

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

**October 2008**

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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 asphalt paving mix. Some familiarity with, or general understanding of the operation of these projects is expected.

The opportunity for generating carbon offsets with this protocol arises primarily from the substitution of a proportion of the bitumen binder used in conventional paving mix for a sulphur extended asphalt modifier (SEAM) product resulting in avoided production of a proportion of the asphalt binder used in conventional asphalt paving mix 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 asphalt, that would have been emitted from hot mix facilities where the baseline practice was the use of conventional paving mix.

### 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 asphalt paving mix 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 asphalt paving mix, composed of approximately 94.7% aggregate and 5.3% bitumen binder (by weight) and produced at a temperature ranging from 150 to 180 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 asphalt must be sulphur extended asphalt modifier (SEAM) pellets or a similar solid sulphur product composed of carbon black, sulphur, and small quantities of plasticizer and H<sub>2</sub>S scavenger additives. The product may also contain wax additives, used to reduce hot mix production and compaction temperatures. This protocol is not applicable to project proponents substituting other products for asphalt binder in paving mix, given the potential differences in sourcing of components, composition and GHG emissions.

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

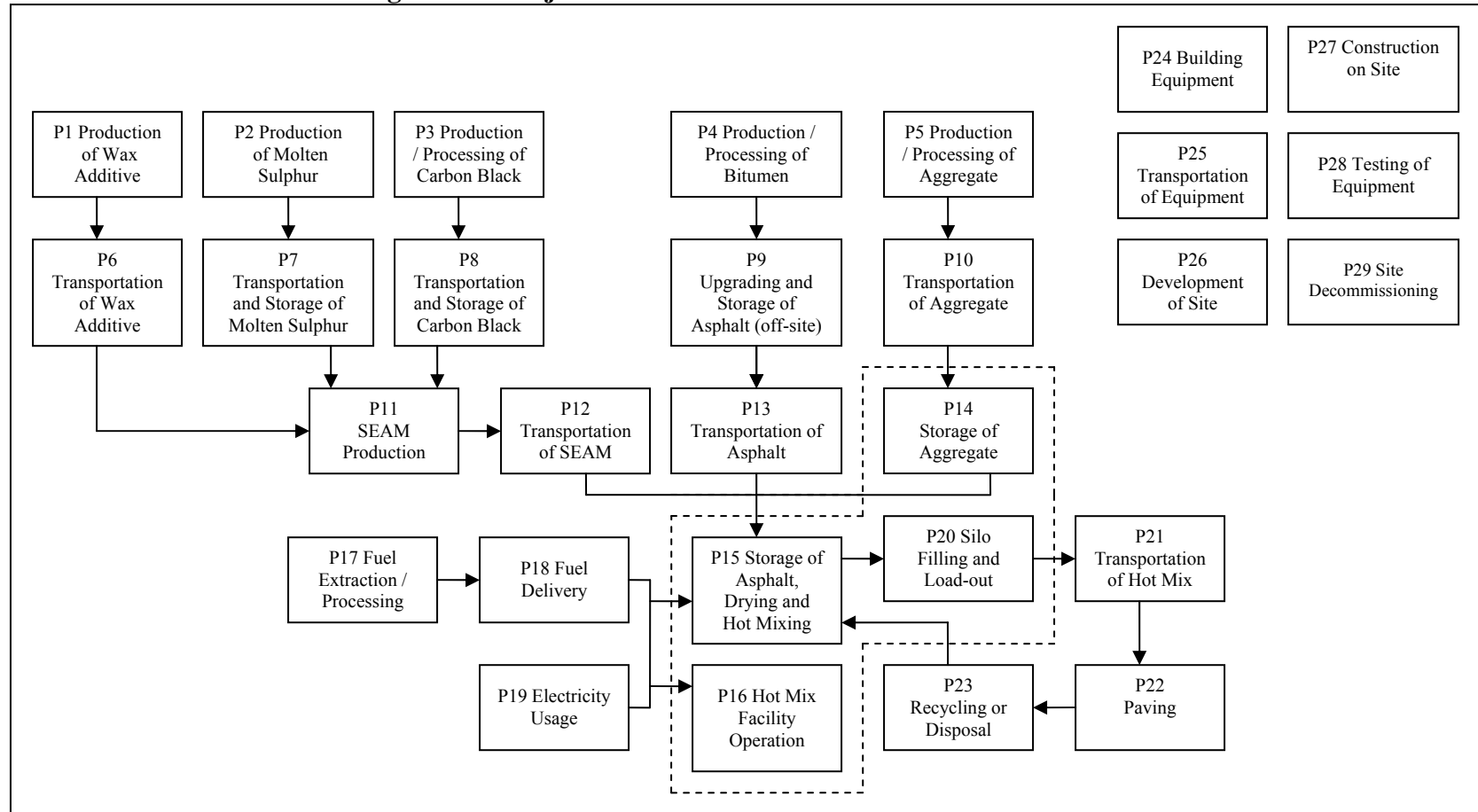
#### Protocol Approach

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 asphalt paving mix for a solid sulphur product such as Sulphur Extended Asphalt Modifier (SEAM). This protocol is also applicable to project developers using SEAM or a similar product with a wax additive (i.e. SEAM plus) to further lower mix and

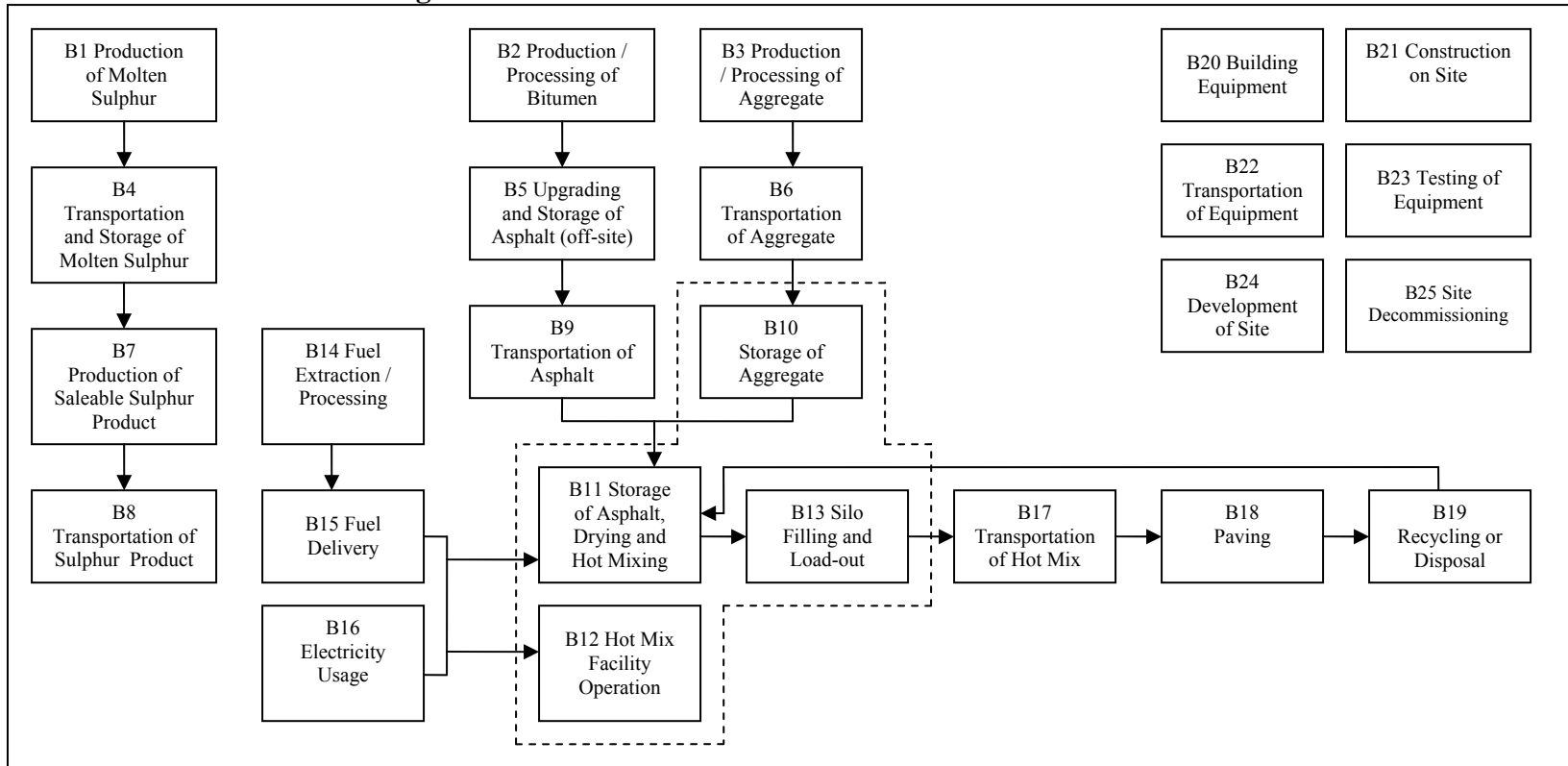
compaction temperatures. The project developer must demonstrate that this baseline condition, illustrated in **FIGURE 1.2**, was either the previous practise or most likely practise based on conventional industry practices. Further, they must show that the quantity of bitumen binder used per unit of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

For those projects that implement the use of SEAM paving mix at new hot mix facilities, where conventional hot asphalt paving mix was not previously used or where fuel usage data is not available, proponents may use a heat equation to quantify the theoretical baseline condition.

**FIGURE 1.1: Process Flow Diagram for Project Condition**



**FIGURE 1.1: Process Flow Diagram for Baseline Condition**



## **Protocol Applicability**

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

1. 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 following documentation: *Handling and Storage of Solid Sulphur, Production, Handling and Use of Seam Paving Mixtures, SEAM Construction Specifications, SEAM Mix Design* and completion of the *Plant Site Checklist* for safe plant use;
2. Hot mix 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.

## **Protocol Flexibility**

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

1. For new facilities and / or project developers that do not have three years of historical fuel usage data, fuel usage for hot mixing may be calculated using the alternate methodology presented in Appendix B for both the project and baseline conditions. To quantify fuel usage for aggregate drying the proponent may either:
  - Exclude fuel usage for aggregate drying in both the project and baseline conditions; or
  - Determine the moisture content of the aggregate and use fuel consumption information from burner manufacturer specifications to quantify fuel usage in both the project and baseline conditions;
2. 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;
3. If the project developer has records of historical mix formulation data (i.e. weight percent of bitumen binder used per tonne of paving mix) prior to SEAM use, this value may be substituted for the default values of 5.3% bitumen and 94.7% aggregate;
4. If three years of historical fuel usage data is not available or upgrades have been made to the facility that render this data inaccurate, the project developer may use

less than three years of data. Justification for use of less than three years of fuel consumption data must be provided;

5. For projects where the use of SEAM can be proven to reduce required pavement thickness (i.e. thickness of bitumen, base and / or wearing course), the alternate methodology provided in Appendix C may be used on a project specific or case by case basis to quantify additional emission reductions achieved through reduced material requirements. This methodology includes consideration of reduced asphalt and aggregate quantities and reduced transportation of loads to the project site. The methodology for generation of baseline pavement thickness must ensure accuracy; and be robust enough to provide uncertainty ranges in the factors; and
6. 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.

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.
Asphalt Handling Emissions:	Intentional and unintentional releases of GHGs during asphalt 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:	Paving mix binder is generally produced at petroleum refineries and serves as a waterproof adhesive that binds the aggregate together. To achieve the desired performance properties for paving, the binder must be produced from a selected crude oil blend and processed to an appropriate grade.

Asphalt: Paving grade asphalt is a product of 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 (ie. vacuum distillation). The asphalt cement (paving grade bitumen) is the residue left after distilling off all of the lighter fuels. After refining asphalt is stored at the refinery at temperatures of approximately 170°C until transportation and delivery to the hot mix facility. Asphalt is commonly referred to as bitumen in the paving industry.

## 2.0 Quantification Development and Justification

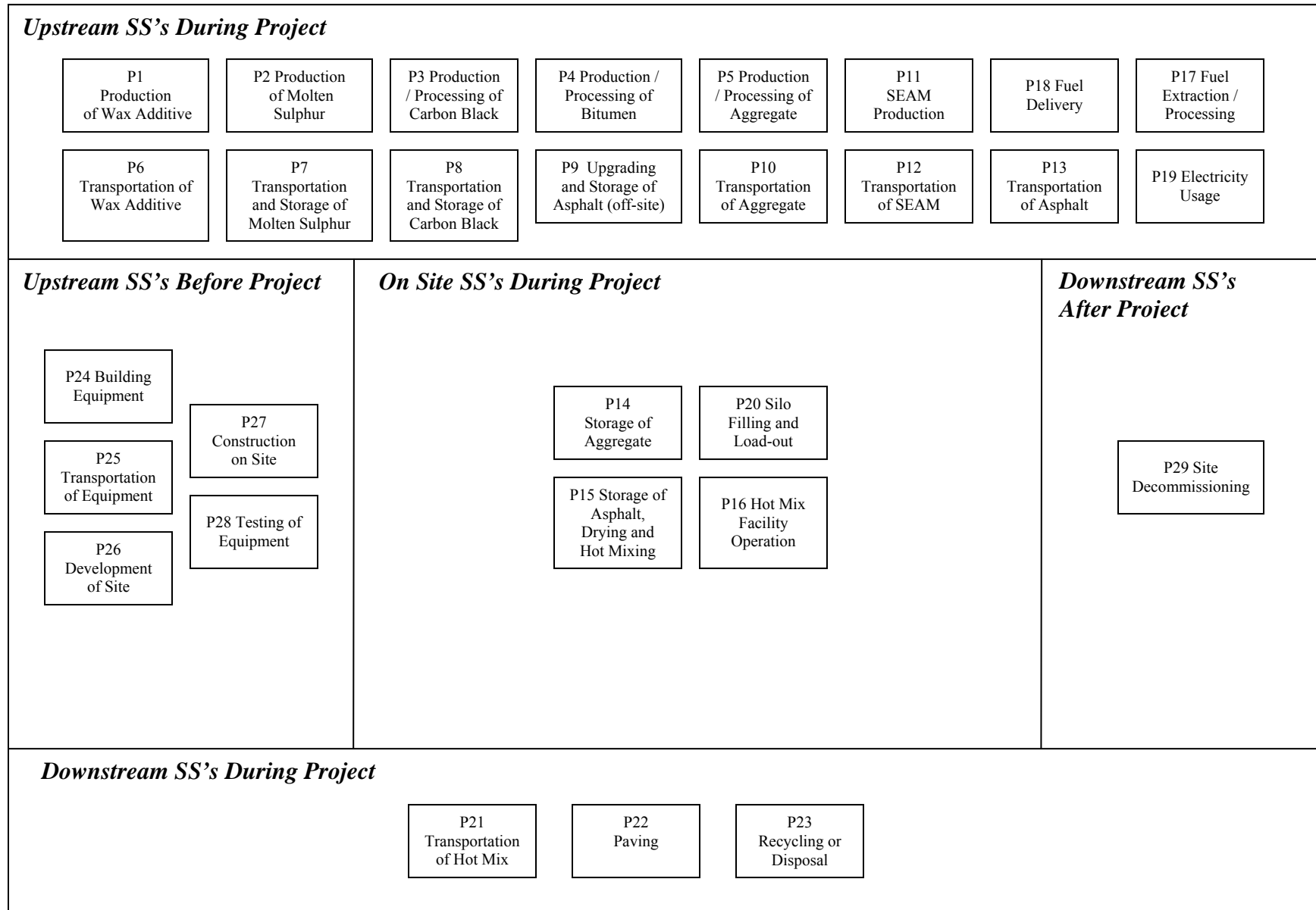
The following sections outline the quantification development and justification.

### 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
<b>Upstream SS's during Project Operation</b>		
P1 Production of Wax Additive	<p>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 SEAM 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.</p> <p>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 the fuels. 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.</p>	Related
P2 Production of Molten Sulphur	<p>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<sub>2</sub> emission regulations being implemented in many jurisdictions.</p> <p>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.</p>	Related
P3 Production / Processing of Carbon Black	<p>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 byproduct of the refining or coke production process), and those attributed to the secondary feedstock (the fossil fuels used in the process).</p> <p>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.</p>	Related
P4 Production / Processing of Bitumen	<p>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.</p> <p>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.</p>	Related
P5 Production / Processing of Aggregate	<p>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.</p>	Related

	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 SEAM 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 Asphalt (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 SEAM Production	SEAM 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 SEAM	The SEAM 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 Asphalt	The asphalt 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 production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are	Related

	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 Usage	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
<b>Onsite SS's during Project Operation</b>		
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 Asphalt, Drying and Hot Mixing	Fossil fuels are required to fuel the burners used to dry and heat the aggregate, bitumen and SEAM to required temperatures for mixing and paving. There may also be emission associated with the asphalt 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 asphalt storage. Facility operation may require any number of energy inputs and mechanical processes excluding those related to processing inputs and generating the paving mix 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 asphalt handling including silo filling and load-out due to asphalt temperatures and loss on heating. The emissions would primarily be associated with the quantity of asphalt consumed.  Quantities of asphalt binder consumed will be the important characteristics to be tracked.	Controlled
<b>Downstream SS's during Project Operation</b>		
P21 Transportation of Hot Mix	The hot paving mix 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	Paving mix will be applied using a paver and compacted using rollers. There may be fugitive emissions during the application and curing of the paving mix. Emissions may be dependant on the temperature and rate of	Controlled

	diluent evaporation.  Temperature, composition and quantities of paving mix 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 paving mix 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
<b>Other</b>		
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 electricity.	Related

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
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## 2.2 Identification of Baseline

The baseline condition for this protocol is the production and usage of conventional hot mix asphalt paving mix. Conventional hot mix asphalt paving mix is composed of approximately 5.3% bitumen binder and 94.7% aggregate (by weight). If the project developer tracks the specific mix formulation and mix temperature used at their facility prior to use of SEAM, these value will be substituted for the above default values.

The baseline approach is considered as a projection based approach with a historic benchmark, depending on data availability. Under this scenario, the emissions from bitumen and aggregate production and bitumen handling would be calculated by modelling and direct measurement of the quantity of bitumen displaced by the project activity. Emissions from fuel consumption and hot mix plant stack emissions would be calculated from historic fuel consumption and emissions data on a per unit of production basis. Paving mix production would be accounted for using direct measurement of sulphur usage and paving mix output in the project activity and displacement of an equivalent quantity of bitumen binder in the baseline.

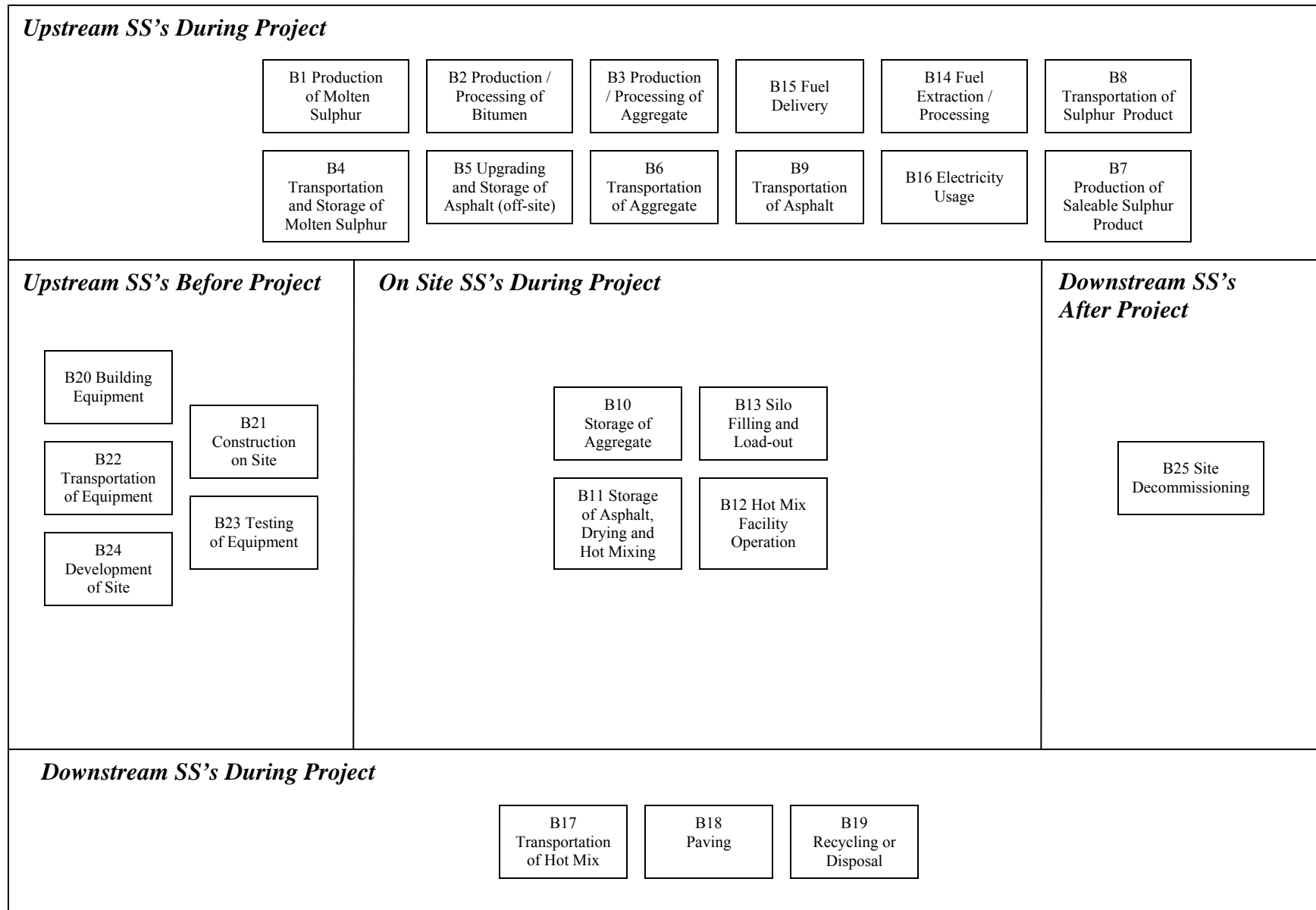
In the absence of historic fuel consumption and emissions data, fuel consumption and stack emissions would be determined using the heat equation and calculated from equivalent quantities of aggregate and bitumen consumed under the baseline condition.

This dynamic approach accounts for the market forces, weather and energy demand and operational parameters without adding multiple streams of material management. There are suitable models that can provide reasonable certainty.

## 2.3 Identification of SS's for the Baseline

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

**FIGURE 2.2: Baseline Element Life Cycle Chart**



**TABLE 2.2: Baseline SS's**

1. SS	2. Description	3. Controlled, Related or Affected
<b>Upstream SS's during Project Operation</b>		
B1 Production of Molten Sulphur	<p>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<sub>2</sub> emission regulations being implemented in many jurisdictions.</p> <p>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.</p>	Related
B2 Production / Processing of Bitumen	<p>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.</p> <p>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.</p>	Related
B3 Production / Processing of Aggregate	<p>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.</p> <p>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.</p>	Related
B4 Transportation and Storage of Molten Sulphur	<p>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.</p>	Related
B5 Upgrading and Storage of Asphalt (Off-site)	<p>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.</p> <p>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.</p>	Related
B6 Transportation of Aggregate	<p>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.</p>	Related

B7 Production of Saleable Sulphur Product	<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>	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 Asphalt	The asphalt 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 Usage	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
<b>Onsite SS's during Project Operation</b>		

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 Asphalt, Drying and Hot Mixing	Fossil fuels are required to fuel the burners used to dry and heat the aggregate, bitumen and SEAM to required temperatures for mixing and paving. There may also be emission associated with the asphalt 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 asphalt storage. Facility operation may require any number of energy inputs and mechanical processes excluding those related to processing inputs and generating the paving mix 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 asphalt handling including silo filling and load-out due to asphalt temperatures and loss on heating. The emissions would primarily be associated with the quantity of asphalt consumed.  Quantities of asphalt binder consumed will be the important characteristics to be tracked.	Controlled
<b>Downstream SS's during Project Operation</b>		
B17 Transportation of Hot Mix	The hot paving mix 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	Paving mix will be applied using a paver and compacted using rollers. There may be fugitive emissions during the application and curing of the paving mix. Emissions may be dependant on the temperature and rate of diluent evaporation.  Temperature, composition and quantities of paving mix 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 paving mix 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
<b>Other</b>		

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 2.3** below. All other SS's listed previously are included.

**TABLE 2.3: Comparison of SS's**

1. Baseline Options	2. Baseline (C, R, A)	2. Project (C, R, A)	4. Include or Exclude from Quantification	5. Justification for Exclusion
<b>Upstream SS's</b>				
P1 Production of Wax Additive	N/A	Related	Exclude	Excluded due to the negligible quantity of wax added to the SEAM 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	Excluded as sulphur is a by-product of gas processing and would be produced in equivalent quantities and by the same process in the project and baseline conditions. As there will be no change in sulphur production due to the project implementation the baseline and project scenarios are functionally equivalent.
B1 Production of Molten Sulphur	Related	N/A		
P3 Production / Processing of Carbon Black	N/A	Related	Include	N/A
P4 Production / Processing of Bitumen	N/A	Related	Include	N/A
B3 Production / Processing of Bitumen	Related	N/A		
P5 Production / Processing of Aggregate	N/A	Related	Include	N/A
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	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 Asphalt (Off-site)	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition given decreased asphalt requirements and therefore it is conservative to exclude them.
B5 Upgrading and Storage of Asphalt (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 SEAM Production	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition or equivalent

B7 Production of Saleable Sulphur Product	Related	N/A	Exclude	in the project and baseline conditions given the process employed to produce SEAM versus other saleable sulphur products. As such it is conservative to exclude them.
P12 Transportation of SEAM	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely greater under the baseline condition (comparing SS P12 with SS B8).
B8 Transportation of Sulphur Product	Related	N/A	Exclude	Excluded as the emissions from transportation are negligible and likely greater under the baseline condition (comparing SS P12 with SS B8).
P13 Transportation of Asphalt	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition given decreased asphalt requirements and therefore it is conservative to exclude them.
B9 Transportation of Asphalt	Related	N/A		
P17 Fuel Extraction / Processing	N/A	Related	Include	N/A
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 Usage	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 Usage	Related	N/A		
<b>Onsite SS's</b>				
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 paving mix produced therefore it is conservative to exclude emissions from storage.
B10 Storage of Aggregate	Controlled	N/A		
P15 Storage of Asphalt, Drying and Hot Mixing	N/A	Controlled	Include	N/A
B11 Storage of Asphalt, 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 asphalt requirements and therefore it is conservative to exclude them.
B13 Silo Filling and Load-out	Controlled	N/A		
<b>Downstream SS's</b>				
P21 Transportation of Hot Mix	N/A	Related	Exclude	Excluded as in the majority of project configurations there will be no change in quantity of paving mix 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	Related	N/A		
P22 Paving	N/A	Related	Exclude	Excluded as emissions will likely be higher in the project condition and given

B18 Paving	Related	N/A		the lack of reliable data to quantify fugitive emissions from paving. Project proponents can include this SS in quantification if a reasonable means of measuring emissions is developed.
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 the project implementation, making the baseline and project scenarios functionally equivalent. Project proponents can include this SS in quantification if a reasonable means of measuring emissions is developed.
B19 Recycling or Disposal	Related	N/A		
<b>Other</b>				
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 2.4**, 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.

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

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

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

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

$\text{Emissions}_{\text{Asphalt Production}}$  = 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 Asphalt, 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

$\text{Emissions}_{\text{Asphalt Production}}$  = 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 Asphalt, Drying and Hot-mixing

**TABLE 2.4: 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
<b>Project SS's</b>						
P17 Fuel Extraction and Processing	Emissions <sub>Fuel Extraction / Processing</sub> = $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_i \text{CO}_2)$ ; $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_i \text{CH}_4)$ ; $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_i \text{N}_2\text{O})$					
	Emissions <sub>Fuel Extraction / Processing</sub>	kg of CO <sub>2E</sub>	N/A	N/A	N/A	Quantity being calculated based on fuel use under P15 Storage of Asphalt, Drying and Hot Mixing.
	Volume of Fuel Combusted for P15 / Vol. Fuel	L/ m <sup>3</sup> / other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO <sub>2</sub> Emissions Factor for Fuel Production and Processing / EF <sub>Fuel CO<sub>2</sub></sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Fuel Production and Processing / EF <sub>Fuel CH<sub>4</sub></sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Fuel Production and Processing / EF <sub>Fuel N<sub>2</sub>O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P3 Production / Processing of Carbon Black	Emissions <sub>Carbon Black Production</sub> = $\sum (\text{Mass}_{\text{SEAM}} * \% \text{C Black} * \text{EF Production}_{\text{CO}_2})$ ; $\sum (\text{Mass}_{\text{SEAM}} * \% \text{C Black} * \text{EF Production}_{\text{CH}_4})$					
	Emissions <sub>Carbon Black Production</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub>	N/A	N/A	N/A	Quantity being calculated.

	Mass of Sulphur Extended Asphalt Modifier (SEAM) Product Consumed / Mass SEAM	kg	Measured	Direct metering or reconciliation of mass received.	Continuous metering or monthly reconciliation	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Percent of Carbon Black in SEAM	%	0.02	Default value estimated from SEAM production process.	Annual	Default value of 0.02 obtained from SEAM producer. Value will be updated on an annual basis, as required.
	CO <sub>2</sub> Emissions Factor for Production of Carbon Black / EF Production <sub>CO2</sub>	kg CO <sub>2</sub> per kg carbon black	Estimated	From IPCC reference documents.	Annual	Reference values obtained from IPCC guidelines. Values are dependant on the production process.
	CH <sub>4</sub> Emissions Factor for Production of Carbon Black / EF Production <sub>CH4</sub>	kg CH <sub>4</sub> per kg carbon black	Estimated	From IPCC reference documents.	Annual	Reference values obtained from IPCC guidelines. Values are dependant on the production process.
P4 Production / Processing of Bitumen	Emissions <sub>Asphalt Production</sub> = $\sum ((\text{Mass Asphalt} * \text{EF Production}_{\text{CO}_2}) / \rho); \sum ((\text{Mass Asphalt} * \text{EF Production}_{\text{CH}_4}) / \rho); \sum ((\text{Mass Asphalt} * \text{EF Production}_{\text{N}_2\text{O}}) / \rho)$					
	Emissions <sub>Asphalt Production</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated.
	Mass of Asphalt Consumed / Mass Asphalt	kg	Measured	Direct metering of quantity of asphalt used for hot mixing or reconciliation of mass received.	Continuous metering or monthly reconciliation	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Density of Asphalt / $\rho$	kg per L	0.98	Default value	Annual	Default value for the density of heavy crude oil.

	CO <sub>2</sub> Emissions Factor for Production of Asphalt / EF Production <sub>CO2</sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Production of Asphalt / EF Production <sub>CH4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Production of Asphalt / EF Production <sub>N2O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	$Emissions_{Aggregate Production} = Mass_{Aggregate} * EF_{CO2E Aggregate Production}$					
P5 Production / Processing of Aggregate	Emissions from the production and mining of aggregate / Emissions <sub>Aggregate Production</sub>	kg of CO <sub>2E</sub>	N/A	N/A	N/A	Quantity being calculated.
	Mass of aggregate consumed / Mass <sub>Aggregate</sub>	t	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 paving mix produced and the mass of binder consumed.	Continuous metering or monthly reconciliation	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Emissions factor for aggregate production / EF <sub>CO2E Aggregate Production</sub>	kg CO <sub>2E</sub> per t aggregate	Estimated	Values provided in Appendix A.	Annual	Reference value
P15 Storage of Asphalt, Drying and Hot Mixing	$Emissions_{Hot Mixing} = Emissions_{Hot Mix Stack} + Emissions_{Fuel Usage}$					
	Emissions <sub>Hot Mixing</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot

						mixing.
$\text{Emissions}_{\text{Hot Mix Stack}} = \sum (\text{Mass}_{\text{Paving}} * \text{EF}_{\text{Mixer}_{\text{CH}_4}}) / \text{Rate} ; \sum (\text{Mass}_{\text{Paving}} * \text{EF}_{\text{Mixer}_{\text{CO}_2}}) / \text{Rate}$						
Emissions <sub>Hot Mix Stack</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub>	N/A	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 paving mix produced / Mass <sub>Paving</sub>	t	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 <sub>4</sub> / EF Mixer <sub>CH4</sub>	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 <sub>2</sub> / EF Mixer <sub>CO2</sub>	kg per hr	Measured	Direct measurement by third party sampling.	Annual		Frequency of metering is highest level possible.
Sampling Production Rate / Rate	t per hr	Measured	Direct measurement of production rate during third party sampling.	Annual		Frequency of metering is highest level possible.

Emissions <sub>Fuel Usage</sub> = $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CO}_2}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CH}_4}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{N}_2\text{O}})$						
Emissions <sub>Fuel Usage</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
Volume of Fuel Combusted / Vol. Fuel	L/ m <sup>3</sup> / other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.  Note that overall hot mix facility fuel usage data may be used given that asphalt storage, aggregate drying and hot mixing will likely represent the majority of facility fuel usage.	
CO <sub>2</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>iCO<sub>2</sub></sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.	
CH <sub>4</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>iCH<sub>4</sub></sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.	
N <sub>2</sub> O Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>iN<sub>2</sub>O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.	
<b>Baseline SS's</b>						
B14 Fuel	Emissions <sub>Fuel Extraction / Processing</sub> = $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CO}_2}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CH}_4}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{N}_2\text{O}})$					

Extraction and Processing	Emissions <sub>Fuel Extraction / Processing</sub>	kg of CO <sub>2E</sub>	N/A	N/A	N/A	Quantity being calculated based on fuel use under B11 Storage of Asphalt, Drying and Hot Mixing
	Volume of Fuel Combusted for B11 / Vol. Fuel	L/ m <sup>3</sup> / other	Measured	Historical fuel usage data or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO <sub>2</sub> Emissions Factor for Fuel Including Production and Processing / EF <sub>Fuel CO<sub>2</sub></sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Fuel Including Production and Processing / EF <sub>Fuel CH<sub>4</sub></sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Fuel Including Production and Processing / EF <sub>Fuel N<sub>2</sub>O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B2 Production / Processing of Bitumen	Emissions <sub>Asphalt Production</sub> = $\sum ((\text{Mass}_{\text{Asphalt}} * \text{Mass}_{\text{Paving}} * \text{EF Production}_{\text{CO}_2}) / \rho); \sum ((\text{Mass}_{\text{Asphalt}} * \text{Mass}_{\text{Paving}} * \text{EF Production}_{\text{CH}_4}) / \rho); \sum ((\text{Mass}_{\text{Asphalt}} * \text{Mass}_{\text{Paving}} * \text{EF Production}_{\text{N}_2\text{O}}) / \rho)$					
	Emissions <sub>Asphalt Production</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated.
	Mass of Asphalt Consumed / Mass <sub>Asphalt</sub>	kg per t paving mix	53	Default value for the quantity of asphalt per tonne of paving mix for conventional paving.	Annual	The asphalt content of conventional asphalt is taken as a default value of 5.3 percent of the paving mix weight or 53 kg per tonne of paving mix. The

						project proponent may substitute the actual mix composition at their facility if known.
	Mass of paving mix produced / Mass <sub>Paving</sub>	t	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.
	Density of Asphalt / ρ	kg per L	0.98	Default value	Annual	Default value for the density of heavy crude oil.
	CO <sub>2</sub> Emissions Factor for Production of Asphalt / EF <sub>Production CO2</sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Production of Asphalt / EF <sub>Production CH4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Production of Asphalt / EF <sub>Production N2O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B3 Production / Processing of Aggregate	$Emissions_{Aggregate Production} = (Mass_{Paving} * Mass_{Aggregate} * EF_{CO2E})$					
	Emissions from the production and mining of aggregate / Emissions <sub>Aggregate Production</sub>	kg of CO <sub>2E</sub>	N/A	N/A	N/A	Quantity being calculated.

	Mass of paving mix produced / Mass <sub>Paving</sub>	t	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 of Aggregate / Mass <sub>Aggregate</sub>	t per t paving mix	0.947	Default value for the quantity of aggregate per tonne of paving mix for conventional paving.	Annual	The aggregate content of conventional asphalt is taken as a default value of 94.7 percent of the paving mix by weight or 947 kg per tonne of paving mix. The project proponent may substitute the actual mix composition at their facility if known.
	Emissions factor for aggregate production / EF <sub>CO2E Aggregate Production</sub>	kg CO <sub>2E</sub> per t aggregate	Estimated	Values provided in Appendix A.	Annual	Reference value
B11 Storage of Asphalt, Drying and Hot Mixing	$Emissions_{Hot\ Mixing} = Emissions_{Hot\ Mix\ Stack} + Emissions_{Fuel\ Usage}$					
	Emissions <sub>Hot Mixing</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
	$Emissions_{Hot\ Mix\ Stack} = \sum (Mass_{Paving} * EF_{Mixer\ CH_4} / Rate) ; \sum (Mass_{Paving} * EF_{Mixer\ CO_2} / Rate)$					
	Emissions <sub>Hot Mix Stack</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub>	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 paving mix produced / $Mass_{Paving}$	t	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 <sub>4</sub> / EF Mixer <sub>CH4</sub>	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 asphalt paving mix.	Annual	Frequency of metering is highest level possible. If results are expressed as total organics, determination of methane 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 <sub>2</sub> / EF Mixer <sub>CO2</sub>	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 asphalt paving mix.	Annual	Frequency of metering is highest level possible.
	Sampling Production Rate / Rate	t per hr	Measured	From historical data for paving mix production rate during third party sampling used to determine emission rates.	Annual	Frequency of metering is highest level possible.
$Emissions_{Fuel\ Usage} = \sum (Vol. Fuel_i * Mass_{Paving} * EF_{Fuel_i CO_2}) ; \sum (Vol. Fuel_i * Mass_{Paving} * EF_{Fuel_i CH_4}) ; \sum (Vol. Fuel_i * Mass_{Paving} * EF_{Fuel_i N_2O})$						
	Emissions <sub>Fuel Usage</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
	Volume of Fuel Combusted / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other per t of paving mix produced	Measured	Historical facility fuel usage data obtained from direct metering or reconciliation of volume in storage (including volumes received)	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

				divided by the volume of paving mix produced over the same period.		Note that overall hot mix facility fuel usage data may be used given that asphalt storage, aggregate drying and hot mixing will represent the majority of facility fuel usage.
	Mass of paving mix produced / Mass <sub>Paving</sub>	t	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.
	CO <sub>2</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> <small>CO2</small>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> <small>CH4</small>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> <small>N2O</small>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

## 2.5.2. Contingent Data Approaches

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

## 2.6 Management of Data Quality

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill the quantification requirements 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.

### 2.6.1 Quality Assurance/Quality Control (QA/QC)

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

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

**TABLE 2.5: Contingent Data Collection Procedures**

1. Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Contingency Method	6. Frequency	7. Justify measurement or estimation and frequency
<b>Project SS's</b>						
P3 Production / Processing of Carbon Black	Mass of Sulphur Extended Asphalt Modifier (SEAM) Product Consumed / Mass SEAM	kg	Measured	Reconciliation of mass of SEAM purchased within given time period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P4 Production / Processing of Bitumen	Mass of Asphalt Consumed / Mass Asphalt	kg	Measured	Direct metering of quantity of asphalt purchased from monthly invoices from the supplier.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P5 Aggregate Production	Mass of aggregate consumed / Mass Aggregate	kg	Estimated	Reconciliation of mass of aggregate purchased within given time period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P15 Storage of Asphalt, Drying and Hot Mixing	Volume of Each Type of Fuel Consumed / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other	Measured	Use of alternate methodology presented in Appendix B or reconciliation of volume of fuel purchased within given time period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Mass Emission Rate of CH <sub>4</sub> / EF Mixer	kg per hr	Measured	Interpolation of previous and following measurements taken or use of emission factors from the US EPA's Emission Inventory.	Annual	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Mass Emission Rate of CO <sub>2</sub> / EF Mixer	kg per hr	Measured	Interpolation of previous and following measurements taken.	Annual	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Sampling Production Rate / Rate	t per hr	Measured	Interpolation of previous and following measurements taken.	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 <sup>3</sup> / other	Measured	Reconciliation of volume of fuel purchased within given time period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
<b>Baseline SS's</b>						
B2 Production / Processing of Bitumen	Mass of Paving Mix Produced / Mass Paving	kg	Measured	Reconciliation of mass of paving mix applied or distance paved and thickness of paving within given time period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
B11 Storage of Asphalt, Drying and Hot Mixing	Volume of Each Type of Fuel Consumed / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other per t paving mix produced	Measured	Use of alternate methodology presented in Appendix B or reconciliation of volume of fuel purchased within given time period divided by the volume of paving mix produced during the same period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Mass Emission Rate of CH <sub>4</sub> / EF Mixer	kg per hr	Measured	Interpolation of previous and following measurements taken or use of emission factors from the US EPA's Emission Inventory.	Annual	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Mass Emission Rate of CO <sub>2</sub> / EF Mixer	kg per hr	Measured	Interpolation of previous and following measurements taken.	Annual	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Sampling Production Rate / Rate	t per hr	Measured	Interpolation of previous and following measurements taken.	Annual	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
B14 Fuel Extraction and Processing	Volume of Fuel Combusted for B11 / Vol. Fuel	L/ m <sup>3</sup> / other	Measured	Reconciliation of volume of fuel purchased within given time period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.

## **APPENDIX A**

### **Relevant Emission Factors**

## Fossil Fuel Usage

All values interpreted from volume 1 of the technical report: A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H<sub>2</sub>S) Emissions by the Upstream Oil and Gas Industry dated September 2004 completed by Clearstone Engineering Ltd. on behalf of the Canadian Association of Petroleum Producers (CAPP).

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

<b>Diesel</b>		
<b>Production</b>		
Emissions Factor (CO <sub>2</sub> )	0.138	kg CO <sub>2</sub> per Litre
Emissions Factor (CH <sub>4</sub> )	0.0109	kg CH <sub>4</sub> per Litre
Emissions Factor (N <sub>2</sub> O)	0.000004	kg N <sub>2</sub> O per Litre
<b>Natural Gas</b>		
<b>Extraction</b>		
Emissions Factor (CO <sub>2</sub> )	0.043	kg CO <sub>2</sub> per m <sup>3</sup>
Emissions Factor (CH <sub>4</sub> )	0.0023	kg CH <sub>4</sub> per m <sup>3</sup>
Emissions Factor (N <sub>2</sub> O)	0.000004	kg N <sub>2</sub> O per m <sup>3</sup>
<b>Processing</b>		
Emissions Factor (CO <sub>2</sub> )	0.090	kg CO <sub>2</sub> per m <sup>3</sup>
Emissions Factor (CH <sub>4</sub> )	0.0003	kg CH <sub>4</sub> per m <sup>3</sup>
Emissions Factor (N <sub>2</sub> O)	0.000003	kg N <sub>2</sub> O per m <sup>3</sup>
<b>Gasoline</b>		
<b>Production</b>		
Emissions Factor (CO <sub>2</sub> )	0.138	kg CO <sub>2</sub> per Litre
Emissions Factor (CH <sub>4</sub> )	0.0109	kg CH <sub>4</sub> per Litre
Emissions Factor (N <sub>2</sub> O)	0.000004	kg N <sub>2</sub> O per Litre

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

<b>Diesel</b>		
Emissions Factor (CO <sub>2</sub> )	2.730	kg CO <sub>2</sub> per Litre
Emissions Factor (CH <sub>4</sub> )	0.000133	kg CH <sub>4</sub> per Litre
Emissions Factor (N <sub>2</sub> O)	0.0004	kg N <sub>2</sub> O per Litre
<b>Natural Gas</b>		
<b>Industrial</b>		
Emissions Factor (CO <sub>2</sub> )	1.891	kg CO <sub>2</sub> per m <sup>3</sup>
Emissions Factor (CH <sub>4</sub> )	0.000037	kg CH <sub>4</sub> per m <sup>3</sup>
Emissions Factor (N <sub>2</sub> O)	0.000033	kg N <sub>2</sub> O per m <sup>3</sup>
<b>Gasoline</b>		
<b>Industrial</b>		
Emissions Factor (CO <sub>2</sub> )	2.830	kg CO <sub>2</sub> per Litre
Emissions Factor (CH <sub>4</sub> )	0.000006	kg CH <sub>4</sub> per Litre
Emissions Factor (N <sub>2</sub> O)	0.000031	kg N <sub>2</sub> O per Litre

## Carbon Black Production

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 <sub>2</sub>	CH <sub>4</sub>	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 a study conducted by Environment Canada and the Canadian Council of Ministers of Environment (CCME) in 2002 titled *Multi-pollutant Emission Reduction Analysis Foundation (MERAFA) for the Hot-mix Asphalt Sector*.

**Table A4: Emission Intensity of Hot Mixing**

Plant Type	CO <sub>2</sub>	CH <sub>4</sub>	Units
Natural Gas Batch Mixer	0.0003	0.0001	kg / kg Asphalt
Natural Gas Drum Mix	0.0003	0.0019	kg / kg Asphalt
No. 2 Fuel Oil Batch Mixer	0.0003	4.15 E-05	kg / kg Asphalt
No. 2 Fuel Oil Drum Mixer	0.0003	0.0002	kg / kg Asphalt

### Aggregate Production

The emission factor for aggregate production was derived based on the three tables included below. An emissions factor of 9.98 kg CO<sub>2E</sub> / Tonne of Aggregate Produced will be used as it is the most conservative number.

**Table A5: QPA Emission Factor**

	Emission Factor	
Aggregate Production	<b>9.98</b>	Kg CO <sub>2E</sub> / 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
<b>Raw Materials Price Index (Non-Metallic Minerals)</b>	100	114.3
<b>Production Cost</b>	\$11.33 / T	\$12.95 / T
<b>Emissions Intensity</b>		0.8 T CO <sub>2E</sub> / \$1000 production
<b>Production Cost</b>		77.22 Tonnes of Aggregate / \$1000
<b>Emissions per Tonne Produced</b>		<b>10.36 kg CO<sub>2E</sub> / T aggregate</b>

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

**Table A7: Canadian Technical Asphalt Association Data**

	Emission Factor	
<b>Crushed Aggregate (0-20 mm)</b>	<b>10</b>	Kg CO <sub>2E</sub> / 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**

### **Alternate Methodology**

**Table B1: Alternate Methodology for calculating Fuel Usage Emissions from Drying and Hot Mixing**

B11 Storage of Asphalt, Drying and Hot Mixing	Emissions Hot Mixing = Emissions Hot Mix Stack + Emissions Fuel Usage					
	Emissions <sub>Hot Mix Stack</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
	Emissions <sub>Hot Mix Stack</sub> = $\sum(\text{Mass}_{\text{Paving}} * \text{Mass}_{\text{Asphalt}} * \text{EF}_{\text{Mixer CH}_4})$ ; $\sum(\text{Mass}_{\text{Paving}} * \text{Mass}_{\text{Asphalt}} * \text{EF}_{\text{Mixer CO}_2})$					
	Emissions <sub>Hot Mix Stack</sub>	kg of CH <sub>4</sub>	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 for CH <sub>4</sub> 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 paving mix produced / Mass <sub>Paving</sub>	t	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 of Asphalt Consumed / Mass <sub>Asphalt</sub>	kg per t paving mix	53	Quantity of asphalt per tonne of paving mix for conventional paving.	Annual	The asphalt content of conventional asphalt is taken as a default value of 5.3 percent of the paving mix weight or 53 kg per tonne of paving mix. The project proponent may substitute the actual mix composition at their facility if known.
	Mass Emission Rate of CH <sub>4</sub> / EF <sub>Mixer CH<sub>4</sub></sub>	kg per kg asphalt	Estimated	From US EPA reference documents	Annual	Emission factors obtained from from the US EPA's Emission Inventory. Values are presented for GHG's from drum and batch mixers at hot mix asphalt plants

						consumed.
Mass Emission Rate of CO <sub>2</sub> / EF Mixer CO <sub>2</sub>	kg per kg asphalt	Estimated	From US EPA reference documents.	Annual		Emission factors obtained from from the US EPA’s Emission Inventory. Values are presented for GHG’s from drum and batch mixers at hot mix asphalt plants per unit of asphalt product consumed.
$\text{Emissions}_{\text{Fuel Usage}} = \sum (\text{Mass}_{\text{Paving}} * \text{Vol. Fuel Mixing}_i * \text{EF}_{\text{Fuel}_i \text{CO}_2}) ; \sum (\text{Mass}_{\text{Paving}} * \text{Vol. Fuel Mixing}_i * \text{EF}_{\text{Fuel}_i \text{CH}_4}) ; \sum (\text{Mass}_{\text{Paving}} * \text{Vol. Fuel Mixing}_i * \text{EF}_{\text{Fuel}_i \text{N}_2\text{O}});$						
Emissions <sub>Fuel Usage</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A		Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
Mass of Paving Mix / Mass <sub>Paving</sub>	t	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.
Volume of Fuel Combusted for Mixing / Vol. Fuel Mixing <sub>i</sub>	L/ m <sup>3</sup> / other per t paving mix	Calculated	Theoretical calculation of the heat required for hot mixing and the volume of fuel required to produce this heat.	Monthly Reconciliation		Value calculated based on heat requirements, the specific heat of each component and the quantity of each component consumed.
CO <sub>2</sub> Emissions Factor for Combustion of Each Type of Fuel / EF <sub>Fuel<sub>i</sub> CO<sub>2</sub></sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual		Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
CH <sub>4</sub> Emissions Factor for Combustion of Each Type of Fuel / EF <sub>Fuel<sub>i</sub> CH<sub>4</sub></sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual		Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

	N <sub>2</sub> O Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> <small>N<sub>2</sub>O</small>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
$\text{Vol. Fuel Mixing}_i = [(\text{Mass}_{\text{Aggregate}} * C_{\text{Agg}} * (T_{\text{Paving Mix}} - T_{\text{Agg}})) + (\text{Mass}_{\text{Asphalt}} * C_{\text{Asphalt}} * (T_{\text{Paving Mix}} - T_{\text{Asphalt}}))] / (\text{HV Fuel}_i * \text{Eff})$						
	Mass of Aggregate / Mass <sub>Aggregate</sub>	kg per t paving mix	947	Default value for the quantity of aggregate per tonne of paving mix for conventional paving.	Continuous metering or monthly reconciliation	The aggregate content of conventional asphalt is taken as a default value of 94.7 percent of the paving mix by weight or 947 kg per tonne of paving mix. The project proponent may substitute the actual mix composition at their facility if known.
	Mass of Asphalt Consumed / Mass <sub>Asphalt</sub>	kg per t paving mix	53	Default value for the quantity of asphalt per tonne of paving mix for conventional paving.	Continuous metering or monthly reconciliation	The asphalt content of conventional asphalt is taken as a default value of 5.3 percent of the paving mix weight or 53 kg per tonne of paving mix. The project proponent may substitute the actual mix composition at their facility if known.
	Specific Heat Capacity of Aggregate / C <sub>Agg</sub>	kJ per kg degree Celsius	0.837	Constant	N/A	Accepted value.
	Specific Heat Capacity of Asphalt / C <sub>Asphalt</sub>	kJ per kg degree Celsius	2.093	Constant	N/A	Accepted value.
	Temperature of Paving Mix Production / T <sub>Paving Mix</sub>	degrees C	Estimated	Direct metering of typical mix temperature prior to use of SEAM or determination from industry best practices for typical hot mix paving production temperatures.	Annual	Represents production temperature of the paving mix. For conventional asphalt a default value of 152 degrees Celsius may be used if site specific temperature data is not available.

	Temperature of Aggregate / T <sub>Agg</sub>	degrees C	Estimated	Direct metering of typical aggregate temperature at the time of mixing or determination from industry best practices from industry best practices for typical temperature of asphalt at time of hot mixing.	Annual	Represents temperature of aggregate at time of mixing / addition of binder.
	Temperature of Asphalt / T <sub>Asphalt</sub>	degrees C	Estimated	Direct metering of typical asphalt temperature at the time of mixing and prior to use of SEAM or determination from industry best practices from industry best practices for typical temperature of asphalt at time of hot mixing.	Annual	Represents temperature of asphalt at time of mixing / addition to the hot mixer.
	Heat Value Fuel / HV Fuel <sub>i</sub>	kJ per m3	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/m3.
	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. May be updated by the project developer depending on the combustion efficiency of the burner / dryer used at the project site.
P15 Storage of Asphalt, Drying and Hot Mixing	$Emissions_{Hot\ Mixing} = Emissions_{Hot\ Mix\ Stack} + Emissions_{Fuel\ Usage}$					
	Emissions <sub>Hot Mixing</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
	$Emissions_{Hot\ Mix\ Stack} = \sum (Mass_{Asphalt} * EF_{Mixer\ CH4})$					
Emissions <sub>Hot Mix Stack</sub>	kg of CH <sub>4</sub>	N/A	N/A	N/A	Note that the emissions from the hot mix stack would need to be quantified at facilities where hot mix stack monitoring includes	

						only mixing process emissions. This parameter would not be calculated at facilities where stack emissions monitoring is conducted at a point that includes both mixing process emissions and ducted emissions from fuel combustion. In this case these emissions would already have been accounted for under the fuel usage variable, described above.
	Mass of Asphalt Consumed / $Mass_{Asphalt}$	kg	Measured	Direct metering of quantity of asphalt used for hot mixing or reconciliation of mass received.	Continuous metering or monthly reconciliation	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Mass Emission Rate of CH <sub>4</sub> / EF Mixer <sub>CH4</sub>	kg per kg asphalt	Estimated	From US EPA reference documents.	Annual	Emission factors obtained from from the US EPA's Emission Inventory. Values are presented for drum and batch mixers at hot mix asphalt plants per unit of asphalt product consumed.
	Mass Emission Rate of CO <sub>2</sub> / EF Mixer <sub>CO2</sub>	kg per kg asphalt	Estimated	From US EPA reference documents.	Annual	Emission factors obtained from from the US EPA's Emission Inventory. Values are presented for drum and batch mixers at hot mix asphalt plants per unit of asphalt product consumed.
	$Emissions_{Fuel\ Usage} = \sum (Mass_{Paving} * Vol. Fuel Mixing_i * EF_{Fuel_i CO2}) ; \sum (Mass_{Paving} * Vol. Fuel Mixing_i * EF_{Fuel_i CH4}) ; \sum (Mass_{Paving} * Vol. Fuel Mixing_i * EF_{Fuel_i N2O}) ;$					
	Emissions <sub>Fuel Usage</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
	Mass of Paving Mix / $Mass_{Paving}$	t	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.
Volume of Fuel Combusted for Mixing / Vol. Fuel Mixing <sub>i</sub>	L/ m <sup>3</sup> / other per t paving mix	Measured	Theoretical calculation of the heat required for hot mixing and the volume of fuel required to produce this heat.	Monthly Reconciliation		Value calculated based on heat requirements, the specific heat of each component and the quantity of each component consumed.
$\text{Vol. Fuel Mixing}_i = ((\text{Vol. Fuel Mixing}_{i \text{Aggregate}} + \text{Vol. Fuel Mixing}_{i \text{Asphalt}} + \text{Vol. Fuel Mixing}_{i \text{SEAM}}) / (\text{HV Fuel}_i * \text{Eff}))$						
	$\text{Vol. Fuel Mixing}_{i \text{Aggregate}} = (\text{Mass}_{\text{Aggregate}} * C_{\text{Agg}} * (T_{\text{Paving Mix}} - T_{\text{Agg}}))^1$					
	$\text{Vol. Fuel Mixing}_{i \text{Asphalt}} = (\text{Mass}_{\text{Asphalt}} * C_{\text{Asphalt}} * (T_{\text{Paving Mix}} - T_{\text{Asphalt}}))$					
	$\text{Vol. Fuel Mixing}_{i \text{SEAM}} = ((\text{Mass}_{\text{SEAM}} * C_{\text{Sulphur}} * (T_{\text{Paving Mix}} - T_{\text{SEAM}})) + (\text{Mass}_{\text{SEAM}} * \text{LH}_{\text{Sulphur}}))$					
Mass of Aggregate / Mass <sub>Aggregate</sub>	kg per t paving mix	Measured	Direct metering or reconciliation of volumes received.	Continuous metering or monthly reconciliation.		Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
Mass of Asphalt / Mass <sub>Asphalt</sub>	kg per t paving mix	Measured	Direct metering or reconciliation of volumes purchased.	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 of SEAM / Mass <sub>SEAM</sub>	kg per t paving mix	Measured	Direct metering or reconciliation of volumes purchased.	Continuous metering or monthly reconciliation.		Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
Specific Heat Capacity of Aggregate / C <sub>Agg</sub>	kJ per kg degree Celsius	0.837	Constant	N/A		Accepted value.
Specific Heat Capacity of Asphalt / C <sub>Asphalt</sub>	kJ per kg degree Celsius	2.093	Constant	N/A		Accepted value.

<sup>1</sup> Alternatively, the volume of fuel required to heat and dry aggregate may be calculated from manufacturer specifications and the moisture content of the aggregate. A suitable methodology is presented in Table B2.

	Asphalt					
	Specific Heat Capacity of Sulphur / C <small>Sulphur</small>	kJ per kg degree Celsius	0.710	Constant	N/A	Accepted value.
	Latent Heat of Melting of Sulphur / LH <small>Sulphur</small>	kJ per kg	39.2	Constant	N/A	Accepted value. Represents the latent heat required to melt SEAM product.
	Temperature of Paving Mix Production / T <small>Paving Mix</small>	degrees C	Estimated	Direct metering of typical mix temperature using SEAM paving mix or determination from industry best practices for typical hot mix paving production temperatures.	Annual	Represents production temperature of the paving mix. For conventional asphalt a default value of 152 degrees Celsius may be used.
	Temperature of Aggregate / T <small>Agg</small>	degrees C	Estimated	Direct metering of typical aggregate temperature at the time of mixing or determination from industry best practices for typical hot mix paving production temperatures.	Annual	Represents temperature of aggregate at time of mixing / addition of binder.
	Temperature of Asphalt / T <sub>Asphalt</sub>	degrees C	Estimated	Direct metering of typical asphalt temperature at the time of mixing or determination from industry best practices for typical hot mix paving production temperatures.	Annual	Represents temperature of asphalt at time of mixing / addition to the hot mixer.
	Temperature of SEAM / T <sub>SEAM</sub>	degrees C	Estimated	Ambient temperature at the hot mix facility.	Annual	Represents temperature of SEAM product at time of mixing / addition to the hot mixer. Typically this will be ambient

						temperature.
	Heat Value Fuel / HV Fuel <sub>i</sub>	kJ per m <sup>3</sup>	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/m <sup>3</sup> .
	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.
	CO <sub>2</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> CO <sub>2</sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> CH <sub>4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> N <sub>2</sub> O	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

**Table B2: Alternate Methodology for Calculating the Volume of Fuel Required to Heat and Dry Aggregate**

$\text{Vol. Fuel Mixing}_i \text{ Aggregate} = \text{Vol. Fuel}_i * \text{Mass}_{\text{Aggregate}}$					
Vol. Fuel Mixing <sub>i</sub> Aggregate	L/ m <sup>3</sup> / other per t paving mix	N/A	N/A	N/A	Quantity being calculated.
Vol. Fuel Combusted for Aggregate Drying / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other per t aggregate	Estimated	From manufacturer specifications of burner fuel consumption.		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.
Mass of Aggregate / Mass <sub>Aggregate</sub>	t per t paving mix	0.947	Default value based on the mass of aggregate per tonne of conventional asphalt paving mix.	Default value	Accepted value for the quantity of aggregate in conventional asphalt paving mix.

## **APPENDIX C**

### **Methodology to Calculate Additional Emission Reductions from Reduced Asphalt Pavement Thickness on a Project by Project Basis**

The alternate methodology outlined below may be applied on a case by case basis for projects for which the use of SEAM can be proven to reduce the thickness of asphalt pavement required.

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the equations provided below and the methodologies outlined in **TABLE C1**, 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:

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

$$\begin{aligned} \text{Emissions}_{\text{Baseline}} = & \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Aggregate Production}} \\ & + \text{Emissions}_{\text{Asphalt Production}} + \text{Emissions}_{\text{Aggregate Transportation}} \\ & + \text{Emissions}_{\text{Asphalt Transportation}} + \text{Emissions}_{\text{Hot Mixing}} \\ & + \text{Emissions}_{\text{Paving Mix Transportation}} \end{aligned}$$

$$\begin{aligned} \text{Emissions}_{\text{Project}} = & \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Carbon Black Production}} \\ & + \text{Emissions}_{\text{Aggregate Production}} + \text{Emissions}_{\text{Asphalt Production}} \\ & + \text{Emissions}_{\text{Aggregate Transportation}} + \text{Emissions}_{\text{Asphalt Transportation}} \\ & + \text{Emissions}_{\text{Hot Mixing}} + \text{Emissions}_{\text{Paving Mix Transportation}} \end{aligned}$$

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

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

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

$\text{Emissions}_{\text{Aggregate Transportation}}$  = emissions under SS B6 Transportation of Aggregate

$\text{Emissions}_{\text{Asphalt Transportation}}$  = emissions under SS B9 Transportation of Asphalt

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

$\text{Emissions}_{\text{Paving Mix Transportation}}$  = emissions under SS B17 Transportation of Hot Mix

$\text{Emissions}_{\text{Project}}$  = 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

Emissions<sub>Asphalt Production</sub> = emissions under SS P4 Production / Processing of Bitumen

Emissions<sub>Aggregate Production</sub> = emissions under SS P5 Production / Processing of Aggregate

Emissions<sub>Aggregate Transportation</sub> = emissions under SS P10 Transportation of Aggregate

Emissions<sub>Asphalt Transportation</sub> = emissions under SS P13 Transportation of Asphalt

Emissions<sub>Hot Mixing</sub> = emissions under SS P15 Storage of Asphalt, Drying and Hot-mixing

Emissions<sub>Paving Mix Transportation</sub> = emissions under SS P21 Transportation of Hot Mix

**TABLE C1: 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
<b>Project SS's</b>						
P17 Fuel Extraction and Processing	Emissions <sub>Fuel Extraction / Processing</sub> = $\sum (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{CO}_2}) ; \sum (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{CH}_4}) ; \sum (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{N}_2\text{O}})$					
	Emissions <sub>Fuel Extraction / Processing</sub>	kg of CO <sub>2E</sub>	N/A	N/A	N/A	Quantity being calculated based on fuel use under P15 Storage of Asphalt, Drying and Hot Mixing.
	Volume of Fuel Combusted for P15 / Vol. Fuel	L/ m <sup>3</sup> / other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation per project.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO <sub>2</sub> Emissions Factor for Fuel Production and Processing / EF <sub>Fuel CO<sub>2</sub></sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Fuel Production and Processing / EF <sub>Fuel CH<sub>4</sub></sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Fuel Production and Processing / EF <sub>Fuel N<sub>2</sub>O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P3 Production /	Emissions <sub>Carbon Black Production</sub> = $\sum (\text{Mass}_{\text{SEAM}} * \% \text{C Black} * \text{EF}_{\text{Production CO}_2}) ; \sum (\text{Mass}_{\text{SEAM}} * \% \text{C Black} * \text{EF}_{\text{Production CH}_4})$					

Processing of Carbon Black	Emissions <sub>Carbon Black Production</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub>	N/A	N/A	N/A	Quantity being calculated.
	Mass of Sulphur Extended Asphalt Modifier (SEAM) Product Consumed / Mass <sub>SEAM</sub>	kg	Measured	Direct metering or reconciliation of mass received.	Continuous metering or monthly reconciliation per project.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Percent of Carbon Black in SEAM	%	0.02	Default value estimated from SEAM production process.	Annual	Default value of 0.02 obtained from SEAM producer. Value will be updated on an annual basis, as required.
	CO <sub>2</sub> Emissions Factor for Production of Carbon Black / EF <sub>Production<sub>CO2</sub></sub>	kg CO <sub>2</sub> per kg carbon black	Estimated	From IPCC reference documents.	Annual	Reference values obtained from IPCC guidelines. Values are dependant on the production process.
	CH <sub>4</sub> Emissions Factor for Production of Carbon Black / EF <sub>Production<sub>CH4</sub></sub>	kg CH <sub>4</sub> per kg carbon black	Estimated	From IPCC reference documents.	Annual	Reference values obtained from IPCC guidelines. Values are dependant on the production process.
P4 Production / Processing of Bitumen	Emissions <sub>Asphalt Production</sub> = $\sum ((\text{Mass Asphalt} * \text{EF Production}_{\text{CO}_2}) / \rho)$ ; $\sum ((\text{Mass Asphalt} * \text{EF Production}_{\text{CH}_4}) / \rho)$ ; $\sum ((\text{Mass Asphalt} * \text{EF Production}_{\text{N}_2\text{O}}) / \rho)$					
	Emissions <sub>Asphalt Production</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated.
	Mass of Asphalt Consumed / Mass Asphalt	kg	Measured	Direct metering of quantity of asphalt used for hot mixing or reconciliation of mass received.	Continuous metering or monthly reconciliation per project.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Density of Asphalt / $\rho$	kg per L	0.98	Default value	Annual	Default value for the density of heavy crude oil.

	CO <sub>2</sub> Emissions Factor for Production of Asphalt / EF Production <sub>CO2</sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Production of Asphalt / EF Production <sub>CH4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Production of Asphalt / EF Production <sub>N2O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	$Emissions_{Aggregate Production} = Mass_{Aggregate} * EF_{CO2E Aggregate Production}$					
P5 Production / Processing of Aggregate	Emissions from the production and mining of aggregate / Emissions <sub>Aggregate Production</sub>	kg of CO <sub>2E</sub>	N/A	N/A	N/A	Quantity being calculated.
	Mass of aggregate consumed / Mass <sub>Aggregate</sub>	t	Measured	Direct measurement of mass of aggregate consumed at the hot mix facility, reconciliation of mass received or determination as the difference between the mass of paving mix produced and the mass of binder consumed.	Continuous metering or monthly reconciliation per project.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Emissions factor for aggregate production / EF <sub>CO2E Aggregate Production</sub>	kg CO <sub>2E</sub> per t aggregate	Estimated	Values provided in Appendix A.	Annual	Reference value
P10 Transportation of Aggregate	$Emissions_{Aggregate Transportation} = \sum ((\# Loads_{Job Number i} * Distance_{Job Number i} * Fuel Eff_{Job Number i} * EF_{Fuel CO2}) ; \sum ((\# Loads_{Job Number i} * Distance_{Job Number i} * Fuel Eff_{Job Number i} * EF_{Fuel CH4}) ; \sum ((\# Loads_{Job Number i} * Distance_{Job Number i} * Fuel Eff_{Job Number i} * EF_{Fuel N2O}))$					

	Emissions <sub>Aggregate Transportation</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated.
	Number of Loads for Each Job / # Loads <sub>Job Number i</sub>	-	Measured	Number of loads recorded.	Every load recorded upon arrival at the site.	Measuring the percent of total load weight would be an incremental industry practice.
	Distance Driven for each Job / Distance <sub>Job Number i</sub>	km	Measured	Distance each load travels.	Per project	The distance of most probable route is measured once for each source of aggregate for each project.
	Fuel Efficiency of the vehicle used for each job / Fuel Eff <sub>Job Number i</sub>	L per 100 km	Estimated	Volume of fuel use is divided by distance travelled.	Annual	This method is conservative as it incorporates all travel time and idling.
	CO <sub>2</sub> Emissions Factor for Each Type of Fuel / EF <sub>Fuel i CO2</sub>	kg CO <sub>2</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Each Type of Fuel / EF <sub>Fuel i CH4</sub>	kg CH <sub>4</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Each Type of Fuel / EF <sub>Fuel i N2O</sub>	kg N <sub>2</sub> O per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P13 Transportation of Asphalt	$\text{Emissions}_{\text{Asphalt Transportation}} = \sum (\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF}_{\text{Fuel CO}_2}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF}_{\text{Fuel CH}_4}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF}_{\text{Fuel N}_2\text{O}})$					
	Emissions <sub>Binder Transportation</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated.

	Number of Loads for Each Job / # Loads <sub>Job Number i</sub>	-	Measured	Number of loads recorded.	Every load recorded upon arrival at the site.	Measuring the percent of total load weight would be an incremental industry practice.
	Distance Driven for each Job / Distance <sub>Job Number i</sub>	km	Measured	Distance each load travels.	Per project	The distance of most probable route is measured once for each source of asphalt for each project.
	Fuel Efficiency of the vehicle used for each job/Fuel Eff <sub>Job Number i</sub>	L per 100 km	Estimated	Volume of fuel use is divided by distance travelled.	Annual	This method is conservative as it incorporates all travel time and idling.
	CO <sub>2</sub> Emissions Factor for Each Type of Fuel / EF <sub>Fuel i CO2</sub>	kg CO <sub>2</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Each Type of Fuel / EF <sub>Fuel i CH4</sub>	kg CH <sub>4</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Each Type of Fuel / EF <sub>Fuel i N2O</sub>	kg N <sub>2</sub> O per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P15 Storage of Asphalt, Drying and Hot Mixing	Emissions <sub>Hot Mixing</sub> = Emissions <sub>Hot Mix Stack</sub> + Emissions <sub>Fuel Usage</sub>					
	Emissions <sub>Hot Mixing</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
	Emissions <sub>Hot Mix Stack</sub> = $\sum (\text{Mass Paving} * \text{EF Mixer}_{\text{CH}_4}) / \text{Rate}$ ; $\sum (\text{Mass Paving} * \text{EF Mixer}_{\text{CO}_2}) / \text{Rate}$					
	Emissions <sub>Hot Mix Stack</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub>	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 for CH <sub>4</sub> 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 paving mix produced / Mass <sub>paving</sub>	t	Measured	Direct metering or reconciliation of quantity delivered to trucks for load-out.	Continuous metering or monthly reconciliation per project.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Mass Emission Rate of CH <sub>4</sub> / EF Mixer <sub>CH4</sub>	kg per hr	Measured	Direct measurement by third party sampling.	Annual	Frequency of metering is highest level possible. If results are expressed as total organics, conversion to methane 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 <sub>2</sub> / EF Mixer <sub>CO2</sub>	kg per hr	Measured	Direct measurement by third party sampling.	Annual	Frequency of metering is highest level possible.
	Sampling Production Rate / Rate	t per hr	Measured	Direct measurement of production rate during third party sampling.	Annual	Frequency of metering is highest level possible.
	$Emissions_{Fuel\ Usage} = \sum (Vol. Fuel_i * EF_{Fuel_i CO2}) ; \sum (Vol. Fuel_i * EF_{Fuel_i CH4}) ; \sum (Vol. Fuel_i * EF_{Fuel_i N2O})$					
	Emissions <sub>Fuel Usage</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
	Volume of Fuel Combusted / Vol. Fuel	L/ m <sup>3</sup> / other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation

					per project.	provides for reasonable diligence.
	CO <sub>2</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i CO2</sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i CH4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i N2O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P21 Transportation of Hot Mix	$\text{Emissions}_{\text{Hot Mix Transportation}} = \sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{CO2}}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{CH4}}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{N2O}})$					
	Emissions <sub>Hot Mix Transportation</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated.
	Number of Loads for Each Job / # Loads <sub>Job Number i</sub>	-	Measured	Number of loads recorded.	Every load recorded upon arrival at the site.	Measuring the percent of total load weight would be an incremental industry practice.
	Distance Driven for each Job / Distance <sub>Job Number i</sub>	km	Measured	Distance each load travels.	Per project	The distance of most probable route between the mixing and paving site is measured once for each project.
	Fuel Efficiency of the vehicle used for each job / Fuel Eff <sub>Job Number i</sub>	L per 100 km	Estimated	Volume of fuel use is divided by distance travelled.	Annual	This method is conservative as it incorporates all travel time and idling.

	CO <sub>2</sub> Emissions Factor for Each Type of Fuel / EF Fuel <sub>i CO2</sub>	kg CO <sub>2</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Each Type of Fuel / EF Fuel <sub>i CH4</sub>	kg CH <sub>4</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Each Type of Fuel / EF Fuel <sub>i N2O</sub>	kg N <sub>2</sub> O per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
<b>Baseline SS's</b>						
B14 Fuel Extraction and Processing	Emissions <sub>Fuel Extraction / Processing</sub> = $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i \text{CO}_2}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i \text{CH}_4}) ; \sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i \text{N}_2\text{O}})$					
	Emissions <sub>Fuel Extraction / Processing</sub>	kg of CO <sub>2</sub> e	N/A	N/A	N/A	Quantity being calculated based on fuel use under B11 Storage of Asphalt, Drying and Hot Mixing.
	Volume of Fuel Combusted for B11 / Vol. Fuel	L/ m <sup>3</sup> / other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation per project.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO <sub>2</sub> Emissions Factor for Fuel Including Production and Processing / EF Fuel <sub>CO2</sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Fuel Including Production and Processing / EF Fuel <sub>CH4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

	N <sub>2</sub> O Emissions Factor for Fuel Including Production and Processing / EF Fuel N <sub>2</sub> O	kg N <sub>2</sub> O per L / m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B2 Production / Processing of Asphalt	Emissions <sub>Asphalt Production</sub> = $\sum ((\text{Length}_{\text{Road}} * \text{Mass}_{\text{Asphalt}} * \text{Mass}_{\text{Paving Mix / km}} * \text{EF Production}_{\text{CO2}}) / \rho)$ ; $\sum ((\text{Length}_{\text{Road}} * \text{Mass}_{\text{Asphalt}} * \text{Mass}_{\text{Paving Mix / km}} * \text{EF Production}_{\text{CH4}}) / \rho)$ ; $\sum ((\text{Length}_{\text{Road}} * \text{Mass}_{\text{Asphalt}} * \text{Mass}_{\text{Paving Mix / km}} * \text{EF Production}_{\text{N2O}}) / \rho)$					
	Emissions <sub>Asphalt Production</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on-site is likely aggregated for each of these SS's.
	Length of road paved / Length <sub>Road</sub>	km	Measured	Direct Measurement	Monthly	Direct measurement is standard practice and highest level possible.
	Mass of paving mix consumed per km of road / Mass <sub>Paving Mix / km</sub>	t paving mix per km	Estimated	Reconciliation of mass of paving mix required from historical data for typical thickness of pavement and base / under-material or use of default value based on industry common practice or modelling.	Monthly	Project specification, modelling or default based on most accurate data available.
	Mass of Asphalt Consumed / Mass <sub>Asphalt</sub>	kg per t paving mix	53	Default value for the quantity of asphalt used for hot mixing.	Annual	The asphalt content of conventional asphalt is 5.3 percent of the paving mix weight or 53 kg per tonne of paving mix. A Project specific value may also be specified.
	Density of Asphalt / $\rho$	kg per L	0.98	Default value	Annual	Default value for the density of heavy crude oil.

	CO <sub>2</sub> Emissions Factor for Production of Asphalt / EF Production <sub>CO2</sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Production of Asphalt / EF Production <sub>CH4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Production of Asphalt / EF Production <sub>N2O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B3 Production / Processing of Aggregate	$Emissions_{Aggregate Production} = Length_{Road} * Mass_{Paving Mix / km} * Mass_{Aggregate} * EF_{CO2E}$					
	Emissions from the production and mining of aggregate / Emissions <sub>Aggregate Production</sub>	kg of CO <sub>2E</sub>	N/A	N/A	N/A	Quantity being calculated.
	Length of road paved / Length <sub>Road</sub>	km	Measured	Direct Measurement	Monthly	Direct measurement is standard practice and highest level possible.
	Mass of paving mix consumed per km of road / Mass <sub>Paving Mix / km</sub>	t paving mix per km	Estimated	Reconciliation of mass of paving mix required from historical data for typical thickness of pavement and base / under-material or use of default value based on industry common practice.	Monthly	Project specification or default based on most accurate data available.
	Mass of Aggregate Consumed / Mass <sub>Aggregate</sub>	t per t paving mix	0.947	Default value for the quantity of aggregate used for hot mixing.	Annual	The aggregate content of conventional asphalt is 94.7 percent of the paving mix weight or 947 kg per tonne of paving mix. A Project specific value may also be specified.

	Emissions factor for aggregate production / EF CO2E Aggregate Production	kg CO <sub>2E</sub> per t aggregate	Estimated	Values provided in Appendix A.	Annual	Reference value
B6 Transportation of Aggregate	$\text{Emissions}_{\text{Aggregate Transportation}} = \sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{CO}_2}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{CH}_4}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{N}_2\text{O}})$					
	Emissions <sub>Aggregate Transportation</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated.
	Number of Loads for Each Job / # Loads <sub>Job Number i</sub>	-	Estimated	Divide theoretical mass of aggregate used by load size.	Per project	Estimated based on project or a standard load size.
	Distance Driven for each Job / Distance <sub>Job Number i</sub>	km	Estimated	Distance each load travels in the project condition.	Per project	The distance of most probable route is measured once for each source of aggregate for each project.
	Fuel Efficiency of the vehicle used for each job/ Fuel Eff <sub>Job Number i</sub>	L per 100 km	Estimated	Fuel efficiency from project condition.	Annual	This method is conservative as it incorporates all travel time and idling.
	CO <sub>2</sub> Emissions Factor for Each Type of Fuel / EF Fuel <sub>i CO2</sub>	kg CO <sub>2</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Each Type of Fuel / EF Fuel <sub>i CH4</sub>	kg CH <sub>4</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Each Type of Fuel / EF Fuel <sub>i N2O</sub>	kg N <sub>2</sub> O per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

B9 Transportation of Asphalt	$\text{Emissions}_{\text{Asphalt Transportation}} = \sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{CO}_2}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{CH}_4}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{N}_2\text{O}})$					
	Emissions <sub>Asphalt Transportation</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated.
	Number of Loads for Each Job Number / # Loads <sub>Job Number i</sub>	-	Estimated	Divide theoretical mass of asphalt used by load size.	Per project	Measuring the percent of total load weight would be an incremental industry practice.
	Distance Driven for each Job / Distance <sub>Project i</sub>	km	Estimated	Distance each load travels in the project condition.	Per project	The distance of most probable route is measured once for each source of binder for each project.
	Fuel Efficiency of the vehicle used for each job / Fuel Eff <sub>Project i</sub>	L per 100 km	Estimated	Fuel Efficiency from project condition.	Annual	This method is conservative as it incorporates all travel time and idling.
	CO <sub>2</sub> Emissions Factor for Each Type of Fuel / EF <sub>Fuel i CO2</sub>	kg CO <sub>2</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Each Type of Fuel / EF <sub>Fuel i CH4</sub>	kg CH <sub>4</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Each Type of Fuel / EF <sub>Fuel i N2O</sub>	kg N <sub>2</sub> O per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B11 Storage of Asphalt, Drying and Hot Mixing	$\text{Emissions}_{\text{Hot Mixing}} = \text{Emissions}_{\text{Hot Mix Stack}} + \text{Emissions}_{\text{Fuel Usage}}$					
	Emissions <sub>Hot Mixing</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and

					hot mixing.
$\text{Emissions}_{\text{Hot Mix Stack}} = \sum ((\text{Length}_{\text{Road}} * \text{Mass}_{\text{Paving Mix / km}} * \text{EF}_{\text{Mixer}_{\text{CH}_4}}) / \text{Rate}) ; \sum ((\text{Length}_{\text{Road}} * \text{Mass}_{\text{Paving Mix / km}} * \text{EF}_{\text{Mixer}_{\text{CO}_2}}) / \text{Rate})$					
Emissions <sub>Hot Mix Stack</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub>	N/A	N/A	N/A	<p>Quantity must be calculated if stack monitoring includes only the emissions from the mixing process.</p> <p>This parameter would not be calculated for CH<sub>4</sub> 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.</p>
Length of road paved / Length <sub>Road</sub>	km	Measured	Direct Measurement	Monthly	Direct measurement is standard practice and highest level possible.
Mass of paving mix consumed per km of road / Mass <sub>Paving Mix / km</sub>	t paving mix per km	Estimated	Reconciliation of mass of paving mix required from historical data for typical thickness of pavement and base / under-material or use of default value based on industry common practice or modelling.	Monthly	Project specification, modelling or default based on most accurate data available.
Mass Emission Rate of CH <sub>4</sub> / EF <sub>Mixer<sub>CH4</sub></sub>	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 asphalt paving mix.	Annual	Frequency of metering is highest level possible. If results are expressed as total organics, conversion to methane 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 <sub>2</sub> / EF <sub>Mixer<sub>CO2</sub></sub>	kg per hr	Measured	From three years of historical data from third party sampling of the	Annual	Frequency of metering is highest level possible.

				mass emission rate when the facility was using conventional asphalt paving mix.		
Sampling Production Rate / Rate	t per hr	Measured		From historical data for paving mix production rate during third party sampling used to determine emission rates.	Annual	Frequency of metering is highest level possible.
$\text{Emissions}_{\text{Fuel Usage}} = \sum (\text{Vol. Fuel}_i * \text{Mass Paving} * \text{EF}_{\text{Fuel}_i \text{CO}_2}) ; \sum (\text{Vol. Fuel}_i * \text{Mass Paving} * \text{EF}_{\text{Fuel}_i \text{CH}_4}) ; \sum (\text{Vol. Fuel}_i * \text{Mass Paving} * \text{EF}_{\text{Fuel}_i \text{N}_2\text{O}})$						
Emissions <sub>Fuel Usage</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A		N/A	N/A	Quantity being calculated in aggregate form as fuel usage is likely aggregated for asphalt storage, aggregate drying and hot mixing.
Volume of Fuel Combusted / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other per t of paving mix produced	Measured		Historical facility fuel usage data obtained from direct metering or reconciliation of volume in storage (including volumes received) divided by the historical volume of paving mix produced over the same period.	Continuous metering or monthly reconciliation per project.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
Mass of paving mix produced / Mass <sub>Paving</sub>	t	Measured		Direct metering or reconciliation of quantity delivered to trucks for load-out.	Continuous metering or monthly reconciliation per project.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
CO <sub>2</sub> Emissions Factor for Combustion of Each Type of Fuel / EF <sub>Fuel<sub>i</sub>CO<sub>2</sub></sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated		From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

	CH <sub>4</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> CH <sub>4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <sub>2</sub> O Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> N <sub>2</sub> O	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B17 Transportation of Paving Mix	$\text{Emissions}_{\text{Paving Mix Transportation}} = \sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{CO}_2}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{CH}_4}) ;$ $\sum ((\# \text{ Loads}_{\text{Job Number } i} * \text{Distance}_{\text{Job Number } i} * \text{Fuel Eff}_{\text{Job Number } i} * \text{EF Fuel}_{\text{N}_2\text{O}})$					
	Emissions <sub>Paving Mix Transportation</sub>	kg of CO <sub>2</sub> ; CH <sub>4</sub> ; N <sub>2</sub> O	N/A	N/A	N/A	Quantity being calculated.
	Number of Loads for Each Job / # Loads <sub>Job Number i</sub>	-	Estimated	Divide theoretical mass of paving mix used by load size.	Per project	Estimated based on project or a standard load size.
	Distance Driven for each Job / Distance <sub>Job Number i</sub>	km	Estimated	Distance each load travels in the project condition.	Per project	The distance of most probable route between the hot mix and paving site is measured once for each project.
	Fuel Efficiency of the vehicle used for each job/ Fuel Eff <sub>Job Number i</sub>	L per 100 km	Estimated	Fuel efficiency from project condition.	Annual	This method is conservative as it incorporates all travel time and idling.
	CO <sub>2</sub> Emissions Factor for Each Type of Fuel / EF Fuel <sub>i</sub> CO <sub>2</sub>	kg CO <sub>2</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Each Type of Fuel / EF Fuel <sub>i</sub> CH <sub>4</sub>	kg CH <sub>4</sub> per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

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	N <sub>2</sub> O Emissions Factor for Each Type of Fuel / EF Fuel <sub>i</sub> N <sub>2</sub> O	kg N <sub>2</sub> O per L, m <sup>3</sup> or other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
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