Category		Title
NFR	2.D.3.b	Road paving with asphalt
SNAP	040611	Road paving with asphalt
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Contents

1 Overview

Asphalt is commonly referred to as bitumen, asphalt cement, asphalt concrete or road oil and is mainly produced in petroleum refineries. In some countries the laid mixed product is also referred to as 'asphalt' but it is also known as 'macadam'.

Asphalt surfaces and pavements are composed of compacted aggregate and an asphalt binder. The asphalt binder may consist of heated asphalt cement (hot mix) or liquefied asphalts (cutback or emulsified). This section covers emissions from asphalt paving operations as well as subsequent releases from the paved surfaces. Emissions from blowing asphalt are addressed in chapter 2.D.3.g 'Chemical products', while emissions from asphalt roofing are discussed in chapter 2.D.3.c.

When coal tar is used in the process, polycyclic aromatic hydrocarbons (PAHs) are emitted. The present Guidebook assumes, however, that this technique is not used anymore therefore no PAHs are emitted in the process of road paving with asphalt. However, in places where coal tar is still used, there will be PAHs emitted to the atmosphere.

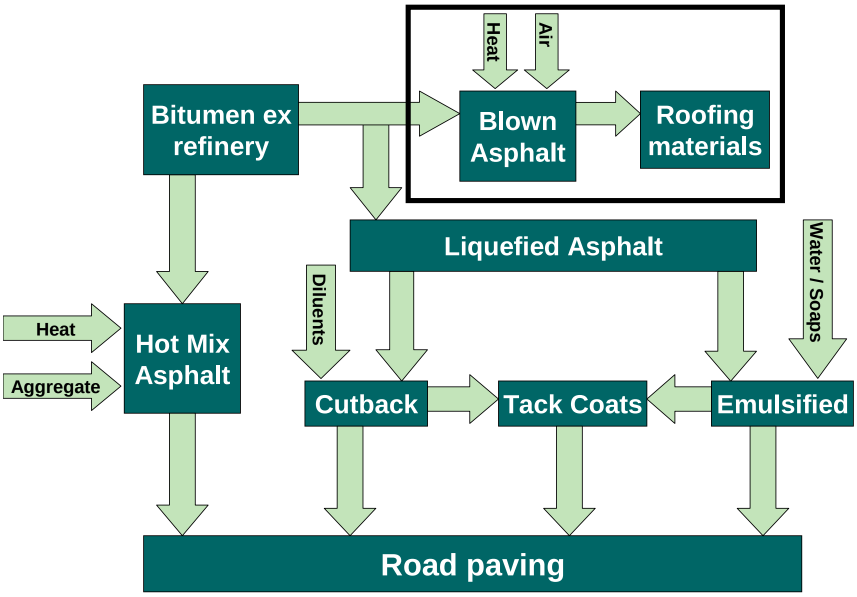
Estimates based on USA asphalt sales in 1991 as reported by the Asphalt Institute (1992) and the maximum available emission factors indicate a maximum emission of approximately 460 000 Mg volatile organic compounds (VOC) from liquefied asphalt paving, which would represent about 0.2 % of total estimated emissions from all sources (US EPA, 1993a).

2 Description of sources

2.1 Process description

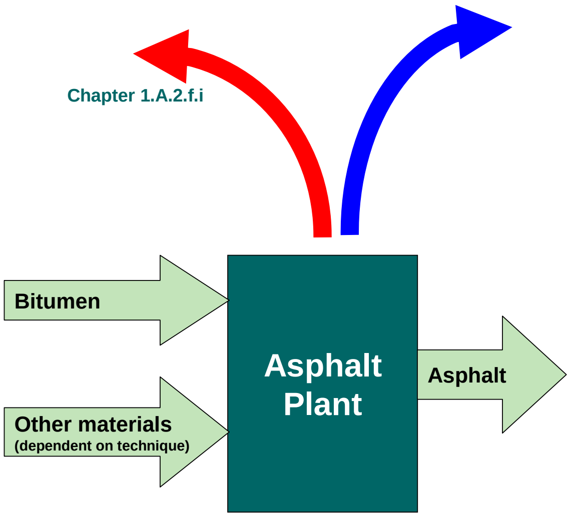
Figure 2.1 gives a complete overview of the activities in the production and use of asphalt. Note that blowing asphalt and asphalt roofing (the black box in the top of the figure) are not included in this chapter.

Figure 2.1 Overview of the production and use of asphalt. This chapter covers all activities shown in the figure, except for the activities captured by the box in the top right.



Asphalt roads are a compacted mixture of aggregate and an asphalt binder. Natural gravel, manufactured stone (from quarries) or by-products from metal ore refining are used as aggregates. Asphalt cement or liquefied asphalt may be used as the asphalt binder. The different techniques used in road paving with asphalt are discussed below in section 2.2 of the present chapter. Figure 2.2 shows the main processes, input and output in this process.

Figure 2.2 General process scheme for source category 2.D.3.b Road paving with asphalt. The red arrow represents combustion emissions (addressed in source category 1.A.2.g.iii) and the blue arrow represents process emissions (discussed in the present chapter).



2.2 Techniques

2.2.1 Asphalt cement

Asphalt cement is semisolid, and must be heated prior to mixing with the aggregate. This is done in hot mix plants, which are considered to be potential sources of common and toxic pollutants. Hot mix plants are normally fixed bulk manufacturing plants. After the hot mix is produced, the mixture is very low in volatile hydrocarbons and is not thought to be a significant source of non-methane volatile organic compounds (NMVOCs) during paving operations (US EPA, 1985).

In order of development, hot mix asphalt paving materials can be manufactured by: batch mix plants; continuous mix plants; parallel flow plants; and counter flow plants. Continuous mix plants are thought to constitute a small portion of production. In the batch process aggregate is dried, sorted, stored and then mixed in a separate pug mill with heated asphalt cement.

In the parallel flow drum mix process, the dryer is used not only to dry the aggregate but also to mix the heated and dried aggregates with the liquid asphalt cement. This combined mixing process means that mixing in the discharge end captures a substantial portion of the aggregate dust. The disadvantage is that because the mixing of aggregate and liquid asphalt occurs in the hot combustion product flow organic emission (gaseous and liquid aerosol) may be greater than in other processes.

In the counter flow plant, the material flow in the drum is opposite to the direction of exhaust gases. Because the liquid asphalt cement and aggregate are mixed in a zone removed from the exhaust gas stream, counter flow drum mix plants are likely to have organic emissions (gaseous and liquid aerosol) that are lower than parallel flow drum mix plants, in addition to greater capacity to accommodate recycled pavement and improved thermal efficiencies.

2.2.2 Liquefied asphalt

Liquefied asphalts may be used as a pavement sealant, as a tack coat, in priming roadbeds for hot mix application and for operations up to several inches thick. Liquefied asphalts are considered to be significant sources of NMVOCs during the mixing and subsequent paving operations. The two types of liquefied asphalt used for road paving are cutback asphalt and emulsified asphalt.

Cutback asphalt is prepared by blending or 'cutting back' asphalt cement with various blends of petroleum distillates. The three categories of cutback asphalt are rapid cure (RC), medium cure (MC) and slow cure (SC). SC, MC and RC cutbacks are prepared by blending asphalt cement with heavy residual oils, kerosene-type solvents, or naphtha and gasoline solvents, respectively. Depending on the viscosity desired, the proportions of solvent generally range from 25 to 45 % by volume. (US EPA, 1985)

Emulsified asphalts are prepared with a blend of water with an emulsifier, which is generically referred to as a soap. The blend consists of 94–98 % water and 2–6 % soaps. As for cutback asphalts, emulsified asphalts can be classified as rapid set (RS), medium set (MS) or slow set (SS) depending on the application and blend percentage. The blend proportions are dependent upon the specific application and operating parameters. It has been reported that emulsified asphalts may have as high as 12 % VOC content (US EPA, 1993b). Emulsified asphalts may also be classified as either anionic (high float) or cationic through the use of particle charge testing (US EPA, 1993a).

2.3 Emissions

2.3.1 Hot mix plants (asphalt cement)

The most significant source of ducted emissions from batch mix plants is the dryer, which emits particulate matter and small amounts of VOCs derived from combustion exhaust gases. Aggregate dust, VOCs and a fine aerosol of liquids are also emitted from the hot-side conveying, classifying and mixing equipment. Vented emissions from these areas may be controlled by equipment ranging from dry mechanical collectors to scrubbers and fabric collectors. Organic vapour and its associated aerosol are also emitted directly to the atmosphere as process fugitives during truck load out and from the bed of the truck during transport. In addition to low molecular weight VOC, these organic emission streams may contain small amounts of polycyclic compounds. The ducted emissions from the heated asphalt storage tanks may include VOC and combustion products from the tank heater. Other fugitive sources of particulate include vehicular traffic and aggregate materials handling.

In parallel flow drum mix plants, the most significant ducted source of emissions is the rotary drum dryer. Emissions include particulate and small amounts of VOCs resulting from incomplete combustion and from the heating and mixing of liquid asphalt cement inside the drum.

Counter flow plants have similar emissions to parallel flow drum mix plants, although VOC emissions are likely to be lower because liquid asphalt cement and aggregate are not in contact with the hot exhaust gas stream. The organic compounds that are emitted are likely to be the result of inefficient combustion.

Process fugitive emissions for parallel and counter flow plants are much lower than batch plants**.** However VOC emissions from transport, handling and load out of the hot mix are likely to be similar.

2.3.2 Liquefied asphalt

For any given amount of asphalt, total emissions are believed to be the same, regardless of stockpiling, mixing and application times. The major source of NMVOCs from the use of liquefied asphalts is the cutback asphalt.

For cutback asphalt, the two major variables affecting both the quantity of NMVOC emitted and the time over which emissions occur are the type and quantity of petroleum distillate used as a diluent. Long-term emissions from cutback asphalts can be estimated by assuming that 95 % of the diluent evaporates from rapid cure (RC) cutback asphalts, 70 % from medium cure (MC) cutbacks and about 25 % from slow cure (SC) asphalts, by weight percent.

Limited test data suggest that, from RC asphalt, 75 % of the total diluent loss occurs on the first day after application, 90 % within the first month and 95 % within three to four months. For MC, evaporation is slower, with about 20 percent loss in the first day, 50 percent in the first week and 70 percent after three to four months. Although no data are available for SC, the total losses are believed to be approximately 25 %, considerably less than for RC or MC, and occur over a considerably longer period of time. (US EPA, 1985)

2.4 Controls

2.4.1 Hot mix plants (asphalt cement)

Dryer exhaust and vent line control equipment ranges from dry mechanical collectors to scrubbers and fabric collectors. Attempts to use electrostatic precipitators have been largely unsuccessful.

The dryer and other potential sources may also be routed to primary dust collection equipment with large diameter cyclones, skimmers or settling chambers. These chambers are often used as classifiers to return collected material to the process. To capture the remaining particulate matter, the primary collector is ducted to a secondary collection device such as a baghouse or a venturi scrubber.

2.4.2 Liquefied asphalts

Emulsions are typically used in place of cutback asphalts to eliminate emissions of NMVOC. Limits on the volatile hydrocarbon content of emulsions can be put in place to limit NMVOC emissions.

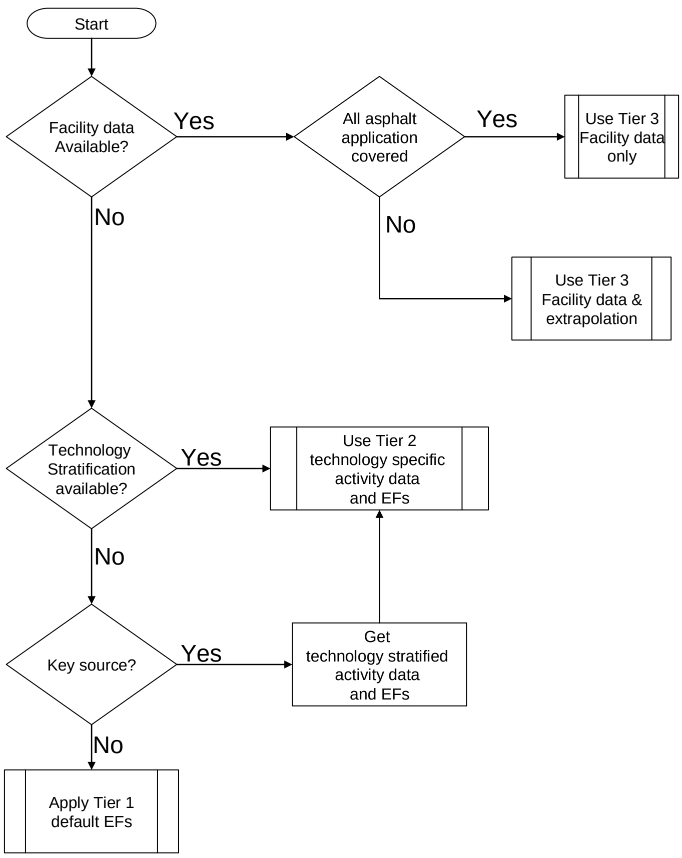
3 Methods

3.1 Choice of method

Figure 3.1 presents the procedure to select the methods for estimating process emissions from road paving with asphalt. The basic approach is as follows:

- If detailed information is available: use it;
- If the source category is a key category, a Tier 2 or better method must be applied and detailed input data must be collected. The decision tree directs the user in such cases to the Tier 2 method, since it is expected that it is more easy to obtain the necessary input data for this approach than to collect facility-level data needed for a Tier 3 estimate;
- The alternative of applying a Tier 3 method, using detailed process modelling is not explicitly included in this decision tree. However, detailed modelling will always be done at facility level and results of such modelling could be seen as 'Facility data' in the decision tree.

Figure 3.1 Decision tree for source category 2.D.3.b Road paving with asphalt.



3.2 Tier 1 default approach

3.2.1 Algorithm

The Tier 1 approach for process emissions from road paving with asphalt uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \qquad (1)$$

Where:

$E_{pollutant}$ = the emission of the specified pollutant

$AR_{production}$ = the activity rate for the road paving with asphalt

$EF_{pollutant}$ = the emission factor for this pollutant

This equation is applied at the national level, using annual national road paving with asphalt.

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all sub-processes in the road paving process.

In cases where specific abatement options are to be taken into account a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used.

3.2.2 Default emission factors

The present subsection provides the Tier 1 emission factor table for emissions from road paving with asphalt. The default emission factors are constructed based on an assessment of the available emission factors from a detailed review of the hot mix industry (US EPA, 2004). In the Tier 1 approach, the emissions of TSP, PM_{10} and $PM_{2.5}$ assume no abatement (uncontrolled emissions). The emission of BC is related to $PM_{2.5}$ and is based on information from US EPA, SPECIATE database version 4.3 (US EPA, 2011). The emission factor represents an average between batch mix and drum mix hot mix asphalt plants.

Emissions of nitrogen oxides (NO_x), sulphur oxides (SO_x) and carbon monoxide (CO) are expected to originate mainly from combustion and are therefore addressed in chapter 1.A.2.g.iii.

Table 3.1 Tier 1 emission factors for source category 2.D.3.b Road paving with asphalt.

<table>
<tr><th colspan="7">Tier 1 default emission factors</th></tr>
<tr><td></td><td>Code</td><td colspan="5">Name</td></tr>
<tr><td>NFR source category</td><td>2.D.3.b</td><td colspan="5">Road paving with asphalt</td></tr>
<tr><td>Fuel</td><td colspan="6">NA</td></tr>
<tr><td>Not applicable</td><td colspan="6">NH_3, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCBs</td></tr>
<tr><td>Not estimated</td><td colspan="6">NO_x, CO, SO_2, PCDD/F, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB</td></tr>
<tr><th rowspan="2">Pollutant</th><th rowspan="2">Value</th><th rowspan="2">Unit</th><th colspan="2">95 % confidence interval</th><th rowspan="2" colspan="2">Reference</th></tr>
<tr><th>Lower</th><th>Upper</th></tr>
<tr><td>NMVOC</td><td>16</td><td>g/Mg asphalt</td><td>3</td><td>100</td><td colspan="2">US EPA (2004)</td></tr>
<tr><td>TSP</td><td>14 000</td><td>g/Mg asphalt</td><td>10</td><td>140 000</td><td colspan="2">US EPA (2004)</td></tr>
<tr><td>PM_{10}</td><td>3 000</td><td>g/Mg asphalt</td><td>4</td><td>10 000</td><td colspan="2">US EPA (2004)</td></tr>
<tr><td>$PM_{2.5}$</td><td>400</td><td>g/Mg asphalt</td><td>1</td><td>2 000</td><td colspan="2">US EPA (2004)</td></tr>
<tr><td>BC</td><td>5.7</td><td>% of $PM_{2.5}$</td><td>2.8</td><td>11</td><td colspan="2">US EPA (2011, file no.: 91159)</td></tr>
</table>

Note:

The TSP, PM_{10} and $PM_{2.5}$ emission factor represents filterable PM emissions. Note that US EPA (2004) includes condensable PM emission factors and factors for controlled plant.

3.2.3 Activity data

The annual weight of asphalt used in road paving is required as a minimum to estimate maximum likely emissions of NMVOCs from this source. If more detailed information is available on the breakdown of this total annual usage (i.e. cement asphalt for hot mix, cutback asphalt and emulsified asphalt) and the diluent contents of the same, then progressively more accurate emission estimates may be done (see the description of the Tier 2 approach in subsection 3.3 below).

3.3 Tier 2 technology-specific approach

3.3.1 Algorithm

The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country.

The approach followed to apply a Tier 2 approach is as follows:

Stratify the road paving in the country to model the different product and process types occurring in the national road paving industry into the inventory by:

- defining the production using each of the separate product and/or process types (together called 'technologies' in the formulae below) separately; and
- applying technology-specific emission factors for each process type:

$$E_{pollutant} = \sum_{technologies} AR_{production,technology} \times EF_{technology,pollutant} \qquad (2)$$

where:

$AR_{production,technology}$	=	the production rate within the source category, using this specific technology
$EF_{technology,pollutant}$	=	the emission factor for this technology and this pollutant

A country where only one technology is implemented will result in a penetration factor of 100 % and the algorithm in equation (3) reduces to:

$$E_{pollutant} = AR_{production} \times EF_{technology,pollutant} \qquad (4)$$

where:

$E_{pollutant}$	=	the emission of the specified pollutant
$AR_{production}$	=	the activity rate for the road paving with asphalt
$EF_{pollutant}$	=	the emission factor for this pollutant

The emission factors in this approach will still include all sub-processes within the road paving industry.

3.3.2 Technology-specific emission factors

It is important to obtain information on asphalt sales for the purposes of paving that is broken down into hot mix, cutback and emulsified classifications. This then permits a generally realistic emission estimation based on reasonable emission factors for each category.

The selection of average emission factors for hot mix, cutback and emulsified asphalt will then depend on the level of regulation in the inventory area. For example, for liquefied asphalt, levels of VOCs in the asphalt may be regulated and emission factors used would reflect the upper limits of the allowable practice. In the case of hot mix plants, knowledge of the industry and its controls would permit the selection of the most appropriate emission factor from the emission factors presented in this section. In the absence of any such information, however, it is good practice to select the emission factors for batch mix plants.

For road paving with asphalt, NO_x, CO and SO_x emission factors are not given in the present chapter. It is assumed that these emissions originate from combustion activities.

Hot mix plant

The present subsection provides uncontrolled emission factors for hot mix plants. Table 3.2 sets out the emission factors for batch mix hot mix asphalt plants, while the emission factors for drum mix plants are given in Table 3.3.

Table 3.2 Tier 2 emission factors for source category 2.D.3.b Road paving with asphalt, batch mix hot mix asphalt plant.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.D.3.b	Road paving with asphalt			
Fuel	NA				
SNAP (if applicable)	040611 Road paving with asphalt				
Technologies/Practices	Batch mix/Hot mix plant				
Region or regional conditions					
Abatement technologies	Uncontrolled				
Not applicable	NH_3, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCBs				
Not estimated	NO_x, CO, SO_2, BC, PCDD/F, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	**Value**	**Unit**	**95 % confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	16	g/Mg asphalt	3	100	US EPA (2004)
TSP	15 000	g/Mg asphalt	10	100 000	US EPA (2004)
PM_{10}	2 000	g/Mg asphalt	4	10 000	US EPA (2004)
$PM_{2.5}$	100	g/Mg asphalt	4	1 000	US EPA (2004)
BC	5.7	% of $PM_{2.5}$	2.8	11	US EPA (2011, file no.: 91159)

Note:
The TSP, PM_{10} and $PM_{2.5}$ emission factor represents filterable PM emissions. Note that US EPA (2004) includes condensable PM emission factors and factors for controlled plant.

Table 3.3 Tier 2 emission factors for source category 2.D.3.b Road paving with asphalt, drum mix hot mix asphalt plant.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.D.3.b	Road paving with asphalt			
Fuel	NA				
SNAP (if applicable)	040611 Road paving with asphalt				
Technologies/Practices	Drum mix/Hot mix plant				
Region or regional conditions					
Abatement technologies	Uncontrolled				
Not applicable	NH_3, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCBs				
Not estimated	NO_x, CO, SO_2, PCDD/F, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	**Value**	**Unit**	**95 % confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	15	g/Mg asphalt	3	100	US EPA (2004)
TSP	13 000	g/Mg asphalt	10	140 000	US EPA (2004)
PM_{10}	3 000	g/Mg asphalt	20	10 000	US EPA (2004)
$PM_{2.5}$	700	g/Mg asphalt	1	2 000	US EPA (2004)
BC	5.7	% of $PM_{2.5}$	2.8	11	US EPA (2011, file no.: 91159)

Note:

The TSP, PM_{10} and $PM_{2.5}$ emission factor represents filterable PM emissions. Note that US EPA (2004) includes condensable PM emission factors and factors for controlled plant.

Cutback asphalt

This section provides a default emission factor for cutback asphalt, based on the German emission inventory, which is based on VDI (2007). An alternative more complex method to estimate emissions is presented in the description of the Tier 3 approach in subsection 3.4 below.

Table 3.4 Tier 2 emission factors for source category 2.D.3.b Road paving with asphalt, evaporative emissions from the use of liquefied cutback asphalt

Tier 2 emission factors					
	Code	Name			
NFR Source Category	2.D.3.b	Road paving with asphalt			
Fuel	NA				
SNAP (if applicable)	040611	Road paving with asphalt			
Technologies/Practices	Liquefied asphalt, Cutback asphalt				
Region or regional conditions					
Abatement technologies	uncontrolled				
Not applicable	NOx, CO, SOx, NH3, TSP, PM10, PM2.5, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Not estimated					
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	30	kg/Mg asphalt	10	100	VDI (2007)

3.3.3 Abatement

A number of add-on technologies exist that are aimed at reducing the emissions of specific pollutants. The resulting emission can be calculated by replacing the technology specific emission factor with an abated emission factor as given in the formula:

$$EF_{technology, abated} = (1 - \eta_{abatement}) \times EF_{technology, unabated} \qquad (5)$$

Where:

$EF_{technology, abated}$	=	the emission factor after implementation of the abatement
$\eta_{abatement}$	=	the abatement efficiency
$EF_{technology, unabated}$	=	the emission factor before implementation of the abatement

The present subsection sets out default abatement efficiencies for a number of abatement options, applicable in this sector.

Hot mix asphalt plants

Abatement efficiencies are calculated with respect to the uncontrolled Tier 2 emission factors for particulates in the previous section.

Table 3.5 Abatement efficiencies ($\eta_{abatement}$) for source category 2.D.3.b Road paving with asphalt

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	2.D.3.b	Road paving with asphalt			
Fuel	NA	not applicable			
SNAP (if applicable)	040611	Road paving with asphalt			
Technologies/Practices	Batch Mix Hot Mix plant				
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default Value	**Lower**	**Upper**	
Venturi / wet scrubber	TSP	99.6%	96%	100%	US EPA (2004)
	PM10	98%	80%	100%	US EPA (2004)
	PM2.5	98%	80%	100%	US EPA (2004)

Table 3.6 Abatement efficiencies ($\eta_{abatement}$) for source category 2.D.3.b Road paving with asphalt

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	2.D.3.b	Road paving with asphalt			
Fuel	NA	not applicable			
SNAP (if applicable)	040611	Road paving with asphalt			
Technologies/Practices	Drum Mix Hot Mix plant				
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default Value	**Lower**	**Upper**	
Venturi / wet scrubber	TSP	99.7%	97%	100%	US EPA (2004)
	PM10	99.7%	97%	100%	US EPA (2004)
	PM2.5	99.7%	97%	100%	US EPA (2004)
Fabric filter	TSP	99.9%	99%	100%	US EPA (2004)
	PM10	99.9%	99%	100%	US EPA (2004)
	PM2.5	99.9%	99%	100%	US EPA (2004)

3.3.4 Activity data

To apply the Tier 2 method, knowledge about the annual weight of asphalt used in road paving is required.

3.4 Tier 3 emission modelling and use of facility data

3.4.1 Algorithm

There are two different methods to apply emission estimation methods that go beyond the technology specific approach described above:

- detailed modelling of the process;
- facility-level emission reports.

Detailed process modelling

A Tier 3 emission estimate, using process details will make separate estimates for the consecutive steps in the process of road paving.

Facility-level data

Since road paving with asphalt is not done at larger facilities but smaller work sites that are often numerous, this section has been omitted in the present chapter. The remainder of this subsection will therefore focus solely on process modelling.

3.4.2 Tier 3 emission modelling and use of facility data

It is good practice to obtain detailed information on the use of each hot mix, cutback asphalt and emulsified asphalt when using a Tier 3 approach. This section will provide guidance to apply this method.

Hot mix plants

For hot mix asphalt, emission factors are based on total product, which includes the weight of the aggregate. Therefore, a survey of the types of hot mix plants by production (or at the very least capacity) and type of control would facilitate the breakdown of hot mix asphalt into categories matching the available emission factors. If this detailed production survey is not possible, then the production may be estimated by assuming that the total asphalt cement used represents 8 % of the total product (US EPA, 1994).

Liquefied asphalt

Simple approach

If there is not sufficient information available to apply the detailed approach described below, an alternative may be to use the Tier 2 emission factor for evaporative emissions from liquefied asphalt. This emission factor however depends on the type of cutback and the volume of diluent in the cutback. The emission factor provided in Tier 2 is an average factor of the emission data in the table below.

Table 3.7 Evaporative VOC emissions from cutback asphalts as a function of the diluent content of the cutback and the asphalt type ([a])

	Percent, by volume of diluent in cutback		
Type of cutback	25 %	35 %	45 %
Rapid cure	17	24	32
Medium cure	14	20	26
Slow cure	5	8	10

([a]) These numbers represent the percentage, by weight, of cutback asphalt evaporated. Factors are based on Asphalt Institute (1992) and US EPA (1985).

([b]) Typical densities assumed for diluents used in RC, MC, and SC cutbacks are 0.7, 0.8 and 0.9 kg/liter, respectively.

([c]) Diluent contents typically range from 25 to 45 %, by volume. Emissions may be linearly interpolated for any given type of cutback between these values.

Detailed approach

For liquefied asphalts, the detailed emission estimation methodology is to estimate emissions from basic principles using detailed product specification and use information. It is assumed that, over the long term, 95 % of the diluent in RC evaporates. Similarly 70 % of MC and 25 % of SC are assumed to evaporate. If the product specification is given that specifies the weight percentage of VOCs in asphalt the calculation of VOCs is fairly straight forward. It is common, however, to specify the diluent content on a percent by volume basis. An example calculation for this situation follows (US EPA, 1985). Additional information when using cutback asphalt is available in US EPA (1985).

EXAMPLE:

Local records indicate that 10 000 kg of RC cutback asphalt, containing 45 % diluent by volume, was applied in a given area during the year. Cutback asphalt is a mixture of diluent and asphalt cement. To determine the VOC emissions, the volume of diluent present in the cutback asphalt must first be determined. Because the density of naphtha (0.7 kg/L) differs from that of asphalt cement (1.1 kg/L), the following equations must be solved to determine the volume of diluent (x) and the volume of asphalt cement (y) in the cutback cement:

10 000 kg cutback asphalt = (x l diluent) (0.7 kg/L) + (y l asphalt cement) (1.1 kg/L)

and

x l diluent = 0.45 (x l diluent + y l asphalt cement)

From these equations, the volume of diluent present in the cutback asphalt is determined to be about 4 900 litres, or about 3 400 kg. Assuming that 95 percent of this is evaporative VOC, emissions are 3 400 kg x 0.95 = 3 200 kg (i.e., 32 % by weight, of the cutback asphalt eventually evaporates).

These equations can be used for MC and SC asphalts by assuming typical diluent densities of 0.8 and 0.9 kg/litre, respectively, unless actual density values are available from local records. If actual diluent contents are not known, a typical value of 35 % may be assumed for inventory purposes.

3.4.3 Activity data

To apply Tier 3, not only the annual weight of asphalt is required but also knowledge about the split between hot mix and cutback asphalt. More detailed information may be used when available, in order to prepare the inventory.

4 Data quality

No specific issues.

4.1 Completeness

No specific issues.

4.2 Avoiding double counting with other sectors

No specific issues.

4.3 Verification

No specific issues.

4.4 Developing a consistent time series and recalculation

No specific issues.

4.5 Uncertainty assessment

The largest source of uncertainty in these estimates will be the level of detail available in terms of the relative breakdown of asphalt into asphalt cement, cutback asphalt and emulsified asphalt. As an example, in the USA in 1991, 86 % of total asphalt sales were asphalt cement for hot mix use. If this was assumed to be RC cutback at an average of 45 %, total emissions would be 6 448 174 tonnes VOC. In comparison, total organic emissions (interpreted as NMVOC) from hot mix plants would be 8 815 Mg for an equivalent amount of asphalt cement, assuming that asphalt cement is 8 % of hot mix. Therefore, the simpler estimation can greatly overestimate emissions of (NM)VOCs.

The state-of-the-art estimations will, however greatly improve the estimates as the detail of the base quantity estimates and characterisations improve.

4.6 Inventory quality assurance/quality control (QA/QC)

No specific issues.

4.7 Gridding

Since most of the emissions occur at the paving locations themselves, emissions can be disaggregated based on the percentage of total paved road surfaces. If this information is not available, the emissions may also be disaggregated based on mobile sources emission estimates or even population.

4.8 Reporting and documentation

No specific issues.

5 Glossary

$AR_{production, technology}$	the production rate within the source category, using a specific technology
$AR_{production}$	the activity rate for the road paving with asphalt
$E_{facility, pollutant}$	the emission of the pollutant as reported by a facility
$E_{pollutant}$	the emission of the specified pollutant
$E_{total, pollutant}$	the total emission of a pollutant for all facilities within the source category
$EF_{country, pollutant}$	a country-specific emission factor
$EF_{pollutant}$	the emission factor for the pollutant
$EF_{technology, abated}$	the emission factor after implementation of the abatement
$EF_{technology, pollutant}$	the emission factor for this technology and this pollutant
$EF_{technology, unabated}$	the emission factor before implementation of the abatement
$Penetration_{technology}$	the fraction of production using a specific technology
$Production_{facility}$	the production rate in a facility
$Production_{total}$	the production rate in the source category
$\eta_{abatement}$	the abatement efficiency

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7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on combustion and industry. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.