions factors for the production and storage of each component. Further equations exist to allow for the calculation of the energy required to heat each component.
Comparison	Assessment of baseline scenario based on the emissions from a control group to compare with the project.	Dynamic.	Reject. This method is analytically and data intensive, and there is significant variation between different sites and potential data confidentiality concerns. This approach is not applicable.
Other	Other quantification that may be applicable to the site-specific circumstances that can be justified with reasonable assurance.	Unknown.	Not Applicable. Project specific.

2.2.1 Selection of Baseline Scenarios

The baseline condition for this protocol is the production and usage of conventional hot mix asphalt. The composition of conventional hot mix asphalt (i.e. relative quantities of aggregate versus bitumen binder) will vary depending on the type of road paved (i.e. major highway, lower volume highway, city collector or lower volume road) and will be produced at a temperature ranging from 130 to a maximum of 155 degrees Celsius. Given that mix formulation and mix temperatures may vary from project to project, the baseline should be defined for each project, each type of hot mix asphalt and / or each type of road paved.

The baseline approach is considered as a performance based approach. The baseline condition is dynamic as it will vary depending on the quantity of hot mix asphalt produced. This dynamic approach accounts for the market forces, weather and energy demand and operational parameters without adding multiple streams of material management.

Under this scenario, the emissions from production and handling of bitumen, aggregate and hot mix asphalt are calculated from direct measurement of the quantities of each component consumed and using emission factors published by Environment Canada, the Canadian Association of Petroleum Producers (CAPP), the Canadian Council of Ministers

(CCME) of Environment, the US Environmental Protection Agency (EPA), the Intergovernmental Panel on Climate Change (IPCC) and other sources.

Under this approach, default values for the composition of each type of road are used to determine the quantities of aggregate and binder consumed. These values were provided by Alberta Transportation for low, medium and high volume roads and are included in APPENDIX B. If available, site-specific data for the relative proportions of aggregate and bitumen binder used at the facility prior to use of a sulphur extender may be substituted for the above default values. A default temperature of 144 degrees Celsius may also be used if site-specific data is not available.

Emissions from hot mixing include the emissions associated with fuel combustion and fugitive emissions of methane from bitumen handling. Emissions from fuel consumption are calculated using a heat equation, with aggregate moisture content also being considered. Hot mix stack emissions from bitumen use are accounted for by direct measurement of the quantity of bitumen consumed. Alternatively, emissions from bitumen handling during hot mixing may be determined from stack sampling conducted for conventional hot mix asphalt and following implementation of the project.

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 2.3**

FIGURE 2.2: Baseline Element Life Cycle Chart

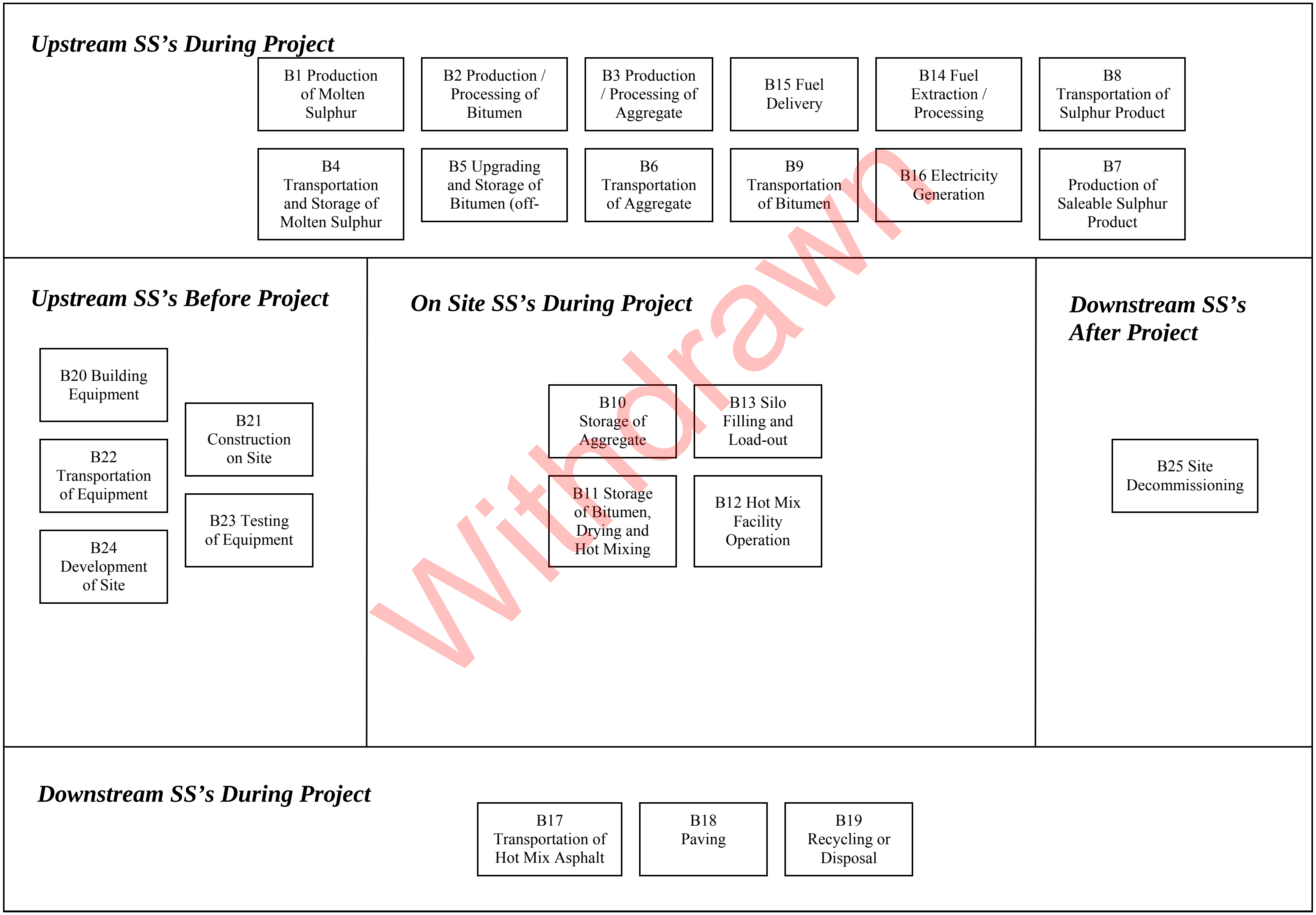


TABLE 2.3: Baseline SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
B1 Production of Molten Sulphur	Molten sulphur is produced as a by-product of fossil fuel production and processing. In particular, it is an output from sulphur recovery units installed by facilities to meet the increasingly stringent SO_2 emission regulations being implemented in many jurisdictions. Each of the energy inputs and fugitive emissions throughout the production process 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 molten sulphur. The total volumes of fuel and emissions for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
B2 Production / Processing of Bitumen	Emissions associated with bitumen production are associated with flaring, fugitive equipment leaks, loading / unloading and reported / unreported venting from production, cleaning and transportation of heavy crude oil for upgrading or refining. Bitumen is produced from vacuum distillation following the fractional distillation process, and may be stored on site at high temperatures prior to transportation to the hot mix facility. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
B3 Production / Processing of Aggregate	Aggregate may be sourced from gravel pits, quarries and other local areas surrounding the hot mix facility. While the volumes of binder and aggregate used in the project and baseline are the same, on a weight basis more aggregate is used in the baseline, because sulphur has a higher specific gravity than bitumen. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
B4 Transportation and Storage of Molten Sulphur	The molten sulphur used to produce a saleable sulphur product may be transported to the project site in insulated trucks and/or by train from the gas processing facility from which it is sourced. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B5 Upgrading and Storage of Bitumen (Off-site)	There may be fuel usage and fugitive / venting emissions associated with storage of liquid asphalt at high temperatures following the vacuum distillation upgrading process prior to transportation. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
B6 Transportation of Aggregate	The aggregate used at the project facility may be transported to the project site by truck and/or train from the local area from which it is sourced. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related

B7 Production of Saleable Sulphur Product	Molten sulphur may be sold in liquid form, or solidified by blocking or forming. Sulphur maintained in liquid form will likely be sold to domestic markets due to the risks associated with storage and transportation. In this case, there will be significant energy use associated with maintain sulphur at sufficiently high temperatures and fugitive emissions associated with its handling. Blocking of sulphur will involve the use of aluminum to strengthen the perimeter of the block, with liquid sulphur being poured inside to solidify. There may be emissions associated with its storage. The third likely alternative is forming. In this process molten sulphur is transported to a facility where it is either sprayed from a tower and solidifies as it falls or is poured onto a conveyor and immersed in water to harden it. In both processes small solid pastilles are formed. Solidified sulphur will be transported and sold to a variety of international markets. There may be fuel usage and fugitive emissions associated with this process. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
B8 Transportation of Sulphur Product	The saleable sulphur product produced may be transported to the project site by truck, barge and/or train depending on the market to which it is sold. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B9 Transportation of Bitumen	The bitumen used at the project facility may be transported to the project site by truck, barge and/or train from the refinery where it is produced. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B14 Fuel Extraction / Processing	Each of the fuels used 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 considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
B15 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. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there are no other delivery emissions as the fuel is already going to the commercial fuelling station. Distance and means of fuel delivery as well as the volumes of fuel delivered are the important characteristics to be tracked.	Related
B16 Electricity Generation	Electricity may be required for operating the hot mix facility (dryers, mixers, facility operation, etc.) and associated equipment. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid if the project activity includes the installation of an electricity generator. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Related

Onsite SS's during Project Operation		
B10 Storage of Aggregate	Aggregate may be stored on-site in open piles or bins prior to drying and hot mixing. There may be fugitive emissions associated with its storage. Quantities of aggregate stored are the important characteristics to be tracked.	Controlled
B11 Storage of Bitumen, Drying and Hot Mixing	Fossil fuels are required to fuel the burners used to dry and heat the aggregate, bitumen and sulphur extender to required temperatures for mixing and paving. There may also be emissions associated with the bitumen storage, aggregate drying and hot mixing processes. Sampling of stack emissions and total volumes fossil fuels consumed are the important characteristics to be tracked.	Controlled
B12 Hot Mix Facility Operation	This SS relates to the greenhouse gas emissions associated with fossil fuel consumption for the operation and maintenance of the hot mix facility, excluding any operation associated with aggregate drying, hot mixing or bitumen storage. Facility operation may require any number of energy inputs and mechanical processes excluding those related to processing inputs and generating the hot mix asphalt for downstream use. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Controlled
B13 Silo Filling and Load out	There may be fugitive emissions associated with bitumen handling including silo filling and load-out due to bitumen temperatures and loss on heating. The emissions would primarily be associated with the quantity of bitumen consumed. Quantities of bitumen binder consumed will be the important characteristics to be tracked.	Controlled
Downstream SS's during Project Operation		
B17 Transportation of Hot Mix Asphalt	The hot mix asphalt produced at the project facility may be transported to the project site by truck and/or train to the paving site. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B18 Paving	Hot mix asphalt will be applied using a paver and compacted using rollers. There may be fugitive emissions during the application and curing of the hot mix asphalt. Emissions may be dependant on the temperature and rate of diluent evaporation. Temperature, composition and quantities of hot mix asphalt applied are the important characteristics to be tracked.	Controlled
B19 Recycling and Disposal	Paving max be recycled 10 to 20 years after application. This will involve milling and grinding the paving and returning it to the hot mix facility. Recycled asphalt pavement (RAP) will then be mixed with new hot mix asphalt at a given proportion and re-used. There may be fuel inputs and fugitive emissions associated with the recycling process. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related

Other		
B20 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. 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
B21 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
B22 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
B23 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
B24 Development of Site	Site development could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. 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
B25 Site Decommissioning	Once the 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 VI of the "Guide to Quantification Methodologies and Protocols: Draft", dated March 2006 (Environment Canada). The justification for the exclusion or conditions upon which SS's may be excluded is provided in **TABLE 2.4** below. All other SS's listed previously are included.

TABLE 2.4: 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 Production of Wax Additive	N/A	Related	Exclude	Excluded due to the negligible quantity of wax added to the sulphur extender product and the immaterial quantity of GHG emissions associated with the production of this quantity of wax.
P2 Production of Molten Sulphur	N/A	Related	Exclude	Note that the emissions associated with these SS's are based on the quantity of sulphur used in the project condition to produce the sulphur extender product. As such, the quantity of sulphur produced in the project and baseline condition would be equivalent. These SS's are excluded as sulphur is a by-product of gas processing and would be produced by the same process in the project and baseline conditions (and in the same quantity). There will be no change in sulphur production due to the project and the baseline and project scenarios are therefore functionally equivalent.
B1 Production of Molten Sulphur	Related	N/A		
P3 Production / Processing of Carbon Black	N/A	Related	Include	Included as the emissions from this SS may be material and can be quantified.
P4 Production / Processing of Bitumen	N/A	Related	Include	Included as the emissions from this SS may be material and can be quantified.
B3 Production / Processing of Bitumen	Related	N/A		
P5 Production / Processing of Aggregate	N/A	Related	Include	Included as the emissions from this SS may be material and can be quantified.
B3 Production / Processing of Aggregate	Related	N/A		
P6 Transportation of Wax Additive	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible given the small quantities of wax additive consumed.
P7 Transportation and Storage of Molten Sulphur	N/A	Related	Exclude	Note that the emissions associated with these SS's are based on the quantity of sulphur used in the project condition. As such, an equivalent quantity of sulphur would be transported in the project and baseline condition. These SS's are excluded, as in the majority of project configurations there will be no change in the distance to sulphur processing facilities and therefore no change in fossil fuel consumption for sulphur transportation, making the baseline and project scenarios functionally equivalent.
B4 Transportation and Storage of Molten Sulphur	Related	N/A		
P8 Transportation and Storage of Carbon Black	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible given the small quantities of carbon black consumed.

P9 Upgrading and Storage of Bitumen (Off-site)	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition given decreased bitumen requirements and therefore it is conservative to exclude them.
B5 Upgrading and Storage of Bitumen (Off-site)	Related	N/A		
P10 Transportation of Aggregate	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition given decreased aggregate requirements and therefore it is conservative to exclude them.
B6 Transportation of Aggregate	Related	N/A		
P11 Sulphur Extender Production	N/A	Related	Exclude	Note that the emissions associated with these SS's are based on the quantity of sulphur used to produce a sulphur extender product in the project condition. An equivalent quantity would therefore have been processed in the project and baseline condition. Emissions are likely lower in the project condition or equivalent in the project and baseline conditions given the process employed to produce the sulphur extender versus other saleable sulphur products. As such it is conservative to exclude them.
B7 Production of Saleable Sulphur Product	Related	N/A	Exclude	
P12 Transportation of Sulphur Extender	N/A	Related	Exclude	Note that the emissions associated with these SS's are based on the quantity of sulphur product used in the project condition. Excluded as the emissions from transportation are negligible and likely greater under the baseline condition (comparing SS P12 with SS B8) given that transportation distances would be further.
B8 Transportation of Sulphur Product	Related	N/A	Exclude	
P13 Transportation of Bitumen	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition given decreased bitumen requirements and therefore it is conservative to exclude them.
B9 Transportation of Bitumen	Related	N/A		
P17 Fuel Extraction / Processing	N/A	Related	Include	Included as the emissions from this SS may be material and can be quantified.
B14 Fuel Extraction / Processing	Related	N/A		
P18 Fuel Delivery	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition given decreased fossil fuel requirements from lower mix temperatures and therefore it is conservative to exclude them.
B15 Fuel Delivery	Related	N/A		
P19 Electricity Generation	N/A	Related	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practises are covered under proposed greenhouse gas regulations.
B16 Electricity Generation	Related	N/A		
Onsite SS's				
P14 Storage of Aggregate	N/A	Controlled	Exclude	Excluded as the quantity of aggregate consumed in the baseline condition will be higher than that consumed in the project condition per unit of hot mix asphalt produced therefore it is conservative to exclude emissions from storage.
B10 Storage of Aggregate	Controlled	N/A		

P15 Storage of Bitumen, Drying and Hot Mixing	N/A	Controlled	Include	Included as the emissions from this SS may be material and can be quantified.
B11 Storage of Bitumen, Drying and Hot Mixing	Controlled	N/A		
P16 Hot Mix Facility Operation	N/A	Controlled	Exclude	Excluded as the quantity in the majority of project configurations the facility's operation (apart from operations related to the SS's P15 and B11) will not be impacted by the project activity and therefore will be functionally equivalent in the baseline and project conditions
B12 Hot Mix Facility Operation	Controlled	N/A		
P20 Silo Filling and Load-out	N/A	Controlled	Exclude	Excluded as emissions from these SS's are not material and lower in the project condition given decreased bitumen requirements and therefore it is conservative to exclude them.
B13 Silo Filling and Load-out	Controlled	N/A		
Downstream SS's				
P21 Transportation of Hot mix asphalt	N/A	Related	Exclude	Excluded as in the majority of project configurations there will be no change in quantity of hot mix asphalt and / or transportation practices and therefore no change in fossil fuel consumption for transportation, making the baseline and project scenarios functionally equivalent.
B17 Transportation of Hot mix asphalt	Related	N/A		
P22 Paving	N/A	Related	Exclude	Excluded as emissions will likely be higher in the project condition and given the lack of reliable data currently available to quantify fugitive emissions from paving. Project proponents can include this SS in quantification if a reasonable means of measuring emissions is developed.
B18 Paving	Related	N/A		
P23 Recycling or Disposal	N/A	Related	Exclude	Excluded as in the majority of project configurations there will be no change in recycling practices due to project implementation, making emissions in the baseline and project scenarios equivalent.
B19 Recycling or Disposal	Related	N/A		
Other				
P26 Development of Site	N/A	Related	Exclude	Emissions from site development are not material given the long project life, and the minimal site development typically required.
B24 Development of Site	Related	N/A	Exclude	Emissions from 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.
B20 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.
P27 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.
B21 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.

P28 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.
B23 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.
P29 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 2.5**, below. A listing of relevant emission factors is provided in **APPENDIX A**. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

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

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Bitumen Production}} + \text{Emissions}_{\text{Aggregate Production}} + \text{Emissions}_{\text{Hot Mixing}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Carbon Black Production}} + \text{Emissions}_{\text{Bitumen Production}} + \text{Emissions}_{\text{Aggregate Production}} + \text{Emissions}_{\text{Hot Mixing}}$$

Where:

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

$\text{Emissions}_{\text{Fuel Extraction / Processing}}$ = emissions under SS B14 Fuel Extraction and Processing

$\text{Emissions}_{\text{Bitumen Production}}$ = emissions under SS B2 Production / Processing of Bitumen

$\text{Emissions}_{\text{Aggregate Production}}$ = emissions under SS B3 Production / Processing of Aggregate

$\text{Emissions}_{\text{Hot Mixing}}$ = emissions under SS B11 Storage of Bitumen, Drying and Hot-mixing

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

$\text{Emissions}_{\text{Fuel Extraction / Processing}}$ = emissions under SS P17 Fuel Extraction and Processing

$\text{Emissions}_{\text{Carbon Black Production}}$ = emissions under SS P3 Production / Processing of Carbon Black

$\text{Emissions}_{\text{Bitumen Production}}$ = emissions under SS P4 Production / Processing of Bitumen

$\text{Emissions}_{\text{Aggregate Production}}$ = emissions under SS P5 Production / Processing of Aggregate

$\text{Emissions}_{\text{Hot Mixing}}$ = emissions under SS P15 Storage of Bitumen, Drying and Hot-mixing

TABLE 2.5: Quantification Procedures

1. 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						
P17 Fuel Extraction and Processing	Emissions $_{Fuel\ Extraction\ /\ Processing}$ = ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$)					
	Emissions $_{Fuel\ Extraction\ /\ Processing}$	kg of CO_{2E}	N/A	N/A	N/A	Quantity being calculated based on fuel use under P15 Storage of Bitumen, Drying and Hot Mixing.
	Volume of Each Type of Fuel Combusted for P15 / Vol. Fuel $_i$	L/ m^3/ other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO_2 Emissions Factor for Fuel Production and Processing / EF Fuel $_{i\ CO2}$	kg CO_2 per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Fuel Production and Processing / EF Fuel $_{i\ CH4}$	kg CH_4 per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Fuel Production and Processing / EF Fuel $_{i\ N2O}$	kg N_2O per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P3 Production / Processing of	Emissions $_{Carbon\ Black\ Production}$ = ∑ (Mass $_{Sulphur\ Extender}$ * % C Black * EF Production $_{CO2}$) / 100; ∑ (Mass $_{Sulphur\ Extender}$ * % C Black * EF Production $_{CH4}$) / 100					

Carbon Black	Emissions $_{Carbon\ Black\ Production}$	kg of CO_2 ; CH_4	N/A	N/A	N/A	Quantity being calculated.
	Mass of Sulphur Extender Product Consumed / Mass $_{Sulphur\ Extender}$	kg	Measured	Direct metering or reconciliation of mass received.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Percent of Carbon Black in Sulphur Extender / % C Black	%	2	Default value estimated from sulphur extender production process.	Annual	Default value of 2% obtained from sulphur extender producer. Value will be updated on an annual basis, as required.
	CO_2 Emissions Factor for Production of Carbon Black / EF Production $_{CO2}$	kg CO_2 per kg carbon black	Estimated	From IPCC reference documents (Appendix A).	Annual	Reference values obtained from IPCC guidelines. Values are dependant on the production process.
	CH_4 Emissions Factor for Production of Carbon Black / EF Production $_{CH4}$	kg CH_4 per kg carbon black	Estimated	From IPCC reference documents (Appendix A).	Annual	Reference values obtained from IPCC guidelines. Values are dependant on the production process.
P4 Production / Processing of Bitumen	Emissions $_{Bitumen\ Production}$ = $\sum$ ((Mass $_{Bitumen}$ * EF Production $_{CO2}$) / ρ); $\sum$ ((Mass $_{Bitumen}$ * EF Production $_{CH4}$) / ρ); $\sum$ ((Mass $_{Bitumen}$ * EF Production $_{N2O}$) / ρ)					
	Emissions $_{Bitumen\ Production}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Mass of Bitumen Consumed / Mass $_{Bitumen}$	kg	Measured	Direct metering of quantity of bitumen used for hot mixing or reconciliation of mass received.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

	Density of Bitumen / ρ	kg per L	0.98	Default value	Annual	Default value for the density of heavy crude oil.
	CO_2 Emissions Factor for Production of Bitumen / EF Production $_{CO2}$	kg CO_2 per L/ m^3/ other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
	CH_4 Emissions Factor for Production of Bitumen / EF Production $_{CH4}$	kg CH_4 per L/ m^3/ other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
	N_2O Emissions Factor for Production of Bitumen / EF Production $_{N2O}$	kg N_2O per L/ m^3/ other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
P5 Production / Processing of Aggregate	$\text{Emissions}_{\text{Aggregate Production}} = \text{Mass}_{\text{Aggregate}} * \text{EF}_{\text{CO2E Aggregate Production}}$					
	Emissions from the production and mining of aggregate / Emissions $_{\text{Aggregate Production}}$	kg of CO_{2E}	N/A	N/A	N/A	Quantity being calculated.
	Mass of aggregate consumed / Mass $_{\text{Aggregate}}$	kg	Measured	Direct measurement of mass of aggregate consumed at the hot mix facility, reconciliation of mass received or calculation as the difference between the mass of hot mix asphalt produced and the mass	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

				of binder consumed.		
	Emissions factor for aggregate production / $EF_{CO2E\ Aggregate\ Production}$	kg CO_{2E} per kg aggregate	Estimated	Value provided in Appendix A.	Annual	The emission factor as stated in Appendix A is applicable to sand, gravel or crushed stone. If other materials are used, an alternate emission factor may be derived or they may be assumed to have an emission factor of zero. This is conservative as more aggregate is consumed in the baseline versus the project condition. This reference value is derived from review and analysis of data available from Statistics Canada, the Quarry Products Industry and the Canadian Technical Asphalt Association.
P15 Storage of Bitumen, Drying and Hot Mixing	$Emissions_{Hot\ Mixing} = Emissions_{Hot\ Mix\ Stack} + Emissions_{Fuel\ Usage}$					
	$Emissions_{Hot\ Mixing}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for bitumen storage, aggregate drying and hot mixing.
	$Emissions_{Hot\ Mix\ Stack} = \sum (Mass_{Bitumen} * EF\ Mixer_{CH4})$					
	$Emissions_{Hot\ Mix\ Stack}$	kg of CH_4	N/A	N/A	N/A	Quantity being calculated. Note that this factor refers to emissions associated with the handling and use of bitumen during hot mixing. Emissions from fuel combustion are quantified under the $Emissions_{Fuel\ Usage}$ variable.
	Mass of Bitumen Consumed / $Mass_{Bitumen}$	kg	Measured	Direct metering of quantity of bitumen used for hot mixing or	Per project with monthly reconciliation if	Both methods are standard practise. Frequency of metering is highest level possible.

				reconciliation of mass received.	project duration is longer than one month.	Frequency of reconciliation provides for reasonable diligence.
	CH_4 Emission Factor for Bitumen Use in Hot Mixing / EF Mixer $_{CH4}$	kg CH_4 per kg bitumen	Estimated	From US EPA reference documents (Appendix A).	Annual	Emission factors obtained from the US EPA's Emission Inventory. Values are presented for drum and batch mixers at hot mix asphalt plants per unit of bitumen product consumed.
	$\text{Emissions}_{\text{Fuel Usage}} = \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\,CO2})\ ;\ \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\,CH4})\ ;\ \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\,N2O})$					
	Emissions $_{\text{Fuel Usage}}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for bitumen storage, aggregate drying and hot mixing.
	Volume of Each Type of Fuel Combusted / Vol. Fuel $_i$	L/ m^3/ other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. Note that overall hot mix facility fuel usage data may be used given that bitumen storage, aggregate drying and hot mixing will likely represent the majority of facility fuel usage.
	CO_2 Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i\,CO2}$	kg CO_2 per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i\,CH4}$	kg CH_4 per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

	N_20 Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
Baseline SS's						
B14 Fuel Extraction and Processing	Emissions $_{Fuel\ Extraction\ /\ Processing}$ = ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; ∑ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$)					
	Emissions $_{Fuel\ Extraction\ /\ Processing}$	kg of CO_{2E}	N/A	N/A	N/A	Quantity being calculated based on fuel use under B11 Storage of Bitumen, Drying and Hot Mixing
	Volume of Each Type of Fuel Combusted for B11 / Vol. Fuel $_i$	L/ m^3/ other	Measured	Quantity of each type of fuel consumed under SS B11.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO_2 Emissions Factor for Fuel Production and Processing / EF Fuel $_{i\ CO2}$	kg CO_2 per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Fuel Production and Processing / EF Fuel $_{i\ CH4}$	kg CH_4 per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Fuel Production and Processing / EF Fuel $_{i\ N2O}$	kg N_2O per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B2 Production / Processing of	Emissions $_{Bitumen\ Production}$ = ∑ ((Mass $_{Bitumen}$ * Mass $_{Paving}$ * EF Production $_{CO2}$) / ρ); ∑ ((Mass $_{Bitumen}$ * Mass $_{Paving}$ * EF Production $_{CH4}$) / ρ); ∑ ((Mass $_{Bitumen}$ * Mass $_{Paving}$ * EF Production $_{N2O}$) / ρ)					

Bitumen	Emissions $_{Bitumen\ Production}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated.
	Mass of Bitumen Consumed / Mass $_{Bitumen}$	kg per tonne hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved (Appendix B).	Per project with monthly reconciliation if project duration is longer than one month.	The bitumen content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved. The project proponent may substitute the actual mix composition at their facility if known.
	Mass of hot mix asphalt produced / Mass $_{Paving}$	tonne	Measured	Direct metering or reconciliation of quantity delivered to trucks for load-out.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Density of Bitumen / ρ	kg per L	0.98	Default value	Annual	Default value for the density of heavy crude oil.
	CO_2 Emissions Factor for Production of Bitumen / EF Production $_{CO2}$	kg CO_2 per L/ m^3/ other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
	CH_4 Emissions Factor for Production of Bitumen / EF Production $_{CH4}$	kg CH_4 per L/ m^3/ other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.

	N_2O Emissions Factor for Production of Bitumen / EF Production $_{N2O}$	kg N_2O per L/ m^3/ other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
B3 Production / Processing of Aggregate	Emissions $_{Aggregate\ Production}$ = (Mass $_{Paving}$* Mass $_{Aggregate}$ * EF CO_{2E})					
	Emissions from the production and mining of aggregate / Emissions $_{Aggregate\ Production}$	kg of CO_{2E}	N/A	N/A	N/A	Quantity being calculated.
	Mass of hot mix asphalt produced / Mass $_{Paving}$	tonne	Measured	Direct metering or reconciliation of quantity delivered to trucks for load-out.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Mass of Aggregate / Mass $_{Aggregate}$	kg per tonne hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved (Appendix B).	Per project with monthly reconciliation if project duration is longer than one month.	The aggregate content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved. The project proponent may substitute the actual mix composition at their facility if known.
	Emissions factor for aggregate production / EF $_{CO2E\ Aggregate\ Production}$	kg CO_{2E} per kg aggregate	Estimated	Value provided in Appendix A.	Annual	The emission factor as stated in Appendix A is applicable to sand, gravel or crushed stone. If other materials are used, an alternate emission factor may be derived or they may be assumed to have an emission factor of zero. This is conservative as more aggregate is consumed in the baseline versus the project condition.

						This reference value is derived from review and analysis of data available from Statistics Canada, the Quarry Products Industry and the Canadian Technical Asphalt Association.
B11 Storage of Bitumen, Drying and Hot Mixing	$\text{Emissions}_{\text{Hot Mixing}} = \text{Emissions}_{\text{Hot Mix Stack}} + \text{Emissions}_{\text{Fuel Usage}}$					
	$\text{Emissions}_{\text{Hot Mixing}}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for bitumen storage, aggregate drying and hot mixing.
	$\text{Emissions}_{\text{Hot Mix Stack}} = \sum(\text{Mass}_{\text{Paving}} * \text{Mass}_{\text{Bitumen}} * \text{EF Mixer}_{CH4})$					
	$\text{Emissions}_{\text{Hot Mix Stack}}$	kg of CH_4	N/A	N/A	N/A	Quantity being calculated. Note that this factor refers to emissions associated with the handling and use of bitumen during hot mixing. Emissions from fuel combustion are quantified under the $\text{Emissions}_{\text{Fuel Usage}}$ variable.
	Mass of hot mix asphalt produced / $\text{Mass}_{\text{Paving}}$	tonne	Measured	Direct metering or reconciliation of quantity delivered to trucks for load-out.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Mass of Bitumen Consumed / $\text{Mass}_{\text{Bitumen}}$	kg per tonne hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved (Appendix B).	Per project with monthly reconciliation if project duration is longer than one month.	The bitumen content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved. The project proponent may substitute the actual mix composition at their facility if known.

	CH_4 Emission Factor for Bitumen Use in Hot Mixing / EF Mixer $_{CH4}$	kg CH_4 per kg bitumen	Estimated	From US EPA reference documents (Appendix A).	Annual	Emission factors obtained from the US EPA's Emission Inventory. Values are presented for drum and batch mixers at hot mix asphalt plants per unit of bitumen product consumed.
	Emissions $_{Fuel\ Usage}$ = ∑ (Mass $_{Paving}$ * Vol. Fuel Mixing $_i$ * EF Fuel $_{i\ CO2}$) ; ∑ (Mass $_{Paving}$ * Vol. Fuel Mixing $_i$ * EF Fuel $_{i\ CH4}$) ; ∑ (Mass $_{Paving}$ * Vol. Fuel Mixing $_i$ * EF Fuel $_{i\ N2O}$);					
	Emissions $_{Fuel\ Usage}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for bitumen storage, aggregate drying and hot mixing.
	Volume of Each Type of Fuel Combusted for Mixing / Vol. Fuel Mixing $_i$	L/ m^3/ other per t hot mix asphalt	Measured	Theoretical calculation of the heat required for hot mixing and the volume of fuel required to produce this heat.	Per project with monthly reconciliation if project duration is longer than one month.	Value calculated based on heat requirements, the specific heat of each component and the quantity of each component consumed.
	CO_2 Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L/ m^3/ other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	Vol. Fuel Mixing $_i$ = (Vol. Fuel Mixing $_{i\ Aggregate}$ + Vol. Fuel Mixing $_{i\ Bitumen}$)					

		$Vol.\ Fuel\ Mixing_{i\ Aggregate} = ((Mass_{Aggregate} * C_{Agg} * (T_{Hot\ mix\ asphalt} - T_{Agg})) / / (HV\ Fuel_i * Eff)) + (Mass_{Aggregate} * Vol.\ Fuel_i)$ [1]				
		$Vol.\ Fuel\ Mixing_{i\ Bitumen} = ((Mass_{Bitumen} * C_{Bitumen} * (T_{Hot\ mix\ asphalt} - T_{Bitumen})) / (HV\ Fuel_i * Eff))$				
	Mass of Aggregate / $Mass_{Aggregate}$	kg per tonne hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved (Appendix B).	Per project with monthly reconciliation if project duration is longer than one month.	The aggregate content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved. The project proponent may substitute site-specific values if the actual composition of conventional hot mix asphalt at their facility if known.
	Mass of Bitumen Consumed / $Mass_{Bitumen}$	kg per tonne hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved (Appendix B).	Per project with monthly reconciliation if project duration is longer than one month.	The bitumen content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved. The project proponent may substitute site-specific values if the actual composition of conventional hot mix asphalt at their facility if known.
	Specific Heat Capacity of Aggregate / C_{Agg}	kJ per kg degree Celsius	0.837	Constant	N/A	Accepted value.
	Specific Heat Capacity of Bitumen / $C_{Bitumen}$	kJ per kg degree Celsius	2.093	Constant	N/A	Accepted value.
	Temperature of Hot mix asphalt Production / T	degrees C	Estimated	Direct metering of typical mix temperature prior to use of sulphur	Per project with monthly reconciliation if	Represents production temperature of hot mix asphalt. If site-specific data is not

[1] The volume of fuel required to heat aggregate is calculated using the heat equation, while the fuel required to dry aggregate is calculated from manufacturer specifications and the moisture content of the aggregate.

	Hot mix asphalt			extender hot mix asphalt or determination from industry common practice from typical hot mix asphalt production temperatures (as specified by Alberta Transportation).	project duration is longer than one month.	available a temperature of 144 degrees Celsius may be applied based on common industry practice. If asphalt grade is softer than 150-200A asphalt or the road is a low volume highway, a temperature of 142 degrees Celsius may be more appropriate.
	Temperature of Aggregate / T_{Agg}	degrees C	Estimated	Direct metering of typical aggregate temperature at the time of mixing or determination from industry best practices for typical hot mix asphalt production temperatures.	Annual	Represents temperature of aggregate at time of mixing / addition of binder.
	Temperature of Bitumen / $T_{Bitumen}$	degrees C	Estimated	Direct metering of typical bitumen temperature at the time of mixing or determination from industry best practices for typical hot mix asphalt production temperatures.	Annual	Represents temperature of bitumen at time of mixing / addition to the hot mixer.
	Heat Value Fuel / HV $Fuel_i$	kJ per m^3	Estimated	Constant	Annual	Accepted value for the type of fuel used to fuel the burner. For natural gas the default value is 38,095 kJ per m^3. For other fuel types an appropriate default value may be used.
	Fuel Combustion and Burner Efficiency / Eff	%	Estimated	Default value of 80% combustion and 80% burner efficiency for a total efficiency of 64%.	Annual	Default value.

	Vol. Fuel Combusted for Aggregate Drying / Vol. Fuel $_i$	L/ m^3/ other per kg aggregate	Estimated	From manufacturer specifications of burner fuel consumption.	Per project with monthly reconciliation if project duration is longer than one month.	Value obtained from manufacturer specification of fuel consumption. Fuel consumption will be dependant on the moisture content of the aggregate.
	Moisture Content of Aggregate	%	Estimated	From regional moisture content of aggregate determined from existing geological studies and / or sampling	Annual	Value obtained from existing geological studies conducted for the region and / or from sampling data. Other sources of data may also be proposed. Note that while this value is not used in calculations, it is required to determine fuel requirements for aggregate drying from manufacturer specifications.

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 2.6**, 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 and be substantiated by company records for the purpose of verification.

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.

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.

2.6.2 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 2.6: 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						
P3 Production / Processing of Carbon Black	Mass of Sulphur Extender Product Consumed / $\text{Mass Sulphur Extender}$	kg	Measured	Reconciliation of mass of sulphur extender purchased within given time period.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P4 Production / Processing of Bitumen	Mass of Bitumen Consumed / $\text{Mass}_{\text{Bitumen}}$	kg	Measured	Direct metering of quantity of bitumen purchased from monthly invoices from the supplier.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P5 Aggregate Production	Mass of aggregate consumed / $\text{Mass}_{\text{Aggregate}}$	kg	Estimated	Reconciliation of mass of aggregate purchased within given time period.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P15 Storage of Bitumen, Drying and Hot Mixing	Volume of Each Type of Fuel Consumed / Vol. Fuel_{i}	L/ m^3/ other	Measured	Reconciliation of volume of fuel purchased within given time period.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Mass of hot mix asphalt produced / $\text{Mass}_{\text{Paving}}$	tonne	Measured	Reconciliation of mass of hot mix asphalt applied or distance paved and thickness of paving within given time period. This approach may assume a paving lane width of 3.75 m for calculation of the mass	Per Project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

				of hot mix required for paving[2].		
	Mass Emission Rate of CH_4 / EF Mixer CH4	kg per kg bitumen	Measured	Use of alternate methodology presented in Appendix C.	Annual	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P17 Fuel Extraction and Processing	Volume of Fuel Combusted for P15	L/ m^3/ other	Measured	Reconciliation of volume of fuel purchased within given time period.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
Baseline SS's						
B2 Production / Processing of Bitumen	Mass of Hot mix asphalt Produced / Mass $_{Paving}$	kg	Measured	Reconciliation from mass of hot mix asphalt applied. If this data is not available mass of hot mix asphalt may be estimated using the distance paved and paving thickness. This approach may assume a paving lane width of 3.75 m for calculation of the mass of hot mix required for paving.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
B2 Production / Processing of Bitumen, B3 Production / Processing of Aggregate and B11 Storage of Bitumen, Drying and Hot Mixing	Mass of hot mix asphalt produced / Mass $_{Paving}$	tonne	Measured	Reconciliation from mass of hot mix asphalt applied. If this data is not available mass of hot mix asphalt may be estimated using the distance paved and paving thickness. This approach may assume a paving lane width of 3.75 m for calculation of the mass of hot mix required for paving.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.

[2] Lane width obtained from the National Resource Council's *Road Rehabilitation Energy Reduction Guide for Canadian Road Builders* dated 2005.

B11 Storage of Bitumen, Drying and Hot Mixing	Mass Emission Rate of CH_4 / EF Mixer CH4	kg per kg bitumen	Measured	Use of alternate methodology presented in Appendix C.	Annual	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.

APPENDIX A

Relevant Emission Factors

Fossil Fuel Usage

Values for fossil fuel production and combustion were obtained from Environment Canada's National Inventory Report, 1990-2005 - Greenhouse Gas Sources and Sinks in Canada. These values are subject to updates and the most recent values published by Environment Canada should be used.

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_2O)	0.000004	kg N_2O 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_2O)	0.000004	kg N_2O 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_2O)	0.000003	kg N_2O 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_2O)	0.000004	kg N_2O per Litre

Table A2: Emission Factors for Natural Gas and NGL's

Source	**Emission Factors**		
	CO_2	**CH_4**	**N_2O**
	g/m^3	**g/m^3**	**g/m^3**
Natural Gas			
Electric Utilities	1891	0.49	0.049
Industrial	1891	0.037	0.033
Producer Consumption	2389	6.5	0.06
Pipelines	1891	1.9	0.05
Cement	1891	0.037	0.034
Manufacturing Industries	1891	0.037	0.033
Residential, Construction, Commercial/Institutional, Agriculture	1891	0.037	0.035
	g/L	**g/L**	**g/L**
Propane			
Residential	1510	0.027	0.108
All Other Uses	1510	0.024	0.108
Ethane	976	N/A	N/A
Butane	1730	0.024	0.108

Table A3: Emission Factors for Refined Petroleum Products

Source	Emission Factors (g/L)		
	CO_2	CH_4	N_2O
Light Fuel Oil			
Electric Utilities	2830	0.18	0.031
Industrial	2830	0.006	0.031
Producer Consumption	2830	0.006	0.031
Residential	2830	0.026	0.006
Forestry, Construction, Public Administration, and Commercial/Institutional	2830	0.026	0.031
Heavy Fuel Oil			
Electric Utilities	3080	0.034	0.064
Industrial	3080	0.12	0.064
Producer Consumption	3080	0.12	0.064
Residential, Forestry, Construction, Public Administration, and Commercial/Institutional	3080	0.057	0.064
Kerosene			
Electric Utilities	2550	0.006	0.031
Industrial	2550	0.006	0.031
Producer Consumption	2550	0.006	0.031
Residential	2550	0.026	0.006
Forestry, Construction, Public Administration, and Commercial/ Institutional	2550	0.026	0.031
Diesel	2730	0.133	0.4
Gasoline (Light Duty Trucks)	2360	0.13	0.25

<u>Bitumen Production</u>

Values for bitumen production were obtained 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).

Heavy Crude Thermal Production		
Emissions Factor (CO_2)	594.2	kg CO_2 per m^3
Emissions Factor (CH_4)	3.75	kg CH_4 per m^3
Emissions Factor (N_2O)	0.009	kg N_2O per m^3

<u>Carbon Black Production</u>

Values for carbon black production were obtained from IPCC 2006 Guidelines. The majority of the world's carbon black is produced by the furnace black process; however production at several facilities in Alberta is by the thermal process. Emission factors for both are equivalent.

Table A3: Emission Intensity of Carbon Black Production

Production Process	CO_2	CH_4	Units
Furnace Black	0.66	0.00006	kg / kg Carbon Black
Thermal	0.66	0.00006	kg / kg Carbon Black

Hot Mixing

Emission factors for hot mixing were derived from the US EPA's AP 42 Emission Inventory Supplement to "*Compilation of Air Pollutant Emission Factors. Vol. 1: Stationary Point and Area Sources" Chapter 11.1 Hot Mix Asphalt Plants* dated 1994. Emission factors represent the methane content of total organic carbon emissions and were calculated assuming a 'typical' content of 5.3% bitumen binder (by weight) in conventional hot mix asphalt.

Table A4: Emission Intensity of Hot Mixing

Plant Type	CH_4	Units
Natural Gas Batch Mixer	0.0001	kg / kg Bitumen
Natural Gas Drum Mix	0.0019	kg / kg Bitumen
No. 2 Fuel Oil Batch Mixer	4.15 E-05	kg / kg Bitumen
No. 2 Fuel Oil Drum Mixer	0.0002	kg / kg Bitumen

Aggregate Production

The emission factor for aggregate production was derived based on the three tables included below. An emissions factor of **0.00998 kg CO_{2E} / kg of aggregate** produced will be used as it is the most conservative number.

Table A5: QPA Emission Factor

	Emission Factor	
Aggregate Production	**9.98**	kg CO_{2E} / tonne of aggregate output

The above value includes the production of aggregates and value-added products such as asphalt and ready-mixed concrete, but does not include the use of energy in delivering products to the market.

Source: "A Sustainable Development Report from the Aggregate and Quarry Products Industry", March 2006. Page 21.

Table A6: Calculation based on Canadian Data

Year	1997	2002
Raw Materials Price Index (Non-Metallic Minerals)	100	114.3
Production Cost	$11.33 / tonne	$12.95 / tonne
Emissions Intensity		0.8 tonnes CO_{2E} / $1000 production
Production Cost		77.22 tonnes of Aggregate / $1000
Emissions per Tonne Produced		**10.36 kg CO_{2E} / t aggregate**

Sources: Statistics Canada; Natural Resources Canada, Canadian Minerals Yearbook, 1998; CANISM

Table A7: Canadian Technical Asphalt Association Data

	Emission Factor	
Crushed Aggregate (0-20 mm)	**10**	Kg CO_{2E} / tonne of aggregate output

Source: The Environmental Road of the Future: Analysis of Energy Consumption and Greenhouse Gas Emissions, Canadian Technical Asphalt Association, 2005, page 25.

APPENDIX B

Conventional Hot Mix Asphalt Default Values

The following default values for conventional hot mix asphalt were provided by Alberta Transportation and represent common industry practices in Alberta. Values represent the percentage of bitumen and aggregate by weight as a function of the weight of total hot mix asphalt produced.

Table B.1 Conventional Hot Mix Asphalt Composition

Type of Road Mix	Type of Road	Bitumen (kg / tonne hot mix asphalt)	Aggregate (kg / tonne hot mix asphalt)
Low Volume	Lower volume roads such as secondary, tertiary and resource roads	50	950
Medium Volume	Lower volume / secondary highways and city collectors	52	948
High Volume	Major highways	55	945

APPENDIX C

Alternate Methodology

Table C1: Alternate Methodology for Calculating Hot Mix Stack Emissions from Site-Specific Data

1. 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						
B11 Storage of Bitumen, Drying and Hot Mixing	Emissions $_{Hot\ Mixing}$ = Emissions $_{Fuel\ Usage}$ + Emissions $_{Hot\ Mix\ Stack}$					
	Emissions $_{Hot\ Mixing}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for bitumen storage, aggregate drying and hot mixing.
	Emissions $_{Fuel\ Usage}$ = Calculated using the methodology outlined in Table 2.5					
	Emissions $_{Hot\ Mix\ Stack}$ = ∑ (Mass $_{Paving}$ * EF Mixer $_{CH4}$) / Rate) ; ∑ (Mass $_{Paving}$* EF Mixer $_{CO2}$) / Rate)					
	Emissions $_{Hot\ Mix\ Stack}$	kg of CO_2 ; CH_4	N/A	N/A	N/A	Quantity must be calculated if stack monitoring includes only the emissions from the mixing process. This parameter would not be calculated if stack emissions monitoring is conducted at a point that includes ducted emissions from fuel combustion. These emissions are accounted for under SS B11's Emissions Fuel Usage variable.
	Mass of hot mix asphalt produced / Mass $_{Paving}$	tonne	Measured	Direct metering or reconciliation of quantity delivered to trucks for load-out.	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Mass Emission Rate of CH_4 / EF Mixer $_{CH4}$	kg per hr	Measured	From three years of historical data from third party sampling of the mass emission rate when	Annual	Frequency of metering is highest level possible. If results are expressed as total organics, determination of methane

				the facility was using conventional hot mix asphalt.		emissions may be accomplished by assuming 27% methane for drum mix and 47% methane for batch mix plants according to guidance provided by the US EPA.
	Mass Emission Rate of CO_2 / EF Mixer $_{CO2}$	kg per hr	Measured	From three years of historical data from third party sampling of the mass emission rate when the facility was using conventional hot mix asphalt.	Annual	Frequency of metering is highest level possible.
	Sampling Production Rate / Rate	tonne per hr	Measured	From historical data for hot mix asphalt production rate during third party sampling used to determine emission rates.	Annual	Frequency of metering is highest level possible.
Baseline SS's						
P15 Storage of Bitumen, Drying and Hot Mixing	Emissions $_{Hot\ Mixing}$ = Emissions $_{Fuel\ Usage}$ + Emissions $_{Hot\ Mix\ Stack}$					
	Emissions $_{Hot\ Mixing}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for bitumen storage, aggregate drying and hot mixing.
	Emissions $_{Fuel\ Usage}$ = Calculated using the methodology outlined in Table 2.5					
	Emissions $_{Hot\ Mix\ Stack}$ = ∑ (Mass $_{Paving}$ * EF Mixer $_{CH4}$) / Rate) ; ∑ (Mass $_{Paving}$ * EF Mixer $_{CO2}$) / Rate)					
	Emissions $_{Hot\ Mix\ Stack}$	kg of CO_2 ; CH_4	N/A	N/A	N/A	Quantity must be calculated if stack emissions monitoring includes only the emissions from the mixing process. This parameter would not be calculated if stack emissions

						monitoring is conducted at a point that includes ducted emissions from fuel combustion. These emissions are accounted for under SS P15's Emissions Fuel Usage variable
	Mass of hot mix asphalt produced / Mass $_{Paving}$	tonne	Measured	Direct metering or reconciliation of quantity delivered to trucks for load-out.	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Mass Emission Rate of CH_4 / EF Mixer $_{CH4}$	kg per hr	Measured	Direct measurement by third party sampling.	Annual	Frequency of metering is highest level possible. If sampling results are expressed as total organics, conversion to methane may be accomplished by assuming that organics are composed of 27% methane for drum mix and 47% methane for batch mix plants according to guidance provided by the US EPA.
	Mass Emission Rate of CO_2 / EF Mixer $_{CO2}$	kg per hr	Measured	Direct measurement by third party sampling.	Annual	Frequency of metering is highest level possible.
	Sampling Production Rate / Rate	tonne per hr	Measured	Direct measurement of production rate during third party sampling.	Annual	Frequency of metering is highest level possible.

APPENDIX D

Specified Gases and Global Warming Potential

Specified Gases and Their Global Warming Potentials

Specified Gas	Chemical Formula	Global Warming Potential (100 year time horizon)
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
HFC-23	CHF_3	11700
HFC-32	CH_2F_2	650
HFC-41	CH_3F	150
HFC-43-10mee	$C_5H_2F_{10}$	1300
HFC-125	C_2HF_5	2800
HFC-134	$C_2H_2F_4$	1000
HFC-134a	CH_2FCF_3	1300
HFC-152a	$C_2H_4F_2$	140
HFC-143	$C_2H_3F_3$	300
HFC-143a	$C_2H_3F_3$	3800
HFC-227ea	C_3HF_7	2900
HFC-236fa	$C_3H_2F_6$	6300
HFC-245ca	$C_3H_3F_5$	560
Sulphur hexafluoride	SF_6	23900
Perfluoromethane	CF_4	6500
Perfluoroethane	C_2F_6	9200
Perfluoroproprane	C_3F_8	7000
Perfluorobutane	C_4F_{10}	7000
Perfluorocyclobutane	$c\text{-}C_4F_8$	8700
Perfluoropentane	C_5F_{12}	7500
Perfluorohexane	C_6F_{14}	7400