



**Blue Source**  
*Canada*

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

**October 2008**

## Table of Contents

<b>1.0 Project and Methodology Scope and Description.....</b>	<b>1</b>
1.1 Protocol Scope and Description.....	1
1.2 Glossary of New Terms .....	5
<b>2.0 Quantification Development and Justification.....</b>	<b>7</b>
2.1 Identification of Sources and Sinks (SS's) for the Project.....	7
2.2 Identification of Baseline.....	14
2.3 Identification of SS's for the Baseline .....	14
2.4 Selection of Relevant Project and Baseline SS's.....	20
2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's .....	24
2.5.1 Quantification Approaches .....	24
2.5.2. Contingent Data Approaches .....	37
2.6 Management of Data Quality.....	37
2.6.1 Record Keeping .....	37
2.6.1 Quality Assurance/Quality Control (QA/QC) .....	37
<b>APPENDIX A.....</b>	<b>41</b>
<b>APPENDIX B.....</b>	<b>45</b>
<b>APPENDIX C.....</b>	<b>53</b>

## List of Figures

FIGURE 1.1	Process Flow Diagram for Project Condition	3
FIGURE 1.2	Process Flow Diagram for Baseline Condition	4
FIGURE 2.1	Project Element Life Cycle Chart	8
FIGURE 2.2	Baseline Element Life Cycle Chart	15

## List of Tables

TABLE 2.1	Project SS's	9
TABLE 2.2	Baseline SS's	16
TABLE 2.3	Comparison of SS's	21
TABLE 2.4	Quantification Procedures	25
TABLE 2.5	Contingent Data Collection Procedures	39

## 1.0 Project and Methodology Scope and Description

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

It should be noted that this protocol in no way indicates that the use of Sulphur Extended Asphalt Modifier (SEAM) is an accepted alternative to conventional bitumen binder for paving projects in Alberta. As such, approval from the relevant government authority is required prior to the use of such products.

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

### 1.1 Protocol Scope and Description

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

This protocol is intended to be applied to hot mix facilities in the hot mix asphalt industry. The sulphur product being substituted for bitumen must be either 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 further reduce hot mix asphalt production and compaction temperatures. Note however that reduced hot mix asphalt production and compaction temperatures are anticipated for hot mix facilities using SEAM without wax additives, and this protocol applies to hot mix facilities using either formulation of SEAM. This protocol is not applicable to project proponents substituting other products for bitumen binder in hot mix asphalt, 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 mix asphalt 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 sulphur product with a wax additive (i.e. SEAM plus) to further lower mix and compaction temperatures.

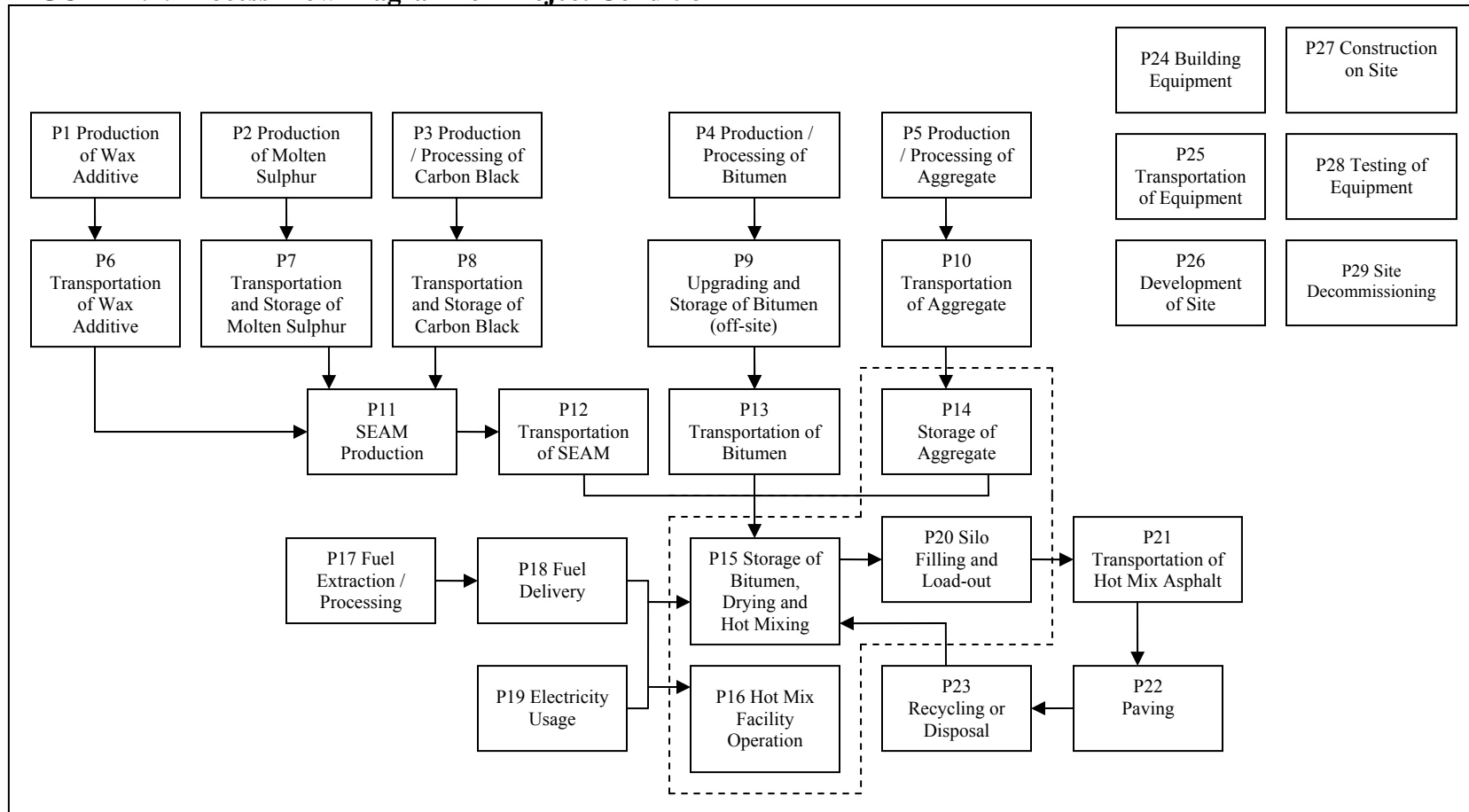
The project developer must demonstrate that the baseline condition, illustrated in **FIGURE 1.2**, was either the previous practise or most likely practise based on conventional industry practices. Further, they must show that the quantity of bitumen binder used per unit of hot mix asphalt produced under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

## Protocol Applicability

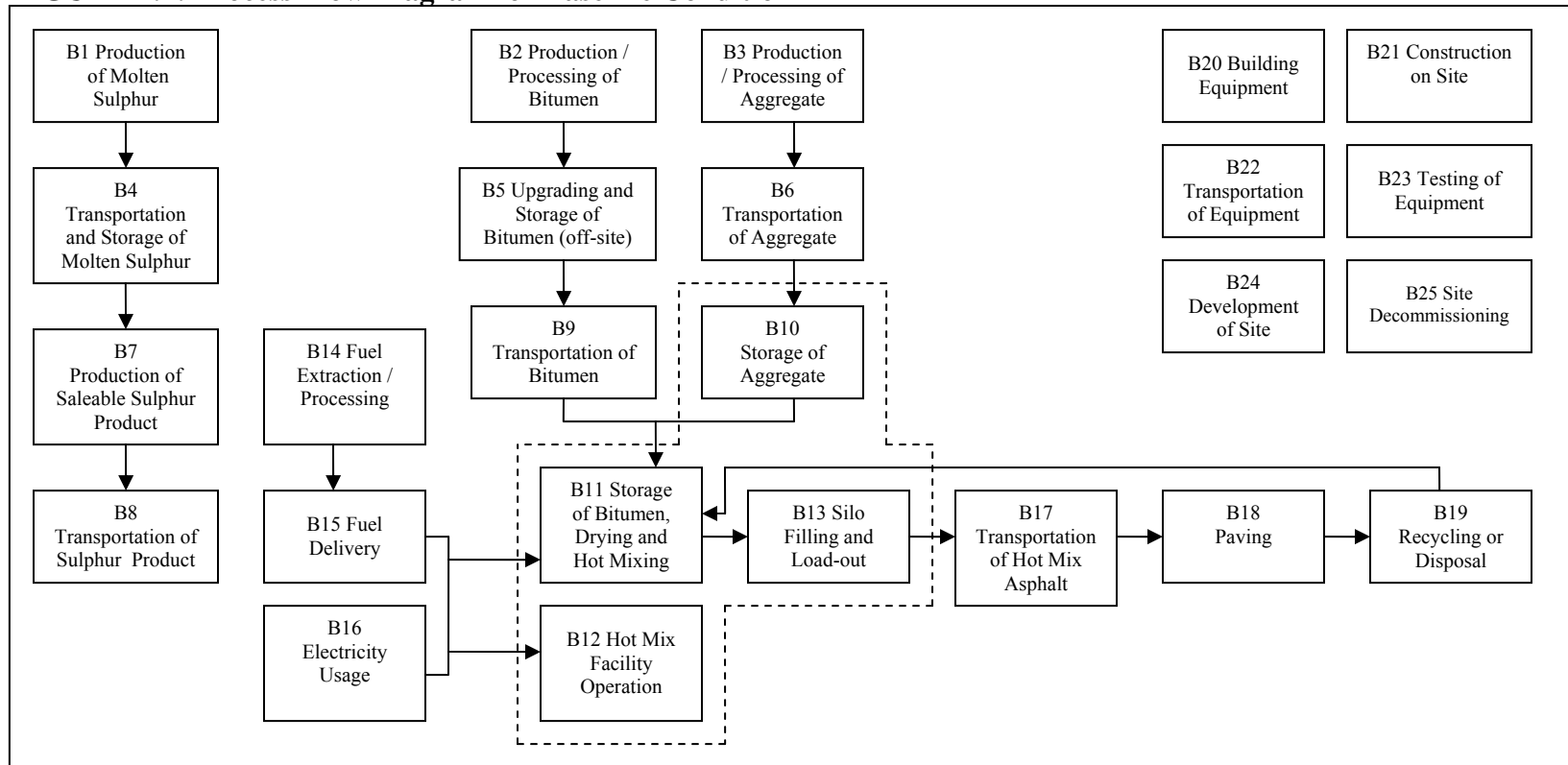
To demonstrate that a project meets the requirements under this protocol, the project developer must provide evidence that:

1. Industry best practices for appropriate handling, mix production temperatures and disposal of any mix produced at temperatures exceeding 155°C are followed. This will require strict adherence to the procedures contained in the 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 asphalt production temperatures are monitored at the plant outlet to ensure production within the appropriate temperature range;
3. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol; and
4. The project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta Offset System.

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



**FIGURE 1.2: Process Flow Diagram for Baseline Condition**



## Protocol Flexibility

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

1. If the project developer has records of historical mix formulation data (i.e. weight percent of bitumen binder and aggregate used per tonne of hot mix asphalt) prior to SEAM use, this value may be substituted for the default values of bitumen and aggregate content included in Appendix B. Note that values must be applicable to the type of road being paved in the Project condition;
2. If hot mix stack emission testing has been conducted at the facility that allows for the characterization of methane emissions from conventional and SEAM hot mix asphalt, this data may be used to quantify the  $E_{\text{Hot Mix Stack}}$  under SS's P15 and B11. The methodology for calculating site-specific emission factors is included in Appendix C;
  - a. This quantification method is included as a flexibility mechanism as hot mix facilities in Alberta are not required to conduct annual sampling or report emissions of CO<sub>2</sub> or total organics;
  - b. Further, note that stack sampling of emissions from the hot mix stack should include only mixing process emissions. AS such, this parameter would not be calculated for CH<sub>4</sub> at facilities where stack emission monitoring is conducted at a point that includes both process emissions from mixing and ducted emissions from fuel combustion. In this case these emissions would already have been accounted for under the fuel usage variable also included in the SS's P15 and B11;
3. The sources and sinks (SS's) B18 and P22 may be added back into the protocol if further sampling and characterization of emissions is conducted and / or appropriate data, calculation methodologies, etc. become available; and
4. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must ensure accuracy; and be robust enough to provide uncertainty ranges in the factors.

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

## 1.2 Glossary of New Terms

### Functional Equivalence

The Project and the Baseline should provide the same function and quality of products or services. This type of comparison requires a common metric or unit of measurement (such as the mass of food processed, units of output per month) for comparison between the Project and Baseline activity.

**Bitumen Handling Emissions:** Intentional and unintentional releases of GHGs during bitumen handling and storage from joints, seals, etc. in processing, piping and treatment equipment.

**Aggregate:** Aggregate is composed of coarse particulate material including sand, gravel, crushed stone, slag, and recycled concrete. It may be sourced from gravel pits, quarries and other local areas surrounding the hot mix facility.

**Binder:** Hot mix asphalt binder serves as a waterproof adhesive that binds the aggregate together and includes the sum of the quantities of bitumen and SEAM consumed.

**Bitumen:** Bitumen is a petroleum based liquid asphalt product, produced from the heavy crude oil refining process. Crude oil at the refinery is first subjected to atmospheric distillation and the short residue is processed in a vacuum tower (ie. vacuum distillation). Paving grade bitumen is the residue left after distilling off all of the lighter fuels. After refining bitumen is stored at the refinery at temperatures of approximately 170°C until transportation and delivery to the hot mix facility.

**Hot Mix Asphalt** Refers to the mixture of binder and aggregate delivered from the hot mix facility to the silo / truck for load-out and delivery to the paving site. The aggregate to binder mix ratio will depend on desired performance properties for paving and may vary at each hot mix facility and for each project.

## 2.0 Quantification Development and Justification

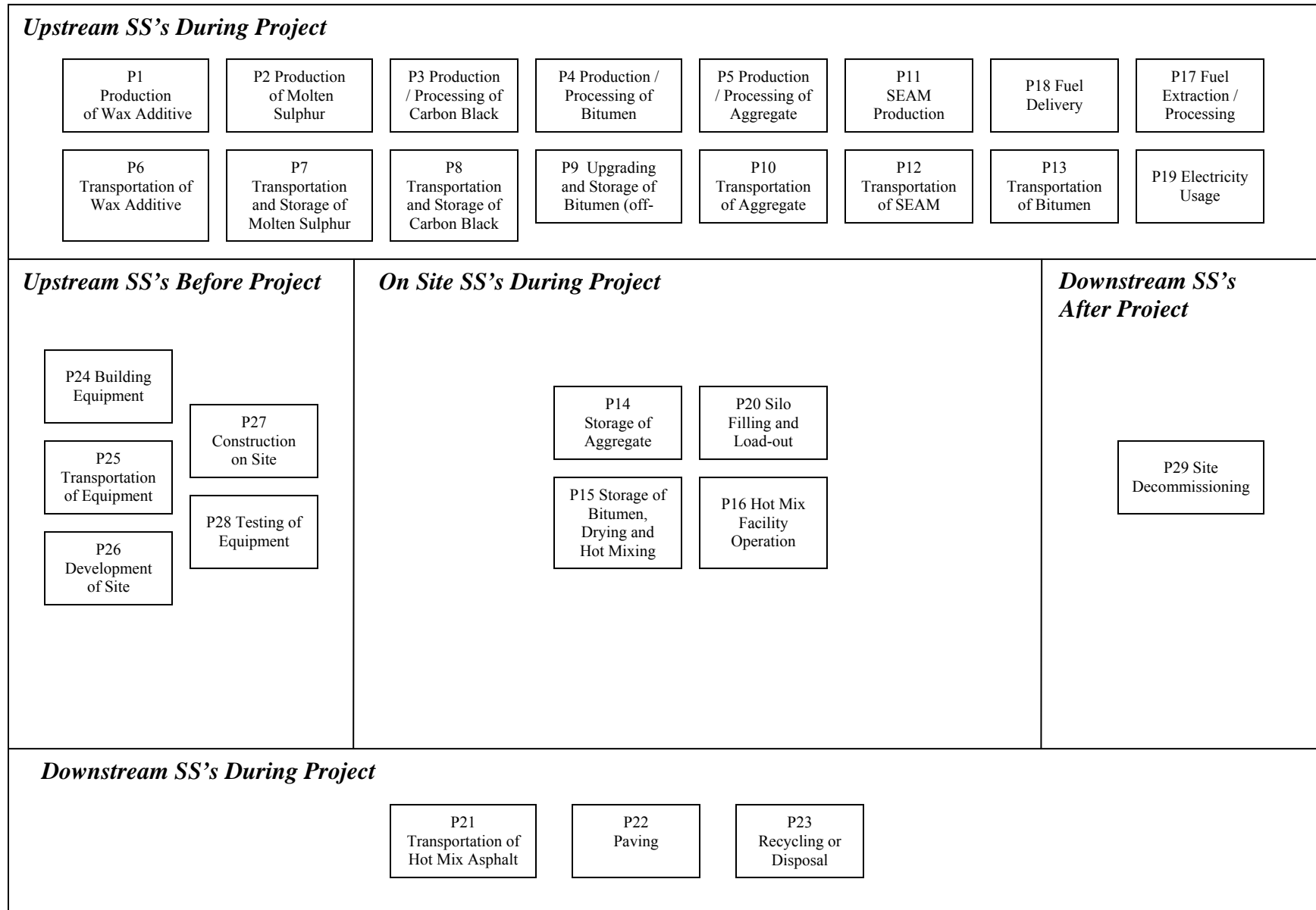
The following sections outline the quantification development and justification.

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

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

Based on the process flow diagrams provided in **FIGURE 1.1** and **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 2.1**.

**FIGURE 2.1: Project Element Life Cycle Chart**



**TABLE 2.1: Project SS's**

1. SS	2. Description	3. Controlled, Related or Affected
<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 this product. Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.</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. 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
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</p>	Related

	<p>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>	
P6 Transportation of Wax Additive	<p>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.</p>	Related
P7 Transportation and Storage of Molten Sulphur	<p>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.</p>	Related
P8 Transportation and Storage of Carbon Black	<p>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.</p>	Related
P9 Upgrading and Storage of Bitumen (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
P10 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
P11 SEAM Production	<p>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.</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
P12 Transportation of SEAM	<p>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.</p>	Related
P13 Transportation of Bitumen	<p>The bitumen used at the project facility may be transported to the project site by truck, barge and/or train from the refinery where it is produced. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.</p>	Related
P17 Fuel Extraction / Processing	<p>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</p>	Related

	production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	
P18 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there are no other delivery emissions as the fuel is already going to the commercial fuelling station. Distance and means of fuel delivery as well as the volumes of fuel delivered are the important characteristics to be tracked.	Related
P19 Electricity 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 Bitumen, 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 emissions associated with the bitumen storage, aggregate drying and hot mixing processes.  Sampling of stack emissions and total volumes fossil fuels consumed are the important characteristics to be tracked.	Controlled
P16 Hot Mix Facility Operation	This SS relates to the greenhouse gas emissions associated with fossil fuel consumption for the operation and maintenance of the hot mix facility, excluding any operation associated with aggregate drying, hot mixing or bitumen storage. Facility operation may require any number of energy inputs and mechanical processes excluding those related to processing inputs and generating the hot mix asphalt for downstream use.  Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Controlled
P20 Silo Filling and Load out	There may be fugitive emissions associated with bitumen handling including silo filling and load-out due to bitumen temperatures and loss on heating. The emissions would primarily be associated with the quantity of bitumen consumed.  Quantities of bitumen binder consumed will be the important characteristics to be tracked.	Controlled
<b>Downstream SS's during Project Operation</b>		
P21 Transportation of Hot Mix Asphalt	The hot mix asphalt produced at the project facility may be transported to the project site by truck and/or train to the paving site. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P22 Paving	Hot mix asphalt will be applied using a paver and compacted using rollers. There may be fugitive emissions	Controlled

	<p>during the application and curing of the hot mix asphalt. Emissions may be dependant on the temperature and rate of diluent evaporation.</p> <p>Temperature, composition and quantities of hot mix asphalt applied are the important characteristics to be tracked.</p>	
P23 Recycling and Disposal	<p>Paving may be recycled 10 to 20 years after application. This will involve milling and grinding the paving and returning it to the hot mix facility. Recycled asphalt pavement (RAP) will then be mixed with new hot mix asphalt at a given proportion and re-used. There may be fuel inputs and fugitive emissions associated with the recycling process.</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
<b>Other</b>		
P24 Building Equipment	<p>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.</p>	Related
P25 Transportation of Equipment	<p>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.</p>	Related
P26 Development of Site	<p>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.</p>	Related
P27 Construction on Site	<p>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.</p>	Related
P28 Testing of Equipment	<p>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</p>	Related

---

	electricity.	
P29 Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

## 2.2 Identification of Baseline

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

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

Under this scenario, the emissions from production and handling of bitumen, aggregate and hot mix asphalt are calculated from direct measurement of the quantities of each component consumed and using emission factors published by Environment Canada, the Canadian Association of Petroleum Producers (CAPP), the Canadian Council of Ministers (CCME) of Environment, the US Environmental Protection Agency (EPA), the Intergovernmental Panel on Climate Change (IPCC) and other sources.

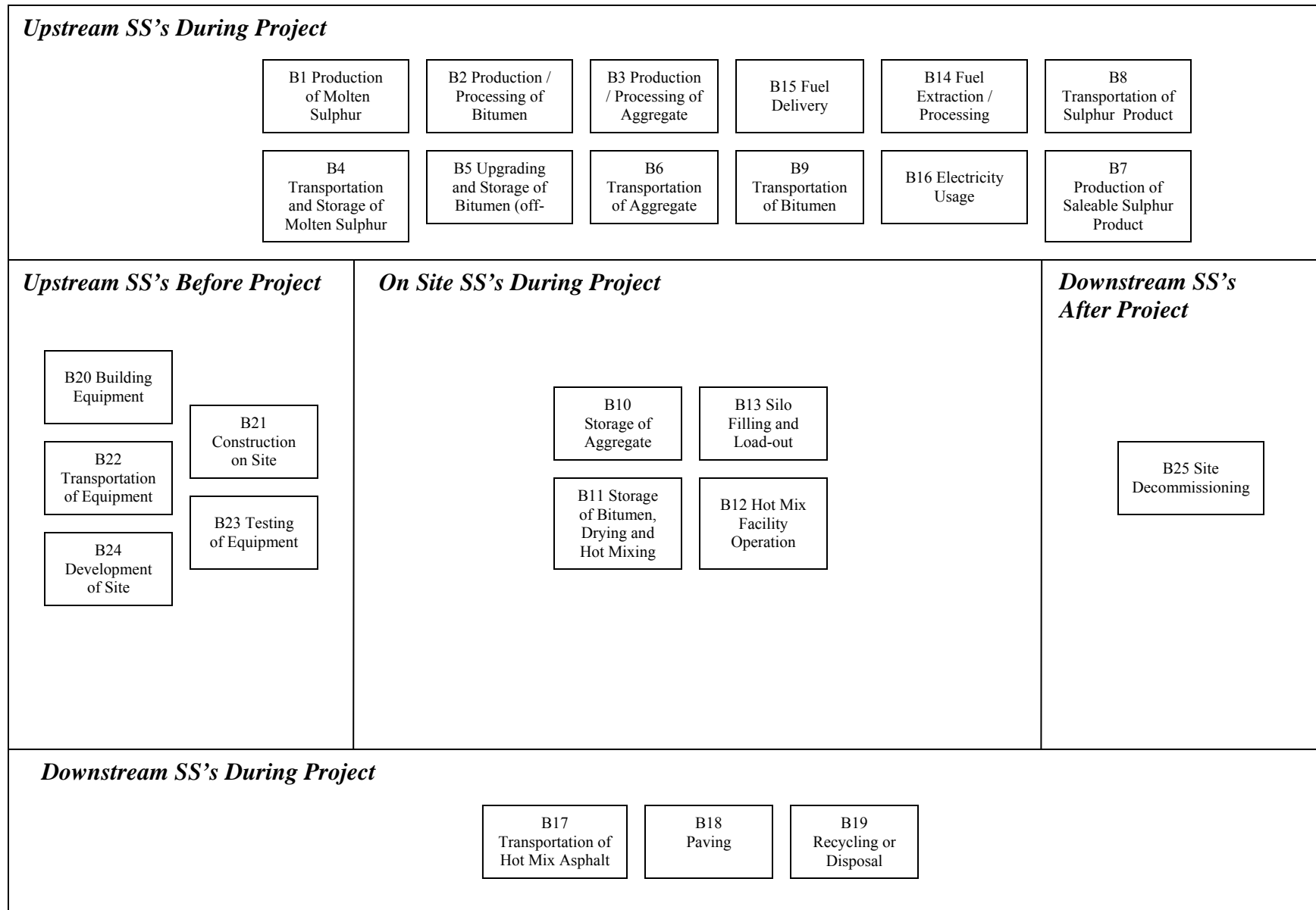
Under this approach, default values for the composition of each type of road are used to determine the quantities of aggregate and binder consumed. These values were provided by Alberta Transportation for low, medium and high volume roads and are included in Appendix B. If available, site-specific data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

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

## 2.3 Identification of SS's for the Baseline

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

**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 Bitumen (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 Bitumen	The bitumen used at the project facility may be transported to the project site by truck, barge and/or train from the refinery where it is produced. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B14 Fuel Extraction / Processing	Each of the fuels used in the baseline will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
B15 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there are no other delivery emissions as the fuel is already going to the commercial fuelling station. Distance and means of fuel delivery as well as the volumes of fuel delivered are the important characteristics to be tracked.	Related
B16 Electricity 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 Bitumen, 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 emissions associated with the bitumen storage, aggregate drying and hot mixing processes.  Sampling of stack emissions and total volumes fossil fuels consumed are the important characteristics to be tracked.	Controlled
B12 Hot Mix Facility Operation	This SS relates to the greenhouse gas emissions associated with fossil fuel consumption for the operation and maintenance of the hot mix facility, excluding any operation associated with aggregate drying, hot mixing or bitumen storage. Facility operation may require any number of energy inputs and mechanical processes excluding those related to processing inputs and generating the hot mix asphalt for downstream use.  Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Controlled
B13 Silo Filling and Load out	There may be fugitive emissions associated with bitumen handling including silo filling and load-out due to bitumen temperatures and loss on heating. The emissions would primarily be associated with the quantity of bitumen consumed.  Quantities of bitumen binder consumed will be the important characteristics to be tracked.	Controlled
<b>Downstream SS's during Project Operation</b>		
B17 Transportation of Hot Mix Asphalt	The hot mix asphalt produced at the project facility may be transported to the project site by truck and/or train to the paving site. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
B18 Paving	Hot mix asphalt will be applied using a paver and compacted using rollers. There may be fugitive emissions during the application and curing of the hot mix asphalt. Emissions may be dependant on the temperature and rate of diluent evaporation.  Temperature, composition and quantities of hot mix asphalt applied are the important characteristics to be tracked.	Controlled
B19 Recycling and Disposal	Paving may be recycled 10 to 20 years after application. This will involve milling and grinding the paving and returning it to the hot mix facility. Recycled asphalt pavement (RAP) will then be mixed with new hot mix asphalt at a given proportion and re-used. There may be fuel inputs and fugitive emissions associated with the recycling process.  Each of the energy inputs and fugitive emissions throughout the production process will need to be sourced and processed. Volumes and types of fuel are the important characteristics to be tracked.	Related
<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 Bitumen (Off-site)	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition given decreased bitumen requirements and therefore it is conservative to exclude them.
B5 Upgrading and Storage of Bitumen (Off-site)	Related	N/A		
P10 Transportation of Aggregate	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition given decreased aggregate requirements and therefore it is conservative to exclude them.
B6 Transportation of Aggregate	Related	N/A		
P11 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 Bitumen	N/A	Related	Exclude	Excluded as these SS's are likely lower in the project condition given decreased bitumen requirements and therefore it is conservative to exclude them.
B9 Transportation of Bitumen	Related	N/A		
P17 Fuel Extraction / Processing	N/A	Related	Include	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 hot mix asphalt produced therefore it is conservative to exclude emissions from storage.
B10 Storage of Aggregate	Controlled	N/A		
P15 Storage of Bitumen, Drying and Hot Mixing	N/A	Controlled	Include	N/A
B11 Storage of Bitumen, Drying and Hot Mixing	Controlled	N/A		
P16 Hot Mix Facility Operation	N/A	Controlled	Exclude	Excluded as the quantity in the majority of project configurations the facility's operation (apart from operations related to the SS's P15 and B11) will not be impacted by the project activity and therefore will be functionally equivalent in the baseline and project conditions
B12 Hot Mix Facility Operation	Controlled	N/A		
P20 Silo Filling and Load-out	N/A	Controlled	Exclude	Excluded as emissions from these SS's are not material and lower in the project condition given decreased bitumen requirements and therefore it is conservative to exclude them.
B13 Silo Filling and Load-out	Controlled	N/A		
<b>Downstream SS's</b>				
P21 Transportation of Hot mix asphalt	N/A	Related	Exclude	Excluded as in the majority of project configurations there will be no change in quantity of hot mix asphalt and / or transportation practices and therefore no change in fossil fuel consumption for transportation, making the baseline
B17 Transportation of Hot	Related	N/A		

mix asphalt				and project scenarios functionally equivalent.
P22 Paving	N/A	Related	Exclude	Excluded as emissions will likely be higher in the project condition and given 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.
B18 Paving	Related	N/A		
P23 Recycling or Disposal	N/A	Related	Exclude	Excluded as in the majority of project configurations there will be no change in recycling practices due to 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

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

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

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

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

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

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

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

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

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

**TABLE 2.4: 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 Bitumen, Drying and Hot Mixing.
	Volume of Each Type of Fuel Fuel Combusted for P15 / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO <sub>2</sub> Emissions Factor for Fuel Production and Processing / 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 (Appendix A).	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 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 (Appendix A).	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 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 (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P3 Production / Processing of	Emissions <sub>Carbon Black Production</sub> = $\sum (\text{Mass}_{\text{SEAM}} * \% \text{C Black} * \text{EF Production}_{\text{CO}_2}) / 100$ ; $\sum (\text{Mass}_{\text{SEAM}} * \% \text{C Black} * \text{EF Production}_{\text{CH}_4}) / 100$					

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.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Percent of Carbon Black in SEAM / % C Black	%	2	Default value estimated from SEAM production process.	Annual	Default value of 2% 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 (Appendix A).	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 (Appendix A).	Annual	Reference values obtained from IPCC guidelines. Values are dependant on the production process.
P4 Production / Processing of Bitumen	Emissions <sub>Bitumen Production</sub> = $\sum ((\text{Mass}_{\text{Bitumen}} * \text{EF Production}_{\text{CO2}}) / \rho) ; \sum ((\text{Mass}_{\text{Bitumen}} * \text{EF Production}_{\text{CH4}}) / \rho) ; \sum ((\text{Mass}_{\text{Bitumen}} * \text{EF Production}_{\text{N2O}}) / \rho)$					
	Emissions <sub>Bitumen 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 Bitumen Consumed / Mass <sub>Bitumen</sub>	kg	Measured	Direct metering of quantity of bitumen used for hot mixing or reconciliation of mass received.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

	Density of Bitumen / $\rho$	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 Bitumen / EF Production <sub>CO2</sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
	CH <sub>4</sub> Emissions Factor for Production of Bitumen / EF Production <sub>CH4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
	N <sub>2</sub> O Emissions Factor for Production of Bitumen / EF Production <sub>N2O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
P5 Production / Processing of Aggregate	$\text{Emissions}_{\text{Aggregate Production}} = \text{Mass}_{\text{Aggregate}} * \text{EF}_{\text{CO2E Aggregate Production}}$					
	Emissions from the production and mining of aggregate / Emissions <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>	kg	Measured	Direct measurement of mass of aggregate consumed at the hot mix facility, reconciliation of mass received or calculation as the difference between the mass of hot mix asphalt produced and the mass	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

				of binder consumed.		
	Emissions factor for aggregate production / EF <small>CO2E Aggregate Production</small>	kg CO <sub>2E</sub> per kg aggregate	Estimated	Values provided in Appendix A.	Annual	Reference value derived from review and analysis of data available from Statistics Canada, the Quarry Products Industry and the Canadian Technical Asphalt Association.
P15 Storage of Bitumen, Drying and Hot Mixing	$Emissions_{Hot\ Mixing} = Emissions_{Hot\ Mix\ Stack} + Emissions_{Fuel\ Usage}$					
	Emissions <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 bitumen storage, aggregate drying and hot mixing.
	$Emissions_{Hot\ Mix\ Stack} = \sum (Mass_{Bitumen} * EF_{Mixer\ CH4})$					
	Emissions <sub>Hot Mix Stack</sub>	kg of CH <sub>4</sub>	N/A	N/A	N/A	Quantity being calculated. Note that this factor refers to emissions associated with the handling and use of bitumen during hot mixing. Emissions from fuel combustion are quantified under the Emissions <sub>Fuel Usage</sub> variable.
	Mass of Bitumen Consumed / Mass <sub>Bitumen</sub>	kg	Measured	Direct metering of quantity of bitumen used for hot mixing or reconciliation of mass received.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CH <sub>4</sub> Emission Factor for Bitumen Use in Hot Mixing / EF <sub>Mixer CH4</sub>	kg CH <sub>4</sub> per kg bitumen	Estimated	From US EPA reference documents (Appendix A).	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 bitumen product consumed.
	$Emissions_{Fuel\ Usage} = \sum (Vol.\ Fuel_i * EF_{Fuel_i\ CO2}) ; \sum (Vol.\ Fuel_i * EF_{Fuel_i\ CH4}) ; \sum (Vol.\ Fuel_i * EF_{Fuel_i\ N2O})$					
	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 bitumen storage, aggregate drying and hot mixing.
	Volume of Each Type of Fuel Combusted / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.  Note that overall hot mix facility fuel usage data may be used given that bitumen storage, aggregate drying and hot mixing will likely represent the majority of facility fuel usage.
	CO <sub>2</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> <small>CO<sub>2</sub></small>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH <sub>4</sub> Emissions Factor for Combustion of Each Type of Fuel / EF Fuel <sub>i</sub> <small>CH<sub>4</sub></small>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From Environment Canada and CAPP reference documents (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N <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 (Appendix A).	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>2E</sub>	N/A	N/A	N/A	Quantity being calculated based on fuel use under B11 Storage of Bitumen, Drying and Hot Mixing

	Volume of Each Type of Fuel Combusted for B11 / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other	Measured	Quantity of each type of fuel consumed under SS B11.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO <sub>2</sub> Emissions Factor for Fuel Production and Processing / 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 (Appendix A).	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 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 (Appendix A).	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 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 (Appendix A).	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B2 Production / Processing of Bitumen	Emissions <sub>Bitumen Production</sub> = $\sum ((\text{Mass}_{\text{Bitumen}} * \text{Mass}_{\text{Paving}} * \text{EF Production}_{\text{CO}_2}) / \rho)$ ; $\sum ((\text{Mass}_{\text{Bitumen}} * \text{Mass}_{\text{Paving}} * \text{EF Production}_{\text{CH}_4}) / \rho)$ ; $\sum ((\text{Mass}_{\text{Bitumen}} * \text{Mass}_{\text{Paving}} * \text{EF Production}_{\text{N}_2\text{O}}) / \rho)$					
	Emissions <sub>Bitumen 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 Bitumen Consumed / Mass <sub>Bitumen</sub>	kg per t hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved (Appendix B).	Per project with monthly reconciliation if project duration is longer than one month.	The bitumen content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved.

						composition at their facility if known.
	Mass of hot mix asphalt produced / Mass <sub>Paving</sub>	t	Measured	Direct metering or reconciliation of quantity delivered to trucks for load-out.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Density of Bitumen / ρ	kg per L	0.98	Default value	Annual	Default value for the density of heavy crude oil.
	CO <sub>2</sub> Emissions Factor for Production of Bitumen / EF <sub>Production CO2</sub>	kg CO <sub>2</sub> per L/ m <sup>3</sup> / other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
	CH <sub>4</sub> Emissions Factor for Production of Bitumen / EF <sub>Production CH4</sub>	kg CH <sub>4</sub> per L/ m <sup>3</sup> / other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
	N <sub>2</sub> O Emissions Factor for Production of Bitumen / EF <sub>Production N2O</sub>	kg N <sub>2</sub> O per L/ m <sup>3</sup> / other	Estimated	From CAPP reference documents (Appendix A).	Annual	Reference values obtained from CAPP for heavy crude oil thermal production. These values are adjusted periodically as part of CAPP's reporting on emissions from the Oil and Gas Industry.
B3 Production /	Emissions <sub>Aggregate Production</sub> = (Mass <sub>Paving</sub> * Mass <sub>Aggregate</sub> * EF <sub>CO2E</sub> )					

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 hot mix asphalt produced / Mass <sub>Paving</sub>	t	Measured	Direct metering or reconciliation of quantity delivered to trucks for load-out.	Per project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Mass of Aggregate / Mass <sub>Aggregate</sub>	kg per t hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved (Appendix B).	Per project with monthly reconciliation if project duration is longer than one month.	The aggregate content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved.  The project proponent may substitute the actual mix composition at their facility if known.
	Emissions factor for aggregate production / EF <sub>CO2E Aggregate Production</sub>	kg CO <sub>2E</sub> per kg aggregate	Estimated	Values provided in Appendix A.	Annual	Reference value derived from review and analysis of data available from Statistics Canada, the Quarry Products Industry and the Canadian Technical Asphalt Association.
B11 Storage of Bitumen, Drying and Hot Mixing	$Emissions_{Hot\ Mixing} = Emissions_{Hot\ Mix\ Stack} + Emissions_{Fuel\ Usage}$					
	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 bitumen storage, aggregate drying and hot mixing.
	$Emissions_{Hot\ Mix\ Stack} = \sum (Mass_{Paving} * Mass_{Bitumen} * EF_{Mixer\ CH4})$					
Emissions <sub>Hot Mix Stack</sub>	kg of CH <sub>4</sub>	N/A	N/A	N/A	Quantity being calculated. Note that this factor refers to emissions associated with the handling and use of bitumen during hot mixing. Emissions	

						from fuel combustion are quantified under the Emissions Fuel Usage variable.
Mass of hot mix asphalt produced / Mass Paving	t	Measured	Direct metering or reconciliation of quantity delivered to trucks for load-out.	Per project with monthly reconciliation if project duration is longer than one month.		Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
Mass of Bitumen Consumed / Mass Bitumen	kg per t hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved (Appendix B).	Per project with monthly reconciliation if project duration is longer than one month.		The bitumen content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved.  The project proponent may substitute the actual mix composition at their facility if known.
CH <sub>4</sub> Emission Factor for Bitumen Use in Hot Mixing / EF Mixer CH <sub>4</sub>	kg CH <sub>4</sub> per kg bitumen	Estimated	From US EPA reference documents (Appendix A).	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 bitumen 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 Fuel Usage	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 bitumen storage, aggregate drying and hot mixing.
Volume of Each Type of Fuel Combusted for Mixing / Vol. Fuel Mixing <sub>i</sub>	L/ m <sup>3</sup> / other per t hot mix asphalt	Measured	Theoretical calculation of the heat required for hot mixing and the volume of fuel required to produce this heat.	Per project with monthly reconciliation if project duration is longer than one month.		Value calculated based on heat requirements, the specific heat of each component and the quantity of each component consumed.

	CO <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 (Appendix A).	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 (Appendix A).	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 (Appendix A).	Annual	Reference values obtained from CAPP and adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
$\text{Vol. Fuel Mixing}_i = (\text{Vol. Fuel Mixing}_{i \text{ Aggregate}} + \text{Vol. Fuel Mixing}_{i \text{ Bitumen}})$						
	$\text{Vol. Fuel Mixing}_{i \text{ Aggregate}} = ((\text{Mass}_{\text{Aggregate}} * C_{\text{Aggregate}} * (T_{\text{Hot mix asphalt}} - T_{\text{Aggregate}})) / (HV_{\text{Fuel}_i} * \text{Eff})) + (\text{Mass}_{\text{Aggregate}} * \text{Vol. Fuel}_i)^1$					
	$\text{Vol. Fuel Mixing}_{i \text{ Bitumen}} = ((\text{Mass}_{\text{Bitumen}} * C_{\text{Bitumen}} * (T_{\text{Hot mix asphalt}} - T_{\text{Bitumen}})) / (HV_{\text{Fuel}_i} * \text{Eff}))$					
	Mass of Aggregate / Mass <sub>Aggregate</sub>	kg per t hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved (Appendix B).	Per project with monthly reconciliation if project duration is longer than one month.	The aggregate content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved.  The project proponent may substitute site-specific values if the actual composition of conventional hot mix asphalt at their facility is known.
	Mass of Bitumen Consumed / Mass <sub>Bitumen</sub>	kg per t hot mix asphalt	Estimated	Use of default values from Alberta Transportation for the type of road being paved.	Per project with monthly reconciliation if project duration is longer than one month.	The bitumen content of conventional hot mix asphalt may be defined using default values provided by Alberta Transportation for the type of road being paved.

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

				(Appendix B).	longer than one month.	Transportation for the type of road being paved.  The project proponent may substitute site-specific values if the actual composition of conventional hot mix asphalt at their facility if known.
	Specific Heat Capacity of Aggregate / C <small>Agg</small>	kJ per kg degree Celsius	0.837	Constant	N/A	Accepted value.
	Specific Heat Capacity of Bitumen / C <small>Bitumen</small>	kJ per kg degree Celsius	2.093	Constant	N/A	Accepted value.
	Temperature of Hot mix asphalt Production / T <small>Hot mix asphalt</small>	degrees C	Estimated	Direct metering of typical mix temperature prior to use of SEAM hot mix asphalt or determination from industry common practice from typical hot mix asphalt production temperatures (as specified by Alberta Transportation).	Per project with monthly reconciliation if project duration is longer than one month.	Represents production temperature of hot mix asphalt. If site-specific data is not available a temperature of 144 degrees Celsius may be applied based on common industry practice.  If asphalt grade is softer than 150-200A asphalt or the road is a low volume highway, a temperature of 142 degrees Celsius may be more appropriate.
	Temperature of Aggregate / T <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 asphalt production temperatures.	Annual	Represents temperature of aggregate at time of mixing / addition of binder.

	Temperature of Bitumen / T Bitumen	degrees C	Estimated	Direct metering of typical bitumen temperature at the time of mixing or determination from industry best practices for typical hot mix asphalt production temperatures.	Annual	Represents temperature of bitumen at time of mixing / addition to the hot mixer.
	Heat Value Fuel / HV Fuel <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 per 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.
	Vol. Fuel Combusted for Aggregate Drying / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other per kg aggregate	Estimated	From manufacturer specifications of burner fuel consumption.	Per project with monthly reconciliation if project duration is longer than one month.	Value obtained from manufacturer specification of fuel consumption. Fuel consumption will be dependant on the moisture content of the aggregate.
	Moisture Content of Aggregate	%	Estimated	From regional moisture content of aggregate determined from existing geological studies and / or sampling	Annual	Value obtained from existing geological studies conducted for the region and / or from sampling data. Other sources of data may also be proposed.  Note that while this value is not used in calculations, it is required to determine fuel requirements for aggregate drying from manufacturer specifications.

## 2.5.2. Contingent Data Approaches

Contingent means for calculating or estimating the required data for the equations outlined in section 2.5.1 are summarized in **TABLE 2.5**, 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.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P4 Production / Processing of Bitumen	Mass of Bitumen Consumed / Mass Bitumen	kg	Measured	Direct metering of quantity of bitumen purchased from monthly invoices from the supplier.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P5 Aggregate Production	Mass of aggregate consumed / Mass Aggregate	kg	Estimated	Reconciliation of mass of aggregate purchased within given time period.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P15 Storage of Bitumen, Drying and Hot Mixing	Volume of Each Type of Fuel Consumed / Vol. Fuel <sub>i</sub>	L/ m <sup>3</sup> / other	Measured	Reconciliation of volume of fuel purchased within given time period.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
	Mass of hot mix asphalt produced / Mass Paving	t	Measured	Reconciliation of mass of hot mix asphalt applied or distance paved and thickness of paving within given time period. This approach may assume a paving lane width of 3.75 m for calculation of the mass	Per Project with monthly reconciliation if project duration is longer than one month.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

				of hot mix required for paving <sup>2</sup> .		
	Mass Emission Rate of CH <sub>4</sub> / EF Mixer CH <sub>4</sub>	kg per kg bitumen	Measured	Use of alternate methodology presented in Appendix C.	Annual	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P17 Fuel Extraction and Processing	Volume of Fuel Combusted for P15	L/ m <sup>3</sup> / other	Measured	Reconciliation of volume of fuel purchased within given time period.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
<b>Baseline SS's</b>						
B2 Production / Processing of Bitumen	Mass of Hot mix asphalt Produced / Mass <sub>Paving</sub>	kg	Measured	Reconciliation from mass of hot mix asphalt applied. If this data is not available mass of hot mix asphalt may be estimated using the distance paved and paving thickness. This approach may assume a paving lane width of 3.75 m for calculation of the mass of hot mix required for paving.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
B2 Production / Processing of Bitumen, B3 Production / Processing of Aggregate and B11 Storage of Bitumen, Drying and Hot Mixing	Mass of hot mix asphalt produced / Mass <sub>Paving</sub>	t	Measured	Reconciliation from mass of hot mix asphalt applied. If this data is not available mass of hot mix asphalt may be estimated using the distance paved and paving thickness. This approach may assume a paving lane width of 3.75 m for calculation of the mass of hot mix required for paving.	Per Project with monthly reconciliation if project duration is longer than one month.	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.

<sup>2</sup> Lane width obtained from the National Resource Council's *Road Rehabilitation Energy Reduction Guide for Canadian Road Builders* dated 2005.

---

B11 Storage of Bitumen, Drying and Hot Mixing	Mass Emission Rate of CH <sub>4</sub> / EF Mixer CH <sub>4</sub>	kg per kg bitumen	Measured	Use of alternate methodology presented in Appendix C.	Annual	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
---	---	-------------------	----------	---	--------	--

# **APPENDIX A**

## **Relevant Emission Factors**

## Fossil Fuel Usage

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

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

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

### Aggregate Production

The emission factor for aggregate production was derived based on the three tables included below. An emissions factor of **0.00998 kg CO<sub>2E</sub> / kg 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**

### **Conventional Hot Mix Asphalt Default Values**

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

**Table B.1 Conventional Hot Mix Asphalt Composition**

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

## **APPENDIX C**

### **Alternate Methodology**

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

1. Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
<b>Project SS's</b>						
B11 Storage of Bitumen, Drying and Hot Mixing	$Emissions_{Hot\ Mixing} = Emissions_{Fuel\ Usage} + Emissions_{Hot\ Mix\ Stack}$					
	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 bitumen storage, aggregate drying and hot mixing.
	$Emissions_{Fuel\ Usage} =$ Calculated using the methodology outlined in Table 2.4					
	$Emissions_{Hot\ Mix\ Stack} = \sum (Mass_{Paving} * EF_{Mixer\ CH_4}) / Rate ; \sum (Mass_{Paving} * EF_{Mixer\ CO_2}) / Rate$					
	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 hot mix asphalt 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 <sub>Mixer CH<sub>4</sub></sub>	kg per hr	Measured	From three years of historical data from third party sampling of the mass emission rate when	Annual	Frequency of metering is highest level possible. If results are expressed as total organics, determination of methane	

				the facility was using conventional hot mix asphalt.		emissions may be accomplished by assuming 27% methane for drum mix and 47% methane for batch mix plants according to guidance provided by the US EPA.
	Mass Emission Rate of CO <sub>2</sub> / EF Mixer CO <sub>2</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 hot mix asphalt.	Annual	Frequency of metering is highest level possible.
	Sampling Production Rate / Rate	t per hr	Measured	From historical data for hot mix asphalt production rate during third party sampling used to determine emission rates.	Annual	Frequency of metering is highest level possible.
<b>Baseline SS's</b>						
P15 Storage of Bitumen, Drying and Hot Mixing	$Emissions_{Hot\ Mixing} = Emissions_{Fuel\ Usage} + Emissions_{Hot\ Mix\ Stack}$					
	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 bitumen storage, aggregate drying and hot mixing.
	$Emissions_{Fuel\ Usage} = \text{Calculated using the methodology outlined in Table 2.4}$					
	$Emissions_{Hot\ Mix\ Stack} = \sum (Mass_{Paving} * EF_{Mixer\ CH4}) / Rate) ; \sum (Mass_{Paving} * EF_{Mixer\ CO2}) / Rate)$					
	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 emissions monitoring includes only the emissions from the mixing process.

This parameter would not be calculated if stack emissions

						monitoring is conducted at a point that includes ducted emissions from fuel combustion. These emissions are accounted for under SS P15's Emissions Fuel Usage variable
	Mass of hot mix asphalt produced / Mass <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.