VCS Methodology

VM0030

Methodology for Pavement Application using Sulphur Substitute

Version 1.0

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Sectoral Scopes 4, 6 & 7

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1 SOURCES

This methodology is based on the *Quantification Protocol for the Substitution of Bitumen Binder in Hot Mix Asphalt Production and Usage v1.0*, issued under the Alberta Specified Gas Emitters Regulation. The methodology uses the latest version of the following CDM tools:

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

In addition, technical and good practice guidance was obtained from Environment Canada's annual greenhouse gas (GHG) reporting, the US Envirnmental Protection Agency's (EPA) Emission Inventory, the Intergovernmental Panel on Climate Change (IPCC), the Canadian Association of Petroleum Producers (CAPP) and various other reliable sources of information pertaining to the hot mix asphalt industry. The good practice guidance and scienctific literature used to develop the methodology are presented in Section 10.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

This methodology quantifies the GHG emission reductions achieved by the substitution of a proportion of the bitumen binder used in conventional hot asphalt paving with a sulphur product. The use of a sulphur product in place of a portion of bitumen binder reduces required quantities of aggregate and bitumen, reduces fuel usage due to reduced mix production temperatures and reduces GHG emissions from the hot mix plant stack and paving.

The sulphur product being substituted for asphalt must be either sulphur extended asphalt modifier (SEAM) pellets or a similar solid sulphur modifier composed of sulphur and small quantities of plasticizer and H_2S scavenger additives. Other additives such as carbon black could be used to impart particular characteristics to the final product. The product may also contain wax additives, used to further reduce hot mix production and compaction temperatures. This methdology applies to hot mix facilities using either formulation of SEAM (with and without wax additives). This methodology is not applicable to project proponents substituting other products for asphalt binder in paving mix. The methodology applies to new construction and overlaying of existing roads. Inclusion of reclaimed asphalt pavement (RAP) would reduce the need for virgin asphalt, so it is possible to combine RAP and SEAM.

A project applying this methodology is considered to be the GHG emissions reductions achieved from the production of sulphur extended asphalt for use in the paving of one or more paving segments. Projects that are applying thismethodology may include hot mix production facilities that do not exclusively produce sulphur-modified asphalts. However, any conventional hot mix asphalt procuded during the crediting period is not eligible for inclusion with the project. (

The project proponent may be the technology owner, hot mix asphalt producer/manufacturer, road owner, or other party associated with the production of sulphur-extended asphalt or development of paving segments paved with sulphur-extended asphalt.

Given that the project proponent could any one of entities listed above, clear right of use must be demonstrated through contractual agreement, or otherwise, in order to to avoid the risk of double counting with other participants in the supply chain.

The project proponent must develop the baseline scenario appropriately for projects that include multiple project activity instances (ie, multiple paving segments), ensuring that the baseline selected is appropriate for all projects to be included in the aggregated quantification.

The baseline scenario would be the production and use of conventional hot mix asphalt, whose composition of aggregate versus bitumen binder will vary depending on the type of road paved (eg, highway versus city street). The project activity could be implemented at existing hot mix facilities or implemented at new facilities as a best practice technology.

Note that as emission reductions generated by projects that apply this methodology are attributed partly to indirect emission from electricity production, projects developed in jurisdictions that have cap-and-trade programs require assessment to ensure double counting does not occur. Therefore, project proponents should be aware of the VCS rules on double counting when a proposed project occurs in a jurisdiction with a cap and trade program covering the electrivity sector, which might render the project unviable.

3 DEFINITIONS

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

Additive
Materials or substances that are included in an asphalt product which do not serve to bind the aggregate, rather they facilitate or modify the binder (or binder substitute) properties to better meet production requirements or product specifications

Aggrerate
Coarse particulate material including sand, gravel, crushed stone, slag, and recycled concrete which may be sourced from gravel pits, quarries and other local areas surrounding the hot mix facility

Binder

A waterproof adhesive that binds the aggregate together. Conventional binder is comprised of bitumen, but for the purposes of this methodology, the word binder may refer to a mix of bitumen and binder substitute.

Binder Substitute

Materials that serve to displace bitumen (the primary conventional binder used for hot mix asphalt production). These substitutes help extend supplies of non-renewable fossil fuels and may also provide other benefits (molten sulphur is an example of a binder substitute which provides lower mix plant temps as a benefit). Binder substitute may be sulphur extender, or an equivalent product.

Bitumen

A viscous liquid petroleum-based product, produced from the heavy crude oil refining and distillation process. Bitumen is also known as asphalt in some parts of the world.

Bitumen Handling Emissions

Intentional and unintentional GHG emissions during bitumen production, handling and storage from the joints, seals and other components of processing, piping and treatment equipment

Conventional Hot Mix Aphalt

A common mixture of asphalt binder and coarse and fine aggregate delivered from the hot mix facility to the silo or truck for load-out and delivery to the paving site. The majority of roads are constructed with conventional hot mix asphalt and operating temperature varying by local project conditions.

Paving Segment

The surface (road, trail, parking lot or other type of surface), specifiable in geographic extent, that is paved with the materials produced from the project activity

Reclaimed Asphalt Pavement (**RAP**)

Asphalt that is produced from feedstocks recovered from existing paved surfaces. RAP can be applied in-situ or recycled through a hot mix facility where it is blended with conventional hot mix asphalt or with a mix including sulphur solid modifers.

Solid Sulphur

The solid state form of elemental sulphur, with the chemical furmula S_8. Solid sulphur is a by-product of industrial processes, such as the desulphurization of natural gas and other hydrocarbon resources. Stockpiles of excess sulphur exist in hydrocarbon-producing regions of the world. Solid sulphur is not SEAM.

Sulphur Extended Asphalt Modifier (**SEAM**)

A solid sulphur extender that is composed of minimum 98 percent sulphur and small quantities of plasticizer and H_2S scavenger additives. SEAM is also referred to as sulphur modifier.

4 APPLICABILITY CONDITIONS

This methodology is applicable to the production and use of hot mix asphalt using a sulphur extender in the asphalt paving process, where the following conditions are met:

1. The baseline scenario is the production and use of hot mix asphalt for paving, and where solid sulphur is not used for paving or as any part of the paving process.
2. Under the baseline scenario, sulphur used in the project to produce hot mix asphalt is a byproduct of other industrial processes and is not produced for use as an extender or modifier in the paving process.
3. Project activities can be undertaken at either a new facility (greenfield site) or existing facility (brownfield site).
4. A proportion of the bitumen binder used in conventional hot mix asphalt production has been substituted with SEAM. This methodology is not applicable to activities that use other binder substitute products that replace bitumen; however, additives which facilitate the substitution of bitumen with SEAM are acceptable.
5. Production procedures must ensure a safe and functionally equivalent product to hot mix asphalt. This requires adherence to procedures issued by the SEAM manufacturer for the handling and storage of solid sulphur, handling and use of the SEAM, construction specifications and mix design. These specifications include appropriate handling temperatures and mix production temperatures. Additionally, any mix produced at temperatures exceeding the maximum allowable mix temperatures specified by the sulphur exptender manufacturer must be safely disposed of.
6. Asphalt products must meet all applicable legal and technical requirements. In the absence of technical specifications for asphalt, the project proponent must demonstrate that asphalt produced under the project scenario provides the equivalent function to asphalt that would have been produced under the baseline scenario.
7. The proportion of RAP used in the project scenario is equivalent to or less than the proporption of RAP used in the baseline scenario. RAP must be mixed at a hot mix facility (not insitu).
8. For projects that consist of multiple project activity instance (ie, multiple paving segments), all of the hot mix asphalt used in the project must have been produced at the same facility.

5 PROJECT BOUNDARY

The project boundary encompases the hot mix facility where the sulphur extended asphalt is produced, as well as the production and processing of bitumen and its additives.

Sources, sinks and reservoirs (SSRs) included in the project and baseline quantification include those that are within the hot mix facility , as well as others that are related to the processing and production of bitumen, bitumen extender, and the associated additives. A generalized process flow diagram of a typical project and baseline are presented below in Figures 1 and 2, respectively.

Figure 1: Project Process Flow Diagram

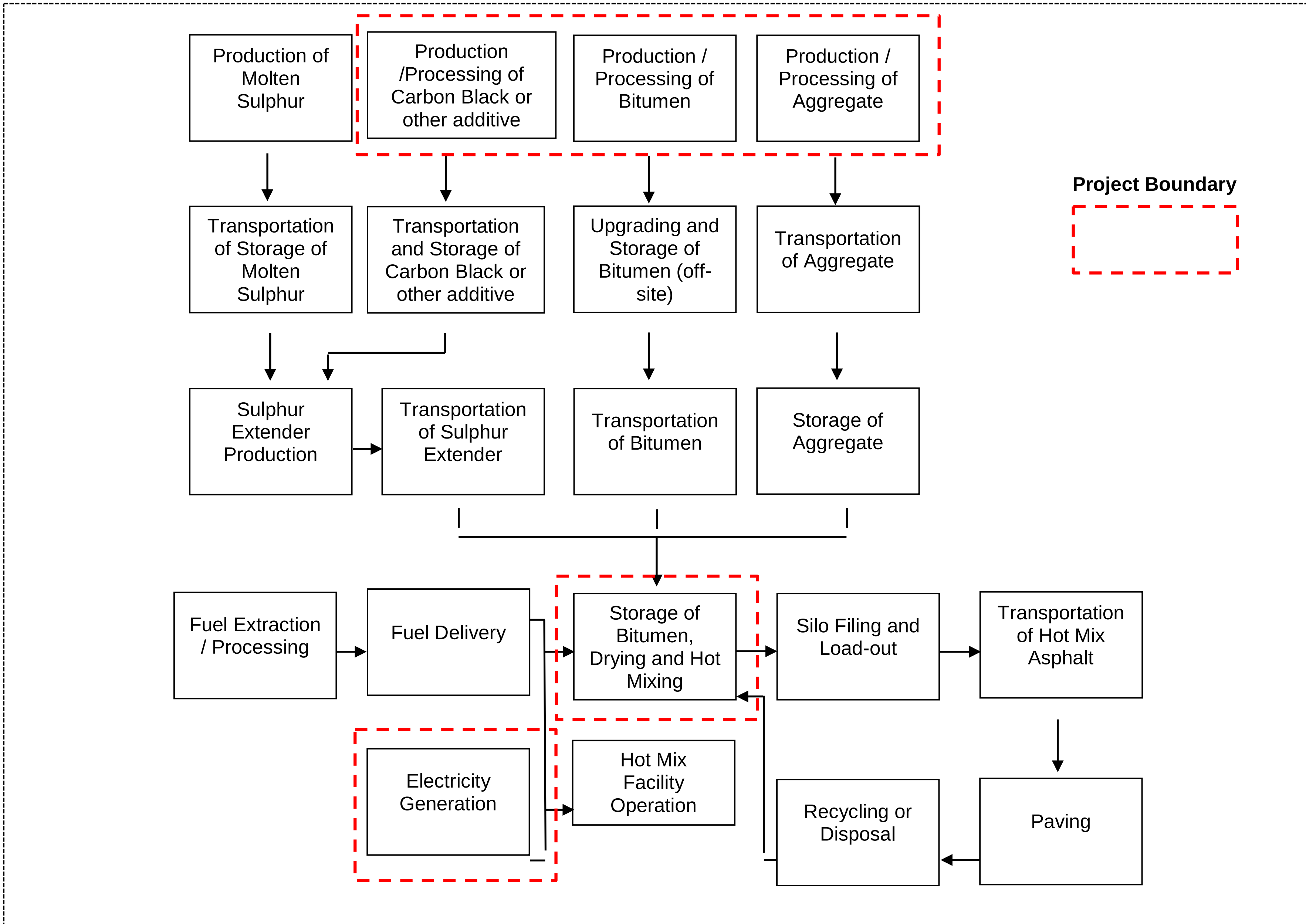

Figure 2: Baseline Process Flow Diagram

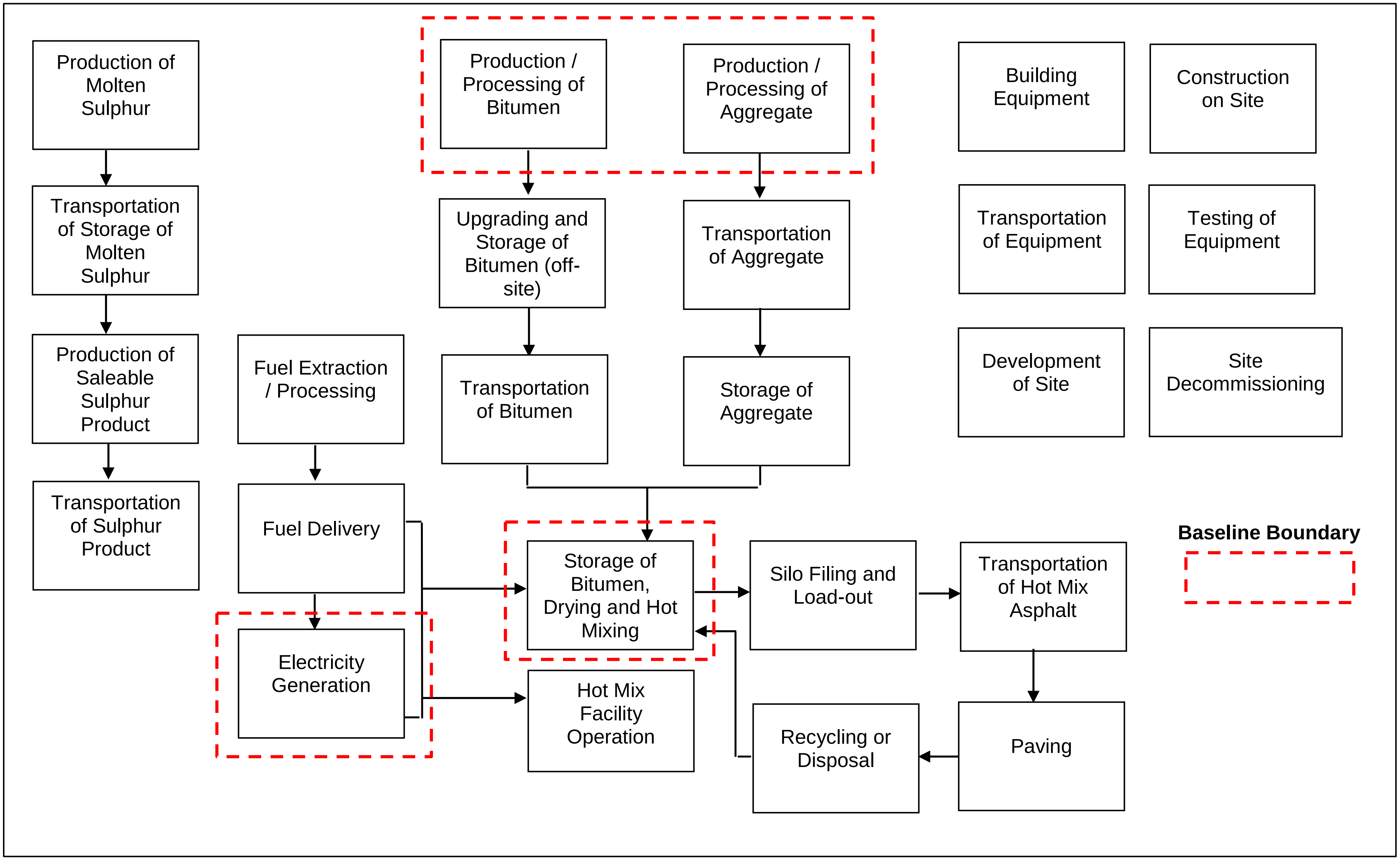

Table 1 below provides justification for the inclusion or exclusion of each of the potential SSRs in the project and baseline scenarios. The project proponent must justify the baseline and project SSRs selected for quantification in the project.

Table 1: GHG Sources, Sinks and Reservoirs

Source		Controlled, Related, or Affected	Gas*	Included	Justification/Explanation
Baseline	Production of molten sulphur	Related	CO_2	No	Excluded as the quantity of molten sulphur produced in the project and baseline scenarios are functionally equivalent. Sulphur is a by-product of gas processing and petroleum refining and would be produced in both the project and baseline scenarios in the same quantity.
			CH_4	No	
			N_2O	No	
	Production/ processing of bitumen	Related	CO_2	Yes	Emissions from the production/processing of bitumen used in asphalt production may be material and can be quantified.
			CH_4	Yes	
			N_2O	Yes	
	Production/Processing of Aggregate	Related	CO_2	Yes	Emissions from the production/processing of aggregate used in asphalt production may be material and may be quantified.
			CH_4	Yes	
			N_2O	Yes	
	Transportation and storage of molten sulphur	Related	CO_2	No	Emissions are based on the quantity of sulphur used in the project scenario, therefore an equivalent quantity of sulphur would be transported in both the project and baseline scenarios. The emissions under this SSR will be functionally equivalent in the project and baseline, as the emissions resulting from transporting the sulphur to the hot mix facility compared to the baseline storage location are negligible.
			CH_4	No	
			N_2O	No	
	Upgrading and storage of bitumen (off-site)	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario. This applies to fuel usage and fugitive emissions attributed to this SSR.
			CH_4	No	
			N_2O	No	

	Transportation of aggregate	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Production of saleable sulphur product	Related	CO_2	No	Emissions are based on the quantity of sulphur used in the project scenario, therefore an equivalent quantity of sulphur would be produced in both the project and baseline scenarios. The emissions under this SSR will be functionally equivalent in the project and baseline, as the production by sulphur processing facilities will remain the same.
			CH_4	No	
			N_2O	No	
	Transportation of sulphur product	Related	CO_2	No	Excluded as the emissions from transportation are negligible.
			CH_4	No	
			N_2O	No	
	Transportation of Bitumen	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Fuel Extraction/Processing	Related	CO_2	No	Excluded for conservativeness to ensure emission reductions from indirect emission sources are not credited to the project
			CH_4	No	
			N_2O	No	
	Transportation of Bitumen	Related	CO_2	No	Excluded for conservativeness to ensure emission reductions from indirect emission sources are not credited to the project
			CH_4	No	
			N_2O	No	
	Fuel delivery	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Electricity generation	Related	CO_2	Yes	Indirect emissions from electricity use may be a material source of emissions. The project proponent must include electricity in the methodology if it is demonstrated to be conservative.
			CH_4	Yes	
			N_2O	Yes	
	Storage of aggregate	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are
			CH_4	No	

			N_2O	No	higher under the baseline scenario.
	Storage of bitumen, drying and hot mixing	Controlled	CO_2	Yes	Included as the emissions may be material and may be quantified. Emissions are dependent on the hot mix temperatures and will therefore vary between the baseline and project scenarios. N_2O emissions are relevant for fuel combustion emissions quantified in this SSR.
			CH_4	Yes	
			N_2O	Yes	
	Hot mix facility operation	Controlled	CO_2	No	Excluded as the hot mix facility's operations will not be impacted by the project activity and will therefore be functionally equivalent in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Silo filling and load-out	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Transportation of hot mix asphalt	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Paving	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Recycling or disposal	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Building equipment	Related	CO_2	No	Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required.
			CH_4	No	
			N_2O	No	
	Transportation of equipment	Related	CO_2	No	Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required.
			CH_4	No	
			N_2O	No	
	Development of site	Related	CO_2	No	Emissions from development of site are not material given the long project
			CH_4	No	

			N_2O	No	life, and the minimal development of site typically required.
	Construction of site	Related	CO_2	No	Emissions from construction of site are not material given the long project life, and the minimal construction of site typically required.
			CH_4	No	
			N_2O	No	
	Testing of equipment	Related	CO_2	No	Emissions from testing of equipment are not material given the long project life, and the minimal testing of equipment typically required.
			CH_4	No	
			N_2O	No	
	Site decommissioning	Related	CO_2	No	Emissions from decommissioning are not material given the long project life, and the minimal decommissioning typically required.
			CH_4	No	
			N_2O	No	
Project	Production of molten sulphur	Related	CO_2	No	Excluded as the quantity of molten sulphur produced in the project and baseline scenarios are functionally equivalent. Sulphur is a by-product of gas processing and would be produced in both the project and baseline scenarios in the same quantity.
			CH_4	No	
			N_2O	No	
	Production/processing of carbon black or other additives	Related	CO_2	Yes	Emissions from the production of additives used in the sulphur extender product may be material and may be quantified.
			CH_4	Yes	
			N_2O	No	Emissions are negligible.
	Production/ processing of bitumen	Related	CO_2	Yes	Emissions from the production/processing of bitumen used in asphalt production may be material and may be quantified.
			CH_4	Yes	
			N_2O	Yes	
	Production/processing of aggregate	Related	CO_2	Yes	Emissions from the production/processing of aggregate used in asphalt production may be material and may be quantified.
			CH_4	Yes	
			N_2O	Yes	
	Transportation and storage of molten sulphur	Related	CO_2	No	Emissions are based on the quantity of sulphur used in the project scenario, therefore an equivalent quantity of sulphur would be transported in both the project and baseline scenarios.
			CH_4	No	
			N_2O	No	

					The emissions under this SSR will be functionally equivalent in the project and baseline, as the emissions resulting from transporting the sulphur to the hot mix facility compared to the baseline storage location are negligible.
	Transportation and storage of carbon black or other additives	Related	CO_2	No	Excluded as the emissions are negligible given the small quantities of additive consumed.
			CH_4	No	
			N_2O	No	
	Upgrading and storage of bitumen (off-site)	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario. This applies to fuel usage and fugitive emissions attributed to this SSR.
			CH_4	No	
			N_2O	No	
	Transportation of aggregate	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Sulphur extender production	Related	CO_2	No	Excluded for simplification. Since the emissions are based on the quantity of sulphur extender used, the emissions would be functionally equivalent under the baseline and project scenarios. The production process includes mixing and solidification of elemental sulphur which occurs in the baseline, therefore emissions are considered to be equivalent between project and baseline.
			CH_4	No	
			N_2O	No	
	Transportation of sulphur extender	Related	CO_2	No	Excluded as the emissions from transportation are negligible.
			CH_4	No	
			N_2O	No	
	Transportation of Bitumen	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Fuel Extraction/Proces	Related	CO_2	No	Excluded for conservativeness to ensure emission reductions from
			CH_4	No	

	sing		N_2O	No	indirect emission sources are not credited to the project
	Fuel Delivery	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Electricity generation	Related	CO_2	Yes	Indirect emissions from electricity use may be a material source of emissions. The project proponent must include electricity in the methodology if it is demonstrated to be conservative.
			CH_4	Yes	
			N_2O	Yes	
	Storage of aggregate	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Storage of bitumen, drying and hot mixing	Controlled	CO_2	Yes	Included as the emissions may be material and may be quantified. Emissions are dependent on the hot mix temperatures and will therefore vary between the baseline and project scenarios. N_2O emissions are relevant for fuel combustion emissions quantified in this SSR.
			CH_4	Yes	
			N_2O	Yes	
	Hot mix facility operation	Controlled	CO_2	No	Excluded as the hot mix facility's operations will not be impacted by the project activity and will therefore be functionally equivalent in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Silo filling and load-out	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Transportation of hot mix asphalt	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Paving	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Recycling or disposal	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are
			CH_4	No	

			N_2O	No	higher under the baseline scenario.

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

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

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

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

Baseline scenarios that include RAP may be considered if the baseline scenario is one with an equivalent or lower proportion of RAP. The project proponent must demonstrate that the use of sulphur extender displaces conventional hot mix bitumen in the baseline scenario. The quantification methods provided in this document do not account for sulphur displacing RAP. Projects using RAP may adjust the volumes or proportions of bitumen displacement with justification, based on the results of the baseline analysis, to ensure a conservative assertion.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

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

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

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

$$BE_y = \frac{(BE_{Bitumen} + BE_{Aggregate} + BE_{Production} + BE_{Electricity})}{1000} \quad (1)$$

Where:

BE_y	=	Baseline emissions in a given year y (t CO_2e)
$BE_{Bitumen}$	=	Emissions due to the production and processing of bitumen (kg CO_2e)
$BE_{Aggregate}$	=	Emissions due to the production and processing of aggregate (kg CO_2e)
$BE_{Production}$	=	Emissions due to the storage of bitumen, drying and hot-mixing (k CO_2e)
$BE_{Electricity}$	=	Emissions due to the generation of electricity for operating the hot mix facility (kg CO_2e)

The emissions due to the production and processing of bitumen are calculated as follows:

$$BE_{Bitumen} = \sum_{x} \left(MF_{Bitumen\ B} \times Mass_{Paving} \times EF\ Bit\ Production_x \times GWP_x \right) \tag{2}$$

Where:

$BE_{Bitumen}$	=	Emissions due to the production and processing of bitumen (kg CO_2e)
$MF_{Bitumen\ B}$	=	Mass fraction of bitumen consumed (kg / t of hot mix produced)
$Mass_{Paving}$	=	Mass of hot mix asphalt produced (t)
$EF\ Bit\ Production_x$	=	Emissions factor for bitumen production and processing for each GHG listed (kg GHG / kg bitumen)
GWP_x	=	Global warming potential for each GHG
x	=	Value for each GHG

The emissions due to the production and processing of aggregate are calculated as follows:

$$BE_{Aggregate} = \sum_{x} \left(MF_{Aggregate\ B} \times Mass_{Paving} \times EF\ Aggregate_x \times GWP_x \right) \tag{3}$$

Where:

$BE_{Aggregate}$	=	Emissions due to the production and processing of aggregate (kg CO_2e)
$MF_{Aggregate\ B}$	=	Mass fraction of aggregate consumed (kg / t of hot mix produced)
$Mass_{Paving}$	=	Mass of hot mix asphalt produced (t)
$EF\ Aggregate_x$	=	Emissions factor for aggregate production and processing for each GHG listed (kg GHG / kg aggregate)
GWP_x	=	Global warming potential for each GHG
x	=	Value for each GHG

The emissions due to the storage of bitumen, drying and hot mixing are calculated using the following equations.

$$BE_{Production} = BE_{Hot\ mix\ stack} + BE_{Fuel\ usage} \tag{4}$$

Where:

$BE_{Production}$ = Emissions due to the storage of bitumen, drying and hot-mixing (kg CO_2e)

$BE_{Hot\ mix\ stack}$ = Emissions from hot mix stack (kg CO_2e)

$BE_{Fuel\ usage}$ = Emissions from fuel usage (kg CO_2e)

The emissions from the hot mix stack are calculated as follows:

$$BE_{Hot\ mix\ stack} = MF_{BitumenB} \times Mass_{Paving} \times EF\ Mixer_{CH4} \times GWP_{CH4} \quad (5)$$

Where:

$BE_{Hot\ mix\ stack}$ = Emissions from hot mix stack (kg CO_2e)

$MF_{Bitumen\ B}$ = Mass fraction of bitumen consumed (kg / t of hot mix produced)

$Mass_{Paving}$ = Mass of hot mix asphalt produced (t)

$EF\ Mixer_{CH4}$ = Emissions factor for CH4 during mixing (kg CH4 / kg bitumen)

GWP_{CH4} = Global warming potential CH4

The emissions due to fuel usage during hot mixing are calculated as follows:

$$BE_{fuel\ usage} = \sum_{i,x} \left(Mass_{Paving} \times Vol\ Fuel\ Mixing_{i,B} \times EF\ Fuel_{i,x} \times GWP_x \right) \quad (6)$$

Where:

$BE_{fuel\ usage}$ = Emissions from fuel usage (kg CO_2e)

$Mass_{Paving}$ = Mass of hot mix asphalt produced (t)

$Vol\ Fuel\ Mixing_{i,\ B}$ = Volume of each type of fuel combusted (L, m3 or other / t of asphalt produced)

$EF\ Fuel_{i,\ x}$ = Emissions factor for fuel combustion (kg GHG / L, m3 or other)

x = Value for each GHG

i = Value for each fuel type applicable to project

The volumes of each type of fuel combusted during hot mixing are calculated based on the heating requirements for hot mixing and the theoretical volume of fuel needed to produce this heat, using the following equations:

$$Vol\ Fuel\ Mixing_i = Vol\ Fuel\ Mixing_{i\ Aggregate} + Vol\ Fuel\ Mixing_{i\ Bitumen} \quad (7)$$

$$Vol\ Fuel\ Mixing_{i\ Aggregate} = \frac{MF_{Aggregate,B} \times Mass_{Paving} \times C_{Aggregate} \times (T_{Hot\ mix} - T_{Aggregate})}{HV_{Fuel\ i} \times Eff} + MF_{Aggregate,B} \times Mass_{Paving} \times Vol\ Fuel_{agg\ i} \quad (8)$$

$$Vol\ Fuel\ Mixing_{i\ Bitumen} = \frac{MF_{Bitumen,B} \times Mass_{Paving} \times C_{Bitumen} \times (T_{Hot\ mix} - T_{Bitumen})}{HV_{Fuel\ i} \times Eff} \quad (9)$$

Where:

Vol Fuel $Mixing_i$	=	Emissions from fuel usage (kg CO_2e)
Vol Fuel $Mixing_{i\ Aggregate}$	=	Mass of hot mix asphalt produced (t)
Vol Fuel $Mixing_{i\ Bitumen}$	=	Volume of each type of fuel combusted (L, m3 or other / t of asphalt produced)
EF $Fuel_{i,\ x}$	=	Emissions factor for fuel combustion (kg GHG / L, m3 or other)
x	=	Value for each GHG
i	=	Value for each fuel type applicable to project
$MF_{Aggregate,B}$	=	Mass fraction of aggregate consumed (kg / t of hot mix produced)
$MF_{Bitumen,\ B}$	=	Mass fraction of bitumen consumed (kg / t of hot mix produced)
$Mass_{Paving}$	=	Mass of hot mix asphalt produced (t)
$C_{Aggregate}$	=	Specific heat capacity of aggregate (kJ / kg °C)
$C_{Bitumen}$	=	Specific heat capacity of bitumen (kJ / kg °C)
T_{Hotmix}	=	Temperature of hot mix asphalt production (°C)
$T_{Aggregate}$	=	Temperature of aggregate (°C)
$T_{Bitumen}$	=	Temperature of bitumen (°C)
$HV_{Fuel\ i}$	=	Heating value of fuel consumed (kJ / m^3)
Eff	=	Fuel combustion and burner efficiency (%).
Vol $Fuel_{agg\ i}$	=	Volume of fuel combusted for aggregate drying (L, m^3 or other / kg of aggregate)

For projects where site-specific stack emissions sampling data is available, the project proponent must calculate emissions due to the storage of bitumen, drying and hot mixing under the baseline scenario as follows:

$$BE_{Hot\ mix\ stack} = \left(\frac{Mass_{Paving} \times EF\ Mixer_{CH4,B,SS}}{Rate_B}\right) GWP_{CH4} + \frac{Mass_{Paving} \times EF\ Mixer_{CO2,B,SS}}{Rate_B} \quad (10)$$

Where:

$Mass_{Paving}$	=	Mass of hot mix asphalt produced (tonne)

$EF\ Mixer_{CH4, B, SS}$	=	Site-specific mass emission rate of CH_4 from the hot mix stack (kg / hr) during conventional hot mix production
$EF\ Mixer_{CO2, B,SS}$	=	Site-specific mass emission rate of CO_2 from the hot mix stack (kg / hr) during conventional hot mix production
$Rate_B$	=	Production rate of conventional hot mix asphalt during stack sampling period (tonne per hour)
GWP_{CH4}	=	Global warming potential for CH_4

The emissions due to electricity generation for operating hot mix facility are calculated as follows:

$$BE_{Electricity} = Electricity_{B} \times EF_{Elec} \quad (11)$$

Where:

$Electricity_B$	=	Electricity used in operating the hot mix facility in the baseline (kWh)
EF_{Elec}	=	Emissions factor for electricity (kg CO_2e/kWh)

8.2 Project Emissions

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

$$PE_y = \frac{(PE_{Add} + PE_{Bitumen} + PE_{Aggregate} + PE_{Production} + PE_{Electricity})}{1000} \quad (12)$$

Where:

PE_y	=	Project emissions in a given year, y (tonne CO_2e)
PE_{Add}	=	Emissions due to the production and processing of carbon black or other additives used in hot mix production (kg CO_2e)
$PE_{Bitumen}$	=	Emissions due to the production and processing of bitumen (kg CO_2e)
$PE_{Aggregate}$	=	Emissions due to the production and processing of aggregate (kg CO_2e)
$PE_{Production}$	=	Emissions due to the storage of bitumen, drying and hot-mixing (kg CO_2e)
$PE_{Electricity}$	=	Emissions due to the generation of electricity for operating the hot mix facility (kg CO_2e)

The emissions due to the production and processing of carbon black or other additives used under the project scenario must be quantified, the following equation provides guidance:

$$PE_{add} = \frac{Mass_{SE} \times \%CB \times EF\ Production_{CO2}}{100} + \frac{Mass_{SE} \times \%CB \times EF\ Production_{CH4}}{100} GWP_{CH4} \quad (13)$$

Where:

PE_{Add}	=	Emissions due to the production and processing of carbon black or other additives used in hot mix production (kg CO_2e)

$Mass_{SE}$ = Mass of sulphur extender consumed (kg)

%CB = Percent of additive (ie. carbon black) in the sulphur extender used (%)

EF $Production_{CO2}$ = CO_2 emissions factor for additive production (kg CO_2 /kg additive)

EF $Production_{CH4}$ = CH_4 emissions factor for additive production (kg CH_4/kg additive)

GWP_{CH4} = Global warming potential for CH_4

The emissions due to the production and processing of bitumen are calculated as follows:

$$PE_{Bitumen} = \sum_{x}(Mass_{Bitumen} \times EF\ Bit\ Production_x \times GWP_x) \quad (14)$$

Where:

$PE_{Bitumen}$ = Emissions due to the production and processing of bitumen (kg CO_2e)

$Mass_{Bitumen}$ = Mass of bitumen consumed (kg)

EF Bit $Production_x$ = Emissions factor for bitumen production and processing for each GHG listed (kg GHG/kg bitumen).

GWP_x = Global warming potential for each GHG (CO_2, CH_4 and N_2O)

x = Value for each GHG (CO_2, CH_4 and N_2O)

The emissions due to the production and processing of aggregate are calculated as follows:

$$PE_{Aggregate} = \sum_{x}\left(Mass_{Aggregate} \times EF\ Aggregate_x \times GWP_x\right) \quad (15)$$

Where:

$PE_{Aggregate}$ = Emissions due to the production and processing of aggregate (kg CO_2e)

$Mass_{Aggregate}$ = Mass of aggregate consumed (kg)

EF $Aggregate_x$ = Emissions factor for aggregate production and processing for each GHG listed (kg GHG/kg of aggregate).

GWP_x = Global warming potential for each GHG (CO_2, CH_4 and N_2O)

x = Value for each GHG (CO_2, CH_4 and N_2O)

The emissions due to the storage of bitumen, drying and hot mixing are calculated as follows:

$$PE_{Production} = PE_{Hot\ mix\ stack} + PE_{Fuel\ usage} \quad (16)$$

Where:

$PE_{Production}$ = Emissions due to the storage of bitumen, drying and hot-mixing (kg CO_2e)

$PE_{Hot\ mix\ stack}$ = Emissions from hot mix stack (kg CO2e)

$PE_{Fuel\ usage}$ = Emissions from fuel usage (kg CO2e)

The emissions from the hot mix stack are calculated as follows:

$$PE_{Hot\ mix\ stack} = Mass_{Bitumen} \times EF\ Mixer_{CH4} \times GWP_{CH4} \quad (17)$$

Where:

$PE_{Hot\ mix\ stack}$ = Emissions from hot mix stack (kg CO2e)

$Mass_{Bitumen}$ = Mass of bitumen consumed (kg)

$EF\ Mixer_{CH4}$ = CH_4 emissions factor for bitumen used in asphalt production (kg CH_4 / kg bitumen).

GWP_{CH4} = Global warming potential for CH_4

The emissions due to fuel usage during hot mixing are calculated as follows:

$$PE_{Fuel\ usage} = \sum_{i,x} \left(Vol\ Fuel\ Mixing_i \times EF\ Fuel_{i,x} \times GWP_x \right) \quad (18)$$

Where:

$PE_{Fuel\ usage}$ = Emissions from fuel usage (kg CO2e)

$Vol\ Fuel\ Mixing_i$ = Volume of each type of fuel combusted during hot mixing (L, m3 or other)

$EF\ Fuel_{i,x}$ = Emissions factor for fuel combustion for each type of fuel used and GHG listed (kg GHG / L, m^3 or other).

GWP_x = Global warming potential for each GHG (CO_2, CH_4 and N_2O)

x = Value for each GHG (CO_2, CH_4 and N_2O)

i = Value for each fuel type applicable to a project

For projects where site-specific stack emissions sampling data are available, the project proponent may calculate emissions due to the storage of bitumen, drying and hot mixing under the project scenario as follows:

$$PE_{Hot\ mix\ stack} = \frac{Mass_{Paving} \times EF\ Mixer_{CH4,SS} \times GWP_{CH4}}{Rate} + \frac{Mass_{Paving} \times EF\ Mixer_{CO2,SS}}{Rate} \quad (19)$$

Were:

$Mass_{Paving}$ = Mass of hot mix asphalt produced (tonne)

$EF\ Mixer_{CH4,\ SS}$ = Site-specific mass emission rate of CH_4 from the hot mix stack (kg/hr)

$EF\ Mixer_{CO2,\ SS}$ = Site-specific mass emission rate of CO_2 from the hot mix stack (kg/hr)

Rate = Production rate of hot mix asphalt during stack sampling period (tonne per hour)

GWP_{CH4} = Global warming potential for CH_4

The emissions due to electricity generation for operating hot mix facility are calculated as follows:

$$PE_{Electricity} = Electricity_P \times EF_{Elec} \tag{20}$$

Where:

$Electricity_P$	=	Electricity used in operating the hot mix facility in the project (kWh)
EF_{Elec}	=	Emissions factor for electricity (kg CO_2e/kWh)

8.3 Leakage

There are no known sources of leakage for this project activity.

8.4 Summary of GHG Emission Reduction and/or Removals

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

$$ER_y = BE_y - PE_y \tag{21}$$

Where:

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

9 MONITORING

9.1 Data and Parameters Available at Validation

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

Should the data parameters listed below not be available at the time of validation, the project proponent must provide a plan for determining and/or monitoring the data during the project. All parameters used must be reviewed at each verification period to ensure the most current and conservative value is used in calculations.

Data / Parameter	$C_{Bitumen}$
Data unit	kJ / kg C°
Description:	Specific heat capacity of bitumen
Equations	9
Source of data	Value of physical or chemical property
Value applied	2.093 kJ / kg C°

Justification of choice of data or description of measurement methods and procedures applied	Based on thermodynamic principles and the theoretical heat capacity of bitumen.
Purpose of data	Calculation of baseline emissions
Comments	The project proponent must determine if the bitumen used for the project is consistent with the definition provided in Section 3.0.

Data / Parameter	$C_{Aggregate}$
Data unit	kJ / kg C°
Description	Specific heat capacity of aggregate
Equations	8
Source of data	Value of physical or chemical property
Value applied	0.837 kJ/kg C°
Justification of choice of data or description of measurement methods and procedures applied	Based on thermodynamic principles and the theoretical heat capacity of aggregate.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must determine if the aggregate used for the project is consistent with the definition provided in Section 3

Data / Parameter	$EF_{Aggregate}$
Data unit	kg GHG/kg of aggregate
Description	Emission factors for aggregate production
Equations	3, 15
Source of data	Estimation; the emission factor must be obtained or calculated from relevant industry data according to the most conservative and regionally appropriate approach possible.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The emissions intensity of aggregate production may vary depending on the type and source of the aggregate used. National emissions factors, or emissions factors created by local industry using internationally accepted procedures should be used preferentially. Regional emissions factors

	may be used if National or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable. In the absence of an appropriate emission factor, a zero value may be assumed. This is conservative as aggregate consumption is higher in the baseline scenario.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$EF_{Bit\ Production}$
Data unit	kg GHG / kg Bitumen
Description	Emission factors for bitumen production
Equations	14
Source of data	Estimation; the emission factor must be obtained or calculated from relevant industry data according to the most conservative and regionally appropriate approach possible.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	National emissions factors, or emissions factors created by local industry using internationally accepted procedures should be used preferentially. Regional emissions factors may be used if national or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable. In the absence of any default value, the reference values provided by CAPP (Appendix A, Table A1) may be used.
Purpose of data	Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of bitumen used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$EF_{MixerCH4}$
Data unit	kg CH_4/kg bitumen
Description	Methane emission factor for bitumen use in hot mixing
Equations	
Source of data	Estimation; the emission factor must be obtained or calculated from relevant industry data according to the most conservative and regionally appropriate approach possible.
Value applied	5 and 17
Justification of choice of data or description of measurement methods and procedures applied	Emission factors are available from equipment manufacturers or governing authorities. National emissions factors, or emissions factors created by local industry using internationally accepted procedures should be used preferentially. Regional emissions factors may be used if national or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable. In the absence of manufacturer-specific emission factors, the emission factors listed in Appendix A, Table A2 must be used
Purpose of data	Calulcation of baseline emissions Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	EF_{Fuel}
Data unit	kg GHG (CO_2, CH_4, N_2O) per L, m3 or other of each type of fuel used
Description	Emission factors for fuel combustion
Equations	6, 9 and 18
Source of data	Estimation; the emission factor must be obtained or calculated from relevant industry data according to the most conservative and regionally appropriate approach

	possible.In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	National emissions factors, or emissions factors created by local industry using internationally accepted procedures should be used preferentially. Regional emissions factors may be used if national or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable.In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics.This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$T_{hot\ mix}$
Data unit	Degree Celsius
Description	Temperature of hot mix asphalt production
Equations	9
Source of data	Estimation based on product requirements, site specific technical analysis or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Default values from industry common practice or from applicable road construction standards must be used when available. Or, it may be measured at the hot mix facility prior to the use of sulphur extender.
Purpose of data	Calculation of baseline emissions
Comment	Default value is 144 deg C based on asphalt production in

	Canada. A temperature of 142 deg C may be more appropriate for softer asphalt or low-volume highways. The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as project description deviation) due to the availability of more recent information. For paving segement developers, a method may be specified to determine a parameter for aggregation of multiple paving segments rather than specifying a value for all paving segments included in the aggregation at the time of validation.

Data / Parameter	$T_{Aggregate}$
Data unit	Degree Celsius
Description	Temperature of aggregate
Equations	9
Source of data	Estimation based on product requirements, or site specific technical analysis or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	If from a brownfield site, this parameter may have been measured at the hot mix facility prior to the use of the sulphur extender. If at a greenfield site,or a brownfield site that is not able to measure then default values may be available from industry best practice.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information. For paving segement developers, a method may be specified to determine a parameter for aggregation of multiple paving segments rather than specifying a value for all paving segments included in the aggregation at the time of validation.

Data / Parameter	$T_{Bitumen}$
Data unit	Degree Celsius
Description	Temperature of bitumen
Equation	9
Source of data	Estimation based on product requirements, site specific technical analysis or measurement
Applied value	
Justification of choice of data or description of measurement methods and procedures applied	Default values may be available from industry common practice. May also be measured at the hot mix facility prior to the use of sulphur extender.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information. For paving segement developers, a method may be specified to determine a parameter for aggregation of multiple paving segments rather than specifying a valuefor all segments included in the aggregation at the time of validation.

Data / Parameter	HV_{Fuel}
Data unit	kJ / m^3
Description	Heating value of fuel
Equations	9
Source of data	Value of physical or chemical property
Applied value	
Justification of choice of data or description of measurement methods and procedures applied	Accepted value for the type of fuel used to power the burner.
Purpose of data	Calculation of baseline emissions
Comment	For natural gas the default value is 38 095 kJ/m^3. For other fuel types an appropriate default value should be used. The

	project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics.

Data / Parameter	Eff
Data unit	%
Description	Fuel combustion and burner efficiency
Equations	9
Source of data	Estimation based on manufacturer specification, site specific technical analysis or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Efficiencies may be available from manufacturer's specifications or as part of the facility's monitoring processes. In the absence of project-specific data, default values should be used. Default values are high and would result in a conservative estimation of emission reductions.
Purpose of data	Calculation of baseline emissions
Comment	Default values are 80% (combustion) and 80% (burner) for a total efficiency of 64%. The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$Vol\ Fuel_{agg}$
Data unit	L, m^3 or other per kg of aggregate
Description	Volume of fuel combusted for aggregate drying
Equations	9
Source of data	Estimation based on dryer manufacturer specification, site specific technical analysis or measurement
Applied value	
Justification of choice of data or	Value may be obtained from manufacturer specifications

description of measurement methods and procedures applied	for fuel consumption.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information. For paving segement developers, a method may be specified to determine a parameter for aggregation of multiple paving segments rather than specifying a value. for all paving segments included in the aggregation at the time of validation. This value is dependent on the moisture content (%) of the aggregate, and may be estimated based on manufacturer's specifications for fuel consumption.

Data / Parameter	EF Production
Data unit	kg (CO_2, CH_4) per kg of additive
Description	Emission factors for the production of additives
Equations	13
Source of data	Estimation based on additive manufacturer specification or project-specific technical analysis
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Reference values may be obtained from IPCC guidelines. Values are dependent on the production process.
Purpose of data	Calculation of project emissions
Comment	IPCC emission factors are provided in Appendix A, Table A3. The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	EF_{Elec}
Data unit	kg CO_2e per kWh
Description	Emissions factor for electricity
Equations	11 and 20
Source of data	Estimation, reference values must be obtained from the relevant national GHG inventory. The value used should be consistent with the source of generation. In the absence of local or regional data, reference values may be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Review of best practice guidance and accepted standards. Reference values are generally available.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$Electricity_{B}$
Data unit	kWh
Description	Electricity used for operating hot mix facility in the baseline
Equations	11
Source of data	Measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Metering of electricity may be direct or by a utility provider. Measurement should be continuous, with monthly aggregation.
Purpose of data	Calculation of baseline emissions
Comment	This parameter may be updated over the course of the

	crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	EF Mixer $_{CO2, B, SS}$, EF Mixer $_{CH4, B, SS}$
Data unit	kg per hour
Description	Mass emission rate of CO_2 and CH_4 from the hot mix stack
Equestions	10 and 19
Source of data	Measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Must be calculated from three years of historical data from third-party sampling of the mass emission rate when the facility was using conventional hot mix asphalt. Direct measurement and average of three years of historical data provides for reasonable quality assurance. It is the responsibility of the project proponent and third party sampler to determine the length of each test and analysis methodology that ensures the accuracy of the sampling procedure. Justification should be provided. The stack sampling of emissions should include only mixing process emissions for any type of plant design (drum or batch mix plants). At least three years of annual stack sampling data should be available from third party sampling when the facility was producing conventional hot mix asphalt for baseline quantification.
Purpose of data	Calculation of baseline emissions Calulcation of project emissions
Any comment	If sampling results are expressed as total organics, conversion to methane may be accomplished by using the default organic composition values of 27% methane for drum mix and 47% methane for batch mix plants, according to guidance provided by the US EPA. The project proponent must ensure that the default value used is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$Rate_B$
Data unit	Tonne per hour
Description	Production rate of conventional hot mix asphalt during the stack sampling period
Equations	10
Source of data	Measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Must be calculated from average of three years of historical data from third-party sampling of the mass emission rate when the facility was producing conventional hot mix asphalt. Direct measurement and average of three years of historical data provides for reasonable quality assurance.
Purpose of data	Calculation of baseline emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	%CB
Data unit	Percent
Description	Percent of additive in sulphur extender
Equations	13
Source of data	Estimation, default value estimated from sulphur extender production process.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	May be determined from sulphur extender producer.
Purpose of data	Calculation of project emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data Unit / Parameter	$MF_{Bitumen\ B}$
Data unit	kg per tonne of hot mix asphalt produced under the baseline scenario

Description	Mass fraction of bitumen consumed under the baseline scenario
Equations	2, 5 and 9
Source of data	Estimation based on paving segment specifications or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Default values may be estimated based on available data. The bitumen content of conventional hot mix asphalt may be estimated using: 1. local or regional paving standards or industry data for the type of road being paved; 2. The actual mix composition for the hot mix facility if known. Note that this parameter does not include RAP.
Purpose of data	Calculation of baseline emissions
Comment	These parameters may become out of date. For paving segement developers, aggregation of multiple paving segments may specify a method to determine this parameter for each paving segment rather than specifying a value for all paving segments included in the aggregation at the time of validation.

Data / Parameter	$MF_{Aggregate\ B}$
Data unit	kg per tonne of hot mix asphalt produced under the baseline scenario
Description	Mass fraction of aggregate
Equations	3 and 9
Source of data	Estimation based on project specifications or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Default values may be obtained from local industry records for the type of road being paved, or actual mix composition for the hot mix facility may be used if known. Note that this parameter does not include RAP.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from

	recognized, credible sources and be geographically and temporally relevant to project specifics. These parameters may become out of date. For paving segement developers, aggregation of multiple paving segments may specify a method to determine this parameter for each paving segment rather than specifying a value for all paving segments included in the aggregation at the time of validation.

9.2 Data and Parameters Monitored

The following data parameters will be monitored during the project.

Data / Parameter	$Mass_{Paving}$
Data unit	tonne
Description	Mass of hot mix asphalt produced
Equations	2, 3, 5, 6, 9, 10 and 19
Source of data	Measurement
Description of measurement methods and procedures to be applied	The project proponent may measure the mass of hot mix asphalt produced in one of three ways: 1. Direct metering ; 2. Reconciliation of quantity delivered to trucks for load-out; 3. Reconciliation of mass of hot mix asphalt applied or distance paved and thickness of paving within a given time period.
Frequency of monitoring/recording	Continuous or per batch, totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$Vol\ Fuel\ Mixing_{Bitumen}$
Data unit	L, m^3 or other

Description	Volume of each type of fuel combusted during the project for storage of bitumen, drying and hot mixing
Equations	6 and 7
Source of data	Measurement in the project scenario, calculation in the baseline scenario
Description of measurement methods and procedures to be applied	The project proponent may measure the volume of fuel consumed in one of two ways: 1. Direct metering or reconciliation of volumes received and in storage; 2. Reconciliation of volume of fuel purchased within a given time period.
Frequency of monitoring/recording	Totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration and maintenance as per requirements of meter manufacturers ensures quality metering. Cross-checking of metered or purchased volumes vs. theoretical fuel use on annual or quarterly basis. Minor variations should be immaterial on an quarterly or annual basis. Long term trends should align with theoretical expectations and remain consistent on a per volume of product basis.
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comment	Overall hot mix facility fuel usage may be used given that bitumen storage, aggregate drying and hot mixing will likely represent the majority of fuel usage for a facility.

Data / Parameter	$Mass_{SE}$
Data unit	kg
Description	Mass of sulphur extender product consumed
Equations	13
Source of data	Measurement
Description of measurement methods and procedures to be applied	The project proponent may measure the mass of sulphur extender in one of two ways: 1. Direct metering or reconciliation of mass received; 2. Reconciliation of mass of sulphur extender purchased within a given time period. This provides a reasonable estimate when direct measurement may not be used.

Frequency of monitoring/recording	Per batch or totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$Mass_{Bitumen}$
Data unit	kg
Description	Mass of bitumen consumed
Equations	14 and 17
Source of data	Measurement
Description of measurement methods and procedures to be applied	The project proponent may measure the mass of bitumen consumed in one of two ways: 1. Direct metering of quantity of bitumen used for hot mixing; 2. Reconciliation of mass received
Frequency of monitoring/recording	Per batch or totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$Mass_{Aggregate}$
Data unit	kg
Description	Mass of aggregate consumed
Equations	15
Source of data	Measurement

Description of measurement methods and procedures to be applied	The project proponent may measure the mass of aggregate consumed in several ways: 1. Direct metering of mass of aggregate consumed at the hot mix facility; 2. Reconciliation of mass received; 3. Calculation as the difference between the mass of hot mix asphalt produced and the sum of mass of binder and all additives consumed; or 4. Reconciliation of mass of aggregate purchased within a given time period.
Frequency of monitoring/recording	Per batch or totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$Electricity_P$
Data unit	kWh
Description	Electricity used for operating hot mix facility in the project
Equations	20
Source of data	Measurement
Description of measurement methods and procedures to be applied	Metering of electricity may be direct or by a utility provider. Measurement should be continuous, with monthly aggregation.
Frequency of monitoring/recording	Totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Electricity utility standard maintenance and calibration procedures apply. Cross-checking of metered values versus engineering estimates or theoretical electricity usage values ensures accuracy between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A

Comment	None

Data / Parameter	EF Mixer $_{CO2, SS}$, EF Mixer $_{CH4, SS}$
Data unit	kg per hour
Description	Mass emission rate of CO_2 and CH_4 from the hot mix stack
	19
Source of data	Measurement
Description of measurement methods and procedures to be applied	Sampling on an annual basis by a third party. Direct measurement with this sampling frequency provide for reasonable quality assurance. Stack monitoring should be conducted at a point that includes process emissions from mixing only, and may not include ducted emissions from fuel combustion or any other emission source from the facility.
Frequency of monitoring/recording	At least annually
QA/QC procedures to be applied	Regular calibration and maintenance as per requirements of meter manufacturers ensures quality metering. Cross-checking of metered values versus engineering estimates or theoretical emission values ensures accuracy between calibration intervals. It is the responsibility of the project proponent and third party sampler to determine the length of each test and analysis methodology that ensures the accuracy of the sampling procedure. Justification should be provided. The stack sampling of emissions should include only mixing process emissions for any type of plant design (drum or batch mix plants). At least three years of annual stack sampling data should be available from third party sampling when the facility was producing conventional hot mix asphalt for baseline quantification.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	If sampling results are expressed as total organics, conversion to methane may be accomplished by using the default organic composition values of 27% methane for drum mix and 47% methane for batch mix plants, according to guidance provided by the US EPA. The project proponent must ensure that the default value used is representative of the type and composition of product

	used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	Rate
Data unit	Tonne per hour
Description	Production rate of hot mix asphalt during the stack sampling period
Equations	19
Source of data	Measurement
Description of measurement methods and procedures to be applied	Sampling on an annual basis by a third party. Direct measurement and this sampling frequency provides for reasonable quality assurance
Frequency of monitoring/recording	Frequency to match EF Mixer $_{CO2, SS}$, EF Mixer $_{CH4, SS}$ sampling frequency
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

9.3 Description of the Monitoring Plan

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

The project proponent must establish and apply quality management procedures to manage data and information. Written procedures 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 conducted for the project.

Record keeping practices must be established that include:

- Electronic recording of values of logged primary parameters for each measurement interval;
- Printing of monthly back-up hard copies of all logged data;
- Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
- Retention of copies of logs and all logged data for at least two years after the end of the crediting period; and
- Keeping all records available for review by a validation/verification body.

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

- Protecting monitoring equipment (eg, temperature gauges)
- Protecting records of monitored data (hard copy and electronic storage) – appropriate record keeping and retention;
- Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records) done to ensure mix formulation is followed and to ensure appropriate payments are made (pay only for what is delivered to site);
- Providing sufficient training to operators to perform maintenance and calibration of monitoring devices as road building staff must have appropriate training to operate the mix plant in such a manner to ensure the right mix is created, meeting the road agency's specifications;
- Establish minimum experience and requirements for operators in charge of project and monitoring; and
- Performing recalculations to make sure no mathematical errors have been made.

In general, data accuracy is inherently addressed in this methodology because the inputs into road-building are metered to ensure mix specifications are met. There is a high degree of certainty in the measurements of binder and aggregate employed to ensure quality of product. Operating temperatures are also closely monitored due to worker health and safety regulatory requirements, and to ensure no wastage of fuel. Fuel quality specifications are provided upon purchase, and these provide the parameters necessary to calculate fuel GHG intensity. The costs of all the inputs into the road are also borne by the contractor, and are monitored and recorded to ensure appropriate payments and cost recoveries are made. The nature of road-building projects therefore provides a high degree of confidence in the data used with the methodology, and addresses significant uncertainties.

- Parameters relevant to the project quantification for which confidence intervals cannot easily be generated include those listed below. Project proponents must demonstrate the factors or values used in the project are appropriately conservative based on the uncertainty of the actual parameter during the project.$T_{hot\ mix}$
- $T_{aggregate}$
- $T_{bitumen}$
- $MF_{bit,\ B}$
- $EF_{Agg,\ x}$
- $EF_{Bit\ Production,\ x}$
- $MF_{Aggregate,\ B}$
- $EF\ Mixer_{CH4}$
- $EF_{Fuel,\ i,\ x}$
- Eff
- $Vol\ Fuel_{agg,\ i}$
- $EF\ Production_x$
- EF_{Elec}
- %CB

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

The project proponent should address uncertainties in measured values by ensuring that meters are appropriately calibrated as prescribed by the manufacturer.

10 REFERENCES

The good practice guidance and best science used to develop the quantification methodology are presented below in Table 5.

Table 2: Good Practice Guidance

Document Title	Publishing Body/Date	Description
ISO 14064-2:2006:	International	ISO 14064-2:2006 specifies principles and

Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements	Organization for Standardization (ISO)	requirements and provides guidance at the project level for quantification, monitoring and reporting of activities intended to cause greenhouse gas (GHG) emission reductions or removal enhancements. It includes requirements for planning a GHG project, identifying and selecting GHG sources, sinks and reservoirs relevant to the project and baseline scenario, monitoring, quantifying, documenting and reporting GHG project performance and managing data quality. This document was used to develop the protocol document and full life cycle analysis of the project and baseline scenarios.
National Inventory Report, 1990-2008 - Greenhouse Gas Sources and Sinks in Canada	Environment Canada, 2010	On behalf of the Government of Canada, Environment Canada develops and publishes annually Canada's GHG inventory. The inventory reporting format is based on international reporting methods agreed to by the Parties to the UNFCCC, using the procedures of the Intergovernmental Panel on Climate Change (IPCC). Emission factors for fossil fuel combustion from this document were used to quantify the emissions from hot mixing and aggregate drying in the project and baseline scenarios.
Alberta Offset System Offset Credit Project Guidance Document	Alberta Environment, 2008	This Offset Credit Project Guidance Document is one of a series of guidance documents prepared for the Specified Gas Emitters Regulatory Framework. The purpose of this Guide is to outline the process and requirements for undertaking offset projects in Alberta.
Emission Factor Documentation For AP-42 Section 11.1, Hot Mix Asphalt Production	US EPA, 2005	Discussion of GHG and VOC emissions and emissions of other air contaminations from hot mix asphalt production. Includes development of emission factors delineated for various process steps and for batch and drum hot mix facilities. Emission factors from asphalt handling were derived from this document. This document was also used to determine which emission sources and sinks at the hot mix asphalt facility would be

		the most significant.
Emission Inventory Improvement Program: Asphalt Paving, Vol. 3, Chapter 17.	US EPA, 2001	Discussion of GHG and VOC emissions and emissions of other air contaminations from hot mix asphalt production. Includes development of emission factors delineated for various process steps and for batch and drum hot mix facilities. Emission factors from asphalt handling were derived from this document. This document was also used to determine which emission sources and sinks at the hot mix asphalt facility would be the most significant.
Multi-pollutant Emission Reduction Analysis Foundation (MERAF) for the Hot-mix Asphalt Sector.	Environment Canada and the Canadian Council of Ministers of Environment (CCME), 2002	This report provides background technical information on the Canadian Hot-Mix Asphalt Sector. It includes a profile of the industry, current and projected emissions from the sector, domestic and international emission standards, best available pollution prevention and control techniques, and possible emission reduction options. This document was used to outline provincial regulations and measurement requirements, and to gain an understanding of common industry practices across Canada.
IPCC Guidelines for National Greenhouse Gas Inventories, Ch. 3, Chemical Industry Emissions.	Intergovernmental Panel on Climate Change (IPCC), 2006	This report provides guidance on estimating greenhouse gas emissions that result from the production of various inorganic and organic chemicals for which there are significant contributions to greenhouse gas emission levels. Included in this chapter are emission factors for carbon black production. Emission factors for the production of carbon black and an understanding of the production process were obtained from this document.
Performance Properties of Paving Mixtures made with Modified Sulphur Pellets. International Society for Asphalt Pavements (ISAP).	International Society for Asphalt Pavement (ISAP), 2008	Discussion of the history of sulphur extended asphalt (SEA) pavement, the development of SEAM, test results for SEAM performance, and the risks and impacts associated with its use. Description of the development of SEAM and the potential impacts and issues associated with

		its use were retrieved from this document.
Cost and Energy Audit of Sulphur Extended Asphalt Paving Construction.	SUDIC and Alberta Transportation, 1984	This report assesses the actual cost and energy usage associated with sulphur extended asphalt (SEA) pavement construction on a large scale commercial project. This document was used to compare SEAM and SEA and to gain an understanding of the potential energy requirements associated with hot mix asphalt production and paving.
Occupational Hygiene Survey: Sulphur-Extended Asphalt Paving Project.	Alberta Transportation, 1981	This report summarizes the gas emission observed during asphalt and SEAM paving projects. This document was used to compare SEAM and SEA and to gain an understanding of the potential risks associated with hot mix asphalt production and paving.
A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H_2S) Emissions by the Upstream Oil and Gas Industry	Canadian Association of Petroleum Producers (CAPP), 2004	A detailed inventory of GHG emissions from the upstream oil and gas sector in Canada with detailed explanations of the methodologies and data sources used. Provides emission factors for the production, processing and combustion of a range of fossil fuel products. Emission factors for the production of bitumen and an understanding of the production process were obtained from this document.
Emission Inventory Guidebook: Processes in Wood, Paper Pulp, Food, Drink and Other Industries, Road Paving with Asphalt	European Environment Agency (EEA), 2006	This report provides a review of the air emissions from various types of asphalt paving mix including hot mix, cutback and liquefied asphalt. This document was used to gain a better understanding of the key emission sources and sinks and potential for variation across different regions and at different sites.

Gravel and Lightly Surfaced Road Resurfacing Projects Quantification Protocol	Alberta Environment, 2008	The Alberta Offset System quantification protocol for gravel and lightly surfaced road resurfacing projects uses an emission factor for aggregate production derived from Statistics Canada, the Aggregates and Quarry Products Association and the Canadian Technical Asphalt Association. References for these documents are provided below: Statistics Canada. (1998). Canadian Minerals Handbook. Canadian Technical Asphalt Association. (2005). The Environmental Road of the Future: Analysis of Energy Consumption and Greenhouse Gas Emissions. Aggregate and Quarry Products Industry. (2006). A Sustainable Development Report from the Aggregate and Quarry Products Industry.
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.	Shell Sulphur Solutions	These documents outline the requirements for safe handling and use of hot mix asphalt using SEAM as a binder. Documents were referenced and included in the methodology as a requirement for its use, to ensure safe handling and production of hot mix asphalt.
Quantification Protocol for the Substitution of Bitumen Binder in Hot Mix Asphalt Production and Usage	Alberta Environment, October 2009	The Alberta Offset System quantification protocol the substitution of bitumen binder in hot mix asphalt production and usage was used as a general guide to baseline and project process flow diagrams and relevant sources, sinks and reservoirs. Global warming potential and specific heat capacity of bitumen and aggregate figures were taken from this protocol.
Fifth edition of the US EPA's AP-42, *Compilation of Air Pollutant Emission Factors*. In Volume 1: *Stationary Point and Area Sources" - Chapter 11.1 (Hot Mix Asphalt Plants),* dated April 2004.	U.S. EPA, 2004	This document was used as a reference for projects where site-specific stack emissions sampling data are available

APPENDIX 1: EMISSIONS FACTORS

Bitumen Production

Values for bitumen production as listed below in Table A1 were obtained from volume 1 of the technical report *A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H_2S) 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). These values were taken from Table 4, entitled 'Summary of emission intensity factors presented by sub-sector of the UOG sector for 2000'. These emissions factors are typical for bitumen production in Canada, and may vary according to geographic location and the refinery. The project proponent must ensure that the emission factors used are applicable to the project.

Table A1: Emission Intensity of Bitumen Production

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

Hot Mixing

Emission factors for hot mixing listed below in Table A2 were derived from the fifth edition of the US EPA's AP-42, *Compilation of Air Pollutant Emission Factors*. In Volume 1: *Stationary Point and Area Sources - Chapter 11.1 (Hot Mix Asphalt Plants),* dated April 2004. Emission factor units for methane are kg/Mg of hot mix asphalt produced.[1]

Table A2: Emission Intensity of Hot Mixing

Plant Type	CH_4	Units
Natural Gas Batch	0.0037	kg / Mg of HMA produced
Natural Gas Drum Mix	0.006	kg / Mg of HMA produced
No. 2 Fuel Oil Batch Mixer	0.0037	kg / Mg of HMA produced
No. 2 Fuel Oil Drum Mixer	0.006	kg / Mg of HMA produced

Carbon Black Production

Values for carbon black production listed below in Table A3 were obtained from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use.[2]

[1] Information retrieved from Table 11.1-6 and Table 11.1-8, for batch or drum mix, respectively.
[2] Please refer to Table 3.23 and 3.24

The majority of the world's carbon black is produced by the furnace black process. Emission factors for both production methods are equivalent.

Table A3: Emission Intensity of Carbon Black Production

Production Process	CO_2			Units
	Primary Feedstock	Secondary Feedstock	Total Feedstock	
Furnace Black	1.96	0.66	2.62	kg / kg carbon black
Thermal	4.59	0.66	5.25	kg / kg carbon black
Production Process	CH_4			Units
No Thermal Treatment	0.0287			kg / kg carbon black
Thermal treatment (default)	0.00006			kg / kg carbon black

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