The Australasian EPD Programme Ltd

APPENDIX TO PRODUCT CATEGORY RULES FOR ASPHALT MIXTURES - AUSTRALIA

22 January 2019

Contents

1. INTRODUCTION

This document is developed as an appendix to the Product Category Rules (PCR) for asphalt mixtures published by the International EPD System (IEPDS 2018) to support development of Environmental Product Declarations (EPDs) in Australia.

This document was developed by members of the Australian Asphalt Pavement Association (AAPA) and start2see. The following organisations were involved in the PCR committee:

Reporting by:

1.1 GENERAL INFORMATION

Name of PCR:	Appendix to PCR Asphalt Mixtures - Australia
Programme operator:	The Australasian EPD Programme Limited www.epd-australasia.com
Appointed PCR moderator:	Rob Rouwette, start2see, rob.rouwette@start2see.com.au
PCR committee:	Australian Asphalt Pavement Assocation Downer Fulton Hogan Boral Colas Kypreos Group
Date of publication:	22 January 2019
Date expiration:	Expiry to be the same as the main PCR.
Open consultation period:	6-11-2018 to 4-12-2018
Standards conformance:	General Programme Instructions of the International EPD® System, version 3.0, and the Instructions of the Australasian EPD Programme – a Regional Annex to the General Programme Instructions (2018) Version 3.0.
The PCR is valid within the following geographical area:	Australia.

1.2 LCA METHODOLOGY

This appendix aligns with the Life Cycle Assessment (LCA) methodology as outlined in the main PCR for Asphalt mixtures by the International EPD System, which complies with the following standards:

- ISO 14025:2006 Environmental Labels and Declarations — Type III Environmental Declarations — Principles and Procedures (ISO 2006a)
- ISO 14040:2006 Environmental Management — Life Cycle Assessment — Principles and Framework (ISO 2006b)
- ISO 14044:2006 Environmental Management — Life Cycle Assessment — Requirements and Guidelines (ISO 2006c)
- EN 15804:2012+A1:2013 Sustainability of Construction Works — Environmental Product Declarations — Core Rules for the Product Category of Construction Products. (CEN 2013)

This document will be reviewed periodically to ensure the content is up-to-date and in line with the relevant PCR and standards.

1.3 COMPARISON OF EPDS

Care should be taken when comparing the environmental profile of different asphalt mixtures. Comparisons should take place over a whole-of-life assessment of pavement designs, using identical system boundaries and consistent background data.

This Australian appendix to the PCR provides further guidance to facilitate development of consistent EPDs in Australia.

2. GOAL AND SCOPE ELEMENTS

The goal and scope elements align with the main Product Category Rules for asphalt mixtures (by the International EPD System), complemented with specific rules for Life Cycle Inventory data (section 2.4) and process allocation (section 2.5).

2.1 REFERENCE UNIT

The reference unit must be determined in relation to the scope of the EPD (see Table 1):

- Cradle-to-gate life cycle stages (A1:A3): the <u>declared unit</u> is "*1 metric tonne of manufactured asphalt mixture*"
- Cradle-to-gate with options (A1:A4): the <u>declared unit</u> is "*1 metric tonne of manufactured asphalt mixture delivered to the construction site*"
- Cradle-to-gate with options (A1:A5): the <u>functional unit</u> is "*A paved surface of 1 m^2, which fulfils specified quality criteria during the Reference Service Life (RSL) of the asphalt ($RSL_{asphalt}$).*"
    - If this value is not available, the values of $RSL_{asphalt}$ from the document *"Long-Life Asphalt Pavements – Technical version. June 2007"* (EAPA 2007) could be taken. See Appendix B. Reference Service Life (RSLasphalt), European average values.

- Cradle-to-gate with options (one or more life cycle stages beyond A1-A5 and as minimum B1 and B4 in addition to A1-A5): the functional unit is "*A paved surface of 1 m², which fulfils specified quality criteria during the Reference Service Life (RSL) of the construction (RSL$_{construction}$). For RSL$_{construction}$, in the case of roads a default value of 40 years shall be taken and for other construction types a value of 30 years.*"

Table 1. EPD types and life cycle stages

	Product stage			Construction stage		Use stage							End-of-life stage				Benefits beyond system boundary
EPD type	**A1**	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
Cradle-to-gate **Declared unit**	Mandatory																
Cradle-to-gate with option **Declared unit/ Functional unit**	Mandatory			Optional		Optional							Optional				Optional
Cradle-to-grave **Functional unit**	Mandatory			Mandatory		Mandatory							Mandatory				Optional

2.2 SYSTEM BOUNDARIES

The International EPD® System has adopted an LCA calculations procedure, which defines life cycle stages in line with EN 15804 (see stages described in Table 1).

As explained in section 2.1, the scope of the LCA for asphalt mixtures shall be "cradle-to-gate" (A1-A3) as a minimum. The scopes of "cradle-to-gate with options" and "cradle-to-grave" (A1-C4, with D as a voluntary stage) are optional:

- A1: Raw Material Supply (mandatory)
- A2: Transport to asphalt plant (mandatory)
- A3: Manufacturing of the asphalt mixture (mandatory)
- A4: Transport to the construction site (optional)
- A5: Asphalt mixture application (optional)
- B1: Use (optional)
- B2: Maintenance of asphalt surface (optional)
- B3: Repair (optional)
- B4: Replacement (optional)
- B5: Refurbishment (information module not considered in this PCR)
- B6: Operational energy use (information module not considered in this PCR)
- B7: Operational water use (information module not considered in this PCR)
- C1: Removal of asphalt (optional)
- C2: Transport to waste management plant (optional)

- C3: Waste processing (optional)
- C4: Disposal (optional)
- D: Benefits and loads beyond the system boundary (optional)

Modules B5 refurbishment, B6 operational energy use and B7 operational water use are information modules not included in this PCR (see Table 2).

Module B5 is not relevant for asphalt mixture. The modules B2 Maintenance, B3 Repair and B4 Replacement completely cover the operations needed for the correct functional performance of the asphalt during its lifetime. B5 Refurbishment is more focused on other type of infrastructures and constructions (as buildings) but in the case of the asphalt mixtures (not only roads), it does not apply.

In the case of B6 and B7 modules, although it is known, for example, that the rugosity of the asphalt (pavement roughness) can significantly affect the energy consumption of vehicles, the science is very imprecise and there are no forms to define this information clearly.

Therefore, these phases will not be considered within the scope of the PCR. In case the owner of the EPD is interested in supplying this information, it shall be reported in the section "Other environmental information" on the EPD.

Table 2. Life cycle stages potentially included in the system boundaries

Product stage			Construction stage		Use stage							End-of-life stage				Benefits beyond system boundary
Raw material supply	Transport	Manufacturing	Transport	Construction-installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
			Scenario		Scenario							Scenario				
✓	✓	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	N/A	✓	✓	✓	✓	✓

✓ = life cycle stage is potentially included in an Environmental Product Declaration that follows the main Product Category Rules for asphalt mixtures.

2.3 SYSTEM DIAGRAM

A detailed system flow diagram for the cradle-to-gate stages (A1-A3) is depicted in Figure 1. The diagram shows which unit processes are relevant for asphalt producers and their suppliers and can assist with data collection.

An LCA for asphalt mixtures shall include all inputs and outputs to the identified unit processes when relevant:

- Specific (primary) data shall be collected for the asphalt production process
- Specific (primary) data shall be collected for transport of most raw materials to the asphalt manufacturer
- Generic (secondary) data may be used for supply chain processes and emissions from the asphalt plant. To improve consistency of EPDs for asphalt mixtures, prescribed generic life cycle inventory data are included in section 2.4 and "Appendix C. Life cycle inventory data".

See sections 5.1 and 5.2 of IEPDS 2018 for more guidance on data collection.

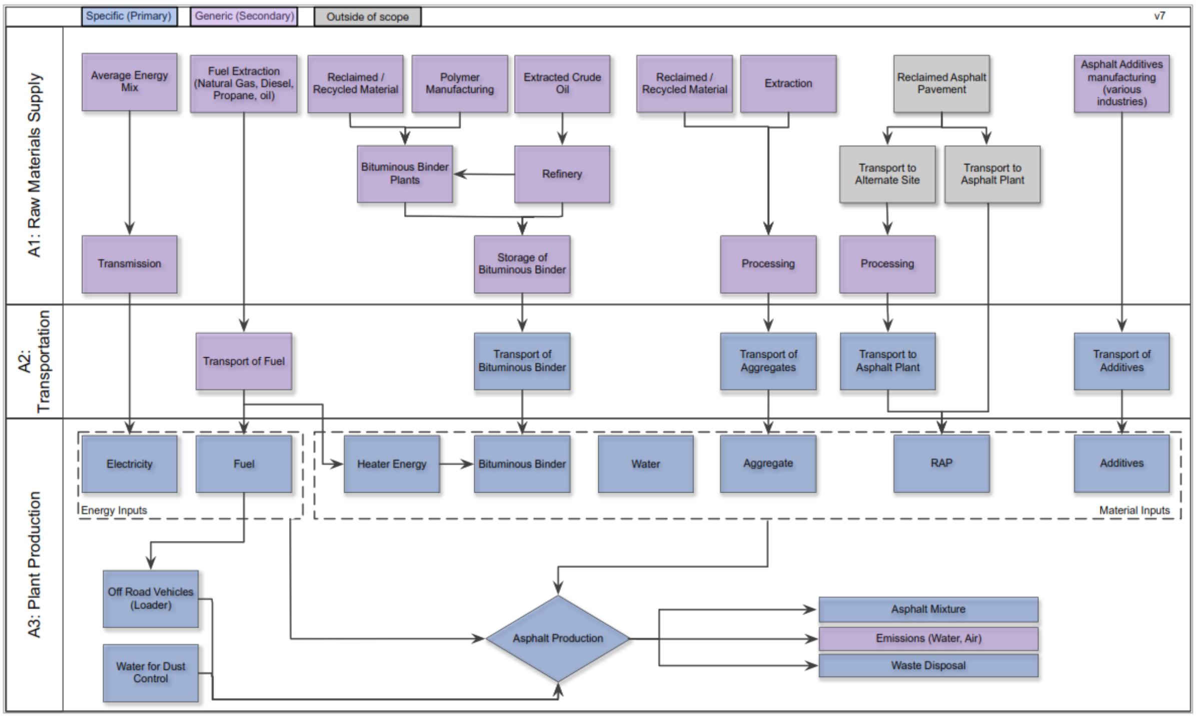

Figure 1. Diagram of system boundaries (stages A1-A3), processes and data types

2.4 LIFE CYCLE INVENTORY DATA

Based on the approach taken by National Asphalt Pavement Association (NAPA 2017), key Australian life cycle inventory data are prescribed in this PCR appendix. An Australian EPD of asphalt mixtures shall use the prescribed life cycle inventory (LCI) data sources for all relevant generic (secondary) data, unless specific (primary) data are available. This approach minimises variances resulting from differences in choice of generic data sources and EPDs in conformance with this PCR appendix will reflect only differences in specific data (plant energy use and material use).

Where possible, generic data are to be sourced from the Australian national life cycle inventory database (AusLCI) and the associated AusLCI shadow database developed by the Australian Life Cycle Assessment Society (ALCAS).[1]

The diagram in Figure 1 indicates for common unit processes whether specific or generic data should be used. All specific data must be reflective of plant production over a period of twelve consecutive months. Annual production data should be as recent as possible and no more than three years old.[2]

2.4.1 ASPHALT PRODUCTION

The asphalt production process requires predominantly specific data, such as material and energy input per unit of asphalt produced:

- Material use comprises of all the material inputs into the mixture and water use at the plant (including for dust suppression).
- Energy (fuel and electricity) is mainly used at the asphalt plant for plant (e.g. storage and dosing, drum mixer), burners (e.g. heating of bitumen, drying of aggregates) and internal transport.
    - Energy use for general management (e.g. office, laboratory) is excluded from the system boundaries as per the main PCR. In practice, it may be too difficult to separate energy use for these overhead processes from the main process. If this is the case, the LCA shall justify any deviation from the main PCR (or other relevant standards and guidelines).
- Production waste is typically recycled internally. Any production waste that is not processed internally shall be included in the inventory.

AAPA members have indicated that emissions to air are not measured in a consistent manner across the industry. Relying solely on specific data is therefore likely to create variations between plants due to differences in emissions measurement. Therefore, generic data shall be used as outlined in Appendix D. Emissions to air, where specific data are not available.

2.4.2 RAW MATERIAL PRODUCTION

In Australia, asphalt typically consists of a bitumen binder, aggregates and fillers. Additives may be added to achieve the desired properties.

In line with section 5 of the main PCR (IEPDS 2018), materials that make up less than 1% of the total mass input - but that are considered environmentally relevant - shall be included when publicly available data exists. Those materials are (not limited to):

- Polymers in binder, broken down into two classes of chemicals: elastomers or rubbers, such as styrene-butadiene-styrene (SBS), and plastomers
- Liquid antistrips, recycling agents and warm-mix chemical additives
- Fibres.

[1] For more information on AusLCI, visit: http://www.auslci.com.au/.

Note: the AusLCI shadow database contains proprietary data and is therefore not published. All LCA consultants with an ecoinvent license can access the AusLCI shadow database by contacting ALCAS.

[2] E.g. If the EPD is published in September 2019, the specific data should cover the 2016 calendar year or 2017 financial year or a more recent period.

To facilitate data collection and minimise variances the most commonly used raw materials are listed in Table 3, together with the prescribed data sources.

The prescribed data sources shall be used for all relevant raw materials in the LCA of asphalt mixtures. If raw materials (including additives) are used in the production of the asphalt mixture that are not listed in Table 3, then appropriate life cycle inventory data should be used. Data gaps are to be avoided.

Table 3. Default data sources for asphalt raw materials and additives

Type	Generic name	Prescribed data source	Database
Bitumen	Bitumen	Bitumen, at refinery/RER U/AusSD U	AusLCI shadow database
Fine aggregates (<5 mm)	Natural sand	Sand, at mine/CH U/AusSD U	AusLCI shadow database
	Manufactured sand	Gravel, crushed, at mine/CH U/AusSD U	AusLCI shadow database
Coarse aggregates (>5 mm)	River aggregates	Gravel, round, at mine/CH U/AusSD U	AusLCI shadow database
	Crushed rock	Gravel, crushed, at mine/CH U/AusSD U	AusLCI shadow database
Mineral fillers	Milled limestone	Limestone, milled, loose, at plant/CH U/AusSD U	AusLCI shadow database
	Bag house dust	Secondary material; no impact at point of generation	N/A
	Fly ash	Secondary material; no impact at point of generation	N/A
Anti-strip agents	Hydrated lime	Lime, hydrated, loose, at plant/CH U/AusSD U	AusLCI shadow database
	Amines	#Diethanolamine, at plant/RER U/AusSD U	AusLCI shadow database
Cold mix additives	Diesel	Diesel, at regional storage/RER U/AusSD U	AusLCI shadow database
	Vegetable based oil	#Canola oil, at oil mill/AU U	AusLCI
Fibres	Cellulose	#Cellulose fibre, inclusive blowing in, at plant/CH U/AusSD U[3] (75%) Limestone, milled, packed, at plant/CH U/AusSD U (15%) Bitumen, at refinery/RER U/AusSD U (10%)[4]	AusLCI shadow database
Polymers	SBS (Styrene-Butadiene-Styrene)	#literature data	See appendix D

[3] The ecoinvent background report (ecoinvent 2007) shows that the energy used for blowing is negligible. Therefore, this process is considered a reasonable proxy for cellulose fibres,

[4] Proxy chosen based on the MSDS for JRS VIATOP premium

Type	Generic name	Prescribed data source	Database
	EVA (Ethylene-Vinyl Acetate)	Ethylene vinyl acetate copolymer, at plant/RER U/AusSD U	AusLCI shadow database
	Fisher-Tropsch wax	#Paraffin, at plant/RER U/AusSD U	AusLCI shadow database
Recycling agents	Re-generated mineral oil	#literature data	See appendix D
Secondary materials	Recycled Asphalt Product (RAP)	Secondary material; processing after end-of-waste to be included	See appendix D
	Crushed glass sand	Adapted from ecoinvent v3	See appendix D
	Ground tyre rubber / rubber crumb	#literature data	See appendix D
Warm mix additives	liquid surfactant, e.g. Cecabase®	#Ethoxylated alcohols, unspecified, at plant/RER U/AusSD U (95%) Phosphoric acid, industrial grade, 85% in H2O, at plant/RER U/AusSD U (5%)[5]	AusLCI shadow database
	Evotherm	#Diethanolamine, at plant/RER U/AusSD U[6]	AusLCI shadow database
	liquid surfactant, e.g. CWM®	#Trimethylamine, at plant/RER U/AusSD U[7]	AusLCI shadow database
	Narrow cut kerosene	#Kerosene, at regional storage/RER U/AusSD U	AusLCI shadow database

 # indicates proxy data have been selected for these additives. The use of proxy data is preferred over leaving data gaps in the LCI.

How to deal with Reclaimed Asphalt Pavement / Recycled Asphalt Product (RAP)?

Definitions of RAP:

- *Reclaimed Asphalt Pavement, when the material comes out of the road*
- *Recycled Asphalt Product, when the material is used in new asphalt.*

Transport of Reclaimed Asphalt Pavement from road end-of-life site to a processing site needs to be included at the end-of-life. Reclaimed Asphalt Pavement reaches the end-of-waste state when the reclaimed, milled material has been collected in a truck and transported to a storage pile, ready to be processed for further use.

Processing (i.e. crushing, screening) and (if processing is conducted at an alternative site) transport of the material to the asphalt plant is part of the life cycle of the secondary material and needs to be accounted for as part of the Recycled Asphalt Product that is incorporated into new asphalt products.

[5] Proxy chosen based on the MSDS for Cecabase RT Bio10 issued by Fulton Hogan

[6] Proxy chosen based on the MSDS for Evotherm PC-1770

[7] Proxy chosen based on the MSDS for Chemoran CWM

2.4.3 ENERGY SOURCES

Energy used in asphalt production typically consists of electricity, natural gas, diesel and/or fuel oil. For production and transport of fuels, as well as generation, transmission and distribution of electricity, generic data can be used. The prescribed data sources for energy inputs are listed in Table 4.

Table 4. Default data sources for energy inputs

Energy type	Prescribed data source	Database
Electricity, Australian	Electricity, low voltage, Australian/AU U	AusLCI
Electricity, NSW/ACT	Electricity, low voltage, New South Wales/AU U	AusLCI
Electricity, Northern Territory	Electricity, low voltage, Northern Territory/AU U	AusLCI
Electricity, Queensland	Electricity, low voltage, Queensland/AU U	AusLCI
Electricity, South Australia	Electricity, low voltage, South Australia/AU U	AusLCI
Electricity, Tasmania	Electricity, low voltage, Tasmania/AU U	AusLCI
Electricity, Victoria	Electricity, low voltage, Victoria/AU U	AusLCI
Electricity, Western Australia	Electricity, low voltage, Western Australia/AU U	AusLCI
Natural gas, Australian, combusted*	Natural gas, burned in industrial furnace >100kW/RER U*	AusLCI shadow database
Natural gas, Australian, fuel	Natural gas, high pressure, Australia/AU U	AusLCI
Diesel, combusted*	Diesel, burned in building machine/GLO U/AusSD U	AusLCI shadow database
Diesel, fuel	Diesel, at regional storage/RER U/AusSD U	AusLCI shadow database
Heavy Fuel Oil, combusted*	Heavy fuel oil, burned in industrial furnace 1MW, non-modulating/RER U/AusSD U	AusLCI shadow database
Heavy Fuel Oil, fuel	Heavy fuel oil, at regional storage/RER U/AusSD U	AusLCI shadow database
LPG, combusted*	liquefied petroleum gas, burned in industrial furnace >100kW/RER U/adapted/AU U	AusLCI
LPG, fuel	Liquefied petroleum gas, at service station/CH U/AusSD U	AusLCI shadow database

** Fuels that are combusted in the manufacturing process to dry and heat raw materials contribute to the plant's process emissions to air. As indicated in section 2.4.1, process emissions to air are to be based on default values, to avoid variations between plants on the basis of measurement accuracy or completeness. See "Appendix D. Emissions to air" for details on how to calculate emissions to air.*

2.4.4 TRANSPORT PROCESSES

Transport is relevant throughout the life cycle of asphalt mixtures, from transport of raw materials and fuels to the asphalt plant to transport of asphalt products to the construction site. For all transport processes, a combination of specific and generic data can be used:

- Specific data relate to the transport mode (e.g. 20 t truck) and transport distance (km) from supplier to asphalt plant.
- Generic data relate to the impacts associated with the transport process. The prescribed data sources for transport processes are listed in Table 5.

Table 5. Default data sources for transport

Type	Prescribed data source	Database
Road transport, truck, 3.5-16t load	Transport, truck, 3,5 to 16t, fleet average/AU U	AusLCI
Road transport, truck 16-28t load	Transport, truck, 16 to 28t, fleet average/AU U	AusLCI
Rail transport	Transport, freight, rail/AU U	AusLCI
Water transport, barge	Transport, barge/RER U/AusSD U	AusLCI shadow database
Water transport, container ship	Transport, transoceanic freight ship/OCE U/AusSD U	AusLCI shadow database
Water transport, bulk tanker	Transport, transoceanic tanker/OCE U/AusSD U	AusLCI shadow database

As a rule, raw materials should be traced back to their production location. As this is not always possible, due to the complex nature of supply logistics it might not always be clear which transport processes are to be included in the LCA, supply transport legs that should be included in the LCA are explained in the following table.

Table 6. Default supply transport legs to be included in the LCA

Raw material input	From	To
Bitumen	Production location or port of acceptance	Asphalt plant
Aggregates	Quarry	Asphalt plant
Additives	Manufacturing location	Asphalt plant
RAP	Average/typical distance from road construction projects	Asphalt plant
Other secondary materials	(end-of-waste) Processing plant	Asphalt plant
Liquid fuels	Immediate supplier of liquid fuel	Asphalt plant

2.4.5 DOWNSTREAM PROCESSES

Downstream processes are only relevant when the EPD covers stages beyond A1:A3. At this stage, downstream processes or scenarios are not standardised.

2.5 PROCESS ALLOCATION

An asphalt plant typically produces a range of asphalt mixtures, depending on customer demand. It is not practical to measure energy consumption for a particular batch and to assign this to a mix design, because the energy consumption can have been influenced by the previous batch. Therefore, it is recommended to use either:

- Method A: Determine the energy use for each mix design based on the composition, specific heat capacity of components, moisture content of raw materials and the plant's overall efficiency.
- Method B: assign the annual energy consumption of the plant equally across all products (by mass).

The method used shall be stated in the EPD.

2.6 IMPACT ASSESSMENT METHOD

The impact assessment method shall follow the main PCR for asphalt mixtures (IEPDS 2018) in line with EN 15804.

Note that bitumen is a feedstock energy source and therefore contributes to the parameter: "Use of non-renewable primary energy resources used as raw materials".

GLOSSARY

AAPA	Australian Asphalt Pavement Association
AEPD	Australasian EPD Programme
ALCAS	Australian Life Cycle Assessment Society
CPC	Central Product Classification
EAPA	European Asphalt Pavement Association
EPA	Environmental Protection Agency
EPD	Environmental Product Declaration
IEPDS	International EPD System
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
NAPA	National Asphalt Pavement Association
PCR	Product Category Rules
RAP	Reclaimed Asphalt Pavement / Recycled Asphalt Product
RSL	Reference Service Life

Units:

kg	kilogram
kWh	kiloWatthour
m^2	square metre
m^3	cubic metre
MJ	MegaJoule
tkm	tonne-kilometre

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APPENDIX A. STAKEHOLDER CONSULTATION

Stakeholders that have been explicitly invited to provide comments on the draft PCR:

- The Australasian EPD Programme
    - Technical Advisory Group
- The International EPD Programme
    - PCR moderator for Asphalt Mixtures (IEPDS 2018)
- Australian Asphalt Pavement Association (AAPA):
    - Alex Fraser
    - Boral
    - Colas
    - Downer
    - Fulton Hogan
    - Kypreos Group
- Infrastructure Sustainability Council of Australia (ISCA)
- Road Authorities:
    - RTA
    - VicRoads
- Australian Life Cycle Assessment Society (ALCAS)
- Life Cycle Association of New Zealand (LCANZ)

A range of other stakeholders have been informed of the publication of the draft document for public consultation.

APPENDIX B. REFERENCE SERVICE LIFE ($RSL_{ASPHALT}$)

Table 7 shows the Durability of Surface Layers expressed in years of service life for major roads / motorways / heavily trafficked roads.

Table 8 shows the Durability of Surface Layers expressed in years of service life for secondary roads.

Table 7. Durability of surface layers on major roads

Major roads / motorways / heavily trafficked			
Type	15% Lowel level	European average	85% Higher level
AC	8	14	18
AC-TL 30-40 mm	8	12	18
AC-VTL 25-30 mm	8	10	12
UTLAC	8	10	12
PA	8	10	14
2L-PA [1])	9	11	12
SMA	14	20	25
HRA	17	21	25
Mastic-A	18	21	24

Soft-A is not used here
[1]) Only based on Dutch results

Table 8. Durability of surface layers on secondary roads

Secondary roads			
Type	15% Lowel level	European average	85% Higher level
AC	10	15	20
AC-TL	10	15	20
AC-VTL	10	12	14
2L-PA [1])	10	11	12
SMA	16	20	25
HRA	20	25	30
Mastic-A	18	24	30
Soft-A	8	12	25

PA and UTLAC are not used here
[1]) Only based on Dutch results

APPENDIX C. LIFE CYCLE INVENTORY DATA

This appendix contains life cycle inventory data for any relevant unit process not included in AusLCI or the AusLCI shadow database, or which has been adjusted. This allows LCA practitioners to duplicate LCI data and minimise variances resulting from differences in choice of generic data sources.

LCI data are provided for the following unit processes:

- Recycled Asphalt Product
- Styrene-Butadiene-Styrene copolymer (SBS)
- Recycled mineral oil
- Crushed glass sand
- Ground tyre rubber

RECYCLED ASPHALT PRODUCT

Reclaimed Asphalt Pavement is often transported directly from the road end-of-life site to an asphalt plant. Energy use for processing Reclaimed Asphalt Pavement into Recycled Asphalt product that is used in the production of new asphalt is therefore typically included in the asphalt plant's energy use. However, some manufacturers use RAP that is processed by contractors off-site. One AAPA member has provided the following data obtained from two RAP processing facilities. The facilities use a power screen with a front-end loader to feed material and then move processed material to a nearby stockpile. No electricity or water is being used for the RAP reprocessing at these two locations.

Table 9. LCI data for Recycled Asphalt Product

Category	Flow	Unit	Amount	Comment
Output: Product	Recycled Asphalt Product (RAP), at processing plant/AU U	kg	1,000	
		Inputs		
Input: Materials /Energy	Diesel, burned in building machine/GLO U/AusSD U	L	0.267	Crushing, screening and front-end loader

SBS

Polymer modified bitumen is widely used for both road and industrial applications. The range of polymer types and the range of polymer contents used in the bitumen vary depending on the technical requirements of the application. One of the most common polymer types used is styrene butadiene styrene (SBS) in its granular form.

An internal industry review of polymer modified products within Europe determined that a typical SBS polymer content is around 3.5% m/m in the final product (Eurobitume 2012).

As LCI data for SBS production are not readily available in AusLCI or the AusLCI shadow database, start2see has developed a proxy LCI for SBS based on proprietary process technology from Eni-Versalis for production of Styrene-Butadiene-Styrene block copolymers (Versalis). Care should be taken when using the proxy LCI, as only high-level data are described in the source document. Furthermore, the amount of butadiene and styrene copolymers can vary from SBS product to SBS product.

Table 10. LCI data for SBS

Category	Flow	Unit	Amount	Comment
Output: Product	Styrene-Butadiene-Styrene copolymer, SBS, at plant/AU U	kg	1	
	Inputs			
Input: Materials /Energy	Polybutadiene, at plant/RER U/AusSD U	kg	0.7	Estimate for butadiene content[8]
Input: Materials /Energy	Polystyrene, general purpose, GPPS, at plant/RER U/AusSD U	kg	0.3	Estimate for styrene content[8]
Input: Materials /Energy	Paraffin, at plant/RER U/AusSD U	kg	0.01	Estimate for paraffinic oil extensor
Input: Materials /Energy	Electricity, high voltage, at grid/US U/AusSD U	kWh	0.5	No production of SBS in Australia. Production assumed to be located in the USA.
Input: Materials /Energy	Steam, for chemical processes, at plant/RER U/AusSD U	kg	5.5	
Input: Materials /Energy	Water, cooling	m^3	0.2	
	Outputs			
Output: Emissions to air	Cyclopentane	kg	0.012	Worst case: assumes solvents are emitted to air

REGENERATED MINERAL OIL

As LCI data for regenerated waste oil are not readily available in AusLCI or the AusLCI shadow database, start2see has developed an Australian LCI for re-generated waste oil based on a study by Abdalla & Fehrenbach (Abdalla 2017).

According to (Abdalla 2017), included processes cover:

- all processes on the refinery site
- transport from the waste producer to the regeneration plant
- all external processes due to regeneration (e.g. fuel production or electrical power supply, crude oil drilling and production, digging and mining).
- downstream processes like waste disposal
- by-products of the regeneration process, e.g. surplus of process energy.

The report covers four different waste oil refining technologies. The LCI below represents an unweighted average across these four technologies. It should be noted that the data in Abdalla & Fehrenbach require an unusual level of interpretation, and the LCI should be considered a proxy for re-refined waste oil.

[8] Proxy composition based on Sigma-Aldrich product 182877 (CAS Number 9003-55-8)

Table 11 contains the description of flows of materials and energy (life cycle inventory) associated with the throughput of 1 tonne of waste oil in a refinery (generating nearly 850 kg fuel oil).

Table 11. LCI data for re-generated waste oil

Category	Flow	Unit	Amount	Comments
Output: Product	Re-refined waste oil, fuel oil (light fuel oil quality), at refinery/RER U/AusSD U	kg	849.1	Co-product allocation unknown. Presume 100%
Output: Product	Re-refined waste oil, gas oil, at refinery/RER U/AusSD U	kg	20	Co-product allocation unknown. Presume 0%
Output: Product	Re-refined waste oil, gases, at refinery/RER U/AusSD U	kg	4.3	Co-product allocation unknown. Presume 0%
Output: Product	Re-refined waste oil, light ends, at refinery/RER U/AusSD U	kg	18.3	Co-product allocation unknown. Presume 0%
		Inputs		
Input: From technosphere	Oil, from technosphere	kg	1000	Waste oil
Input: Materials /Energy	Bentonite, at mine/DE U/AusSD U	kg	18	
Input: Materials /Energy	Electricity, medium voltage, production UCTE, at grid/UCTE U/AusSD/Link U	MJ	54.05	
Input: Materials /Energy	Refinery gas, burned in furnace/MJ/RER U/AusSD U	MJ	838.35	
Input: Transport	Transport, lorry >16t, fleet average/RER U/AusSD/Link U	tkm	100	Transport of waste oil to refinery
Input: Transport	Transport, freight, rail/RER U/AusSD/Link U	tkm	600	Transport of waste oil to refinery

CRUSHED GLASS SAND

The LCI data for Australian “crushed glass sand” are based on a glass cullet process in the ecoinvent v3.4 database: “Glass cullet, sorted {RoW}| treatment of waste glass from unsorted public collection, sorting | Cut-off, U”. Key inputs to the process need to be changed (as per Table 12) in order to make the process more representative for Australia.

Important note: Other inputs and outputs (not mentioned in the table hereafter) remain unchanged from the ecoinvent v3.4 process and have to be included in the LCI.[9]

Table 12. Partial LCI data for crushed glass sand

Category	Updated flow	Unit	Amount	Original name
Output: Product	Glass cullet, sorted {AU}| treatment of waste glass from unsorted public collection, sorting | Cut-off, U	kg	1	Glass cullet, sorted {RoW}| treatment of waste glass from unsorted public collection, sorting | Cut-off, U
		Inputs		
Input: Materials /Fuels	electricity, low voltage, Australian/AU U	kWh	0.00375	Electricity, medium voltage {AU}| market for | Cut-off, U Electricity, medium voltage {NZ}| market for electricity, medium voltage | Cut-off, U Electricity, medium voltage {RAF}| market group for | Cut-off, U Electricity, medium voltage {RAS}| market group for | Cut-off, U Electricity, medium voltage {RLA}| market group for | Cut-off, U Electricity, medium voltage {RNA}| market group for | Cut-off, U Electricity, medium voltage {RoW}| market for | Cut-off, U Electricity, medium voltage {RU}| market for | Cut-off, U

GROUND TYRE RUBBER / CRUMB RUBBER

Finely ground tyre rubber (crumb rubber) can be used as a substitute for bitumen. As LCI data for ground tyre rubber are not readily available in AusLCI or the AusLCI shadow database, start2see has developed an Australian LCI for ground tyre rubber based on a study by Corti & Lombardi (Corti 2004). The process described in Table 13 includes grinding, crushing and mechanical pulverization of waste tyres.

The co-product allocation can have a significant effect on the impacts for the two types of crumb rubber that are produced. Finer crumb rubber has a higher value than coarser material. This is reflected in the presumed economic allocation factors.

[9] To protect ecoinvent's intellectual property, only the changes to the process are listed in this document.

Table 13. LCI data for rubber crumb

Category	Flow	Unit	Amount	Comments
Output: Product	Rubber from waste tyres, fine pulverised (<0.7 mm)/AU U	kg	630	Crumb rubber Co-product allocation estimated at 66% (~$650/t)*
Output: Product	Rubber from waste tyres, pulverised (<2 mm)/AU U	kg	310	Ground tyre rubber Co-product allocation estimated at 28% (~$550/t)*
Output: Product	Textile fibres from waste tyres/AU U	kg	60.0	Co-product allocation estimated at 0% (~$0/t)*
Output: Product	Iron scrap from waste tyres/AU U	kg	380.3	Co-product allocation estimated at 6% (~$100/t)*
		Inputs		
Input: Materials /Energy	Tyres	kg	1,380.3	
Input: Materials /Energy	electricity, low voltage, Australian/AU U	MJ	1,512	
Input: Materials /Energy	tap water, at user, Australia/AU U	kg	207	
Input: Materials /Energy	Steel, converter, unalloyed, at plant/RER U/AusSD U	kg	0.608	
Input: Materials /Energy	Lubricating oil, at plant/RER U/AusSD U	kg	0.015	
		Outputs		
Output: Emissions to air	Particulates, < 2.5 um	kg	0.264	
Output: Waste water	Treatment, sewage, to wastewater treatment, class 2/CH U/AusSD U	kg	207	

** Indicative values of co-products have been provided by the Australian Tyre Recyclers Association, November 2018.*

APPENDIX D. EMISSIONS TO AIR

The default emissions to air for asphalt production are based on data from the United States Environmental Protection Agency (US EPA 2004).

Emissions at an asphalt plant

Source: United States Environmental Protection Agency (US EPA 2004)

As with most facilities in the mineral products industry, batch mix Hot Mix Asphalt (HMA) plants have two major categories of emissions: ducted sources (those vented to the atmosphere through some type of stack, vent, or pipe), and fugitive sources (those not confined to ducts and vents but emitted directly from the source to the ambient air). Ducted emissions are usually collected and transported by an industrial ventilation system having one or more fans or air movers, eventually to be emitted to the atmosphere through some type of stack. Fugitive emissions result from process and open sources and consist of a combination of gaseous pollutants and PM.

The most significant ducted source of emissions of most pollutants from batch mix HMA plants is the rotary drum dryer. The dryer emissions consist of water (as steam evaporated from the aggregate); PM; products of combustion (carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur oxides (SO_x)); carbon monoxide (CO); and small amounts of organic compounds of various species (including volatile organic compounds (VOC), methane (CH_4) and hazardous air pollutants (HAP)). The CO and organic compound emissions result from incomplete combustion of the fuel. It is estimated that between 70 and 90 percent of the energy used at HMA plants is from the combustion of natural gas.

Other potential process sources include the hot-side conveying, classifying, and mixing equipment, which are vented either to the primary dust collector (along with the dryer gas) or to a separate dust collection system. The vents and enclosures that collect emissions from these sources are commonly called “fugitive air” or “scavenger” systems.

The emissions to air are partly due to the plant’s fuel combustion. The emissions to air for an asphalt mixture are determined based on:

- default factors (kg/tonne asphalt) that are independent of the natural gas usage (see Table 14)
- calculated factors based on the maximum value from either US EPA data or emission estimates based on natural gas use (see Table 15).

Table 14. Default asphalt plant emissions to air, kg/tonne asphalt

Emission to air	Quantity	Unit	Source
Acenaphthene	4.50E-07	kg/tonne	US EPA 2004 reported values
Arsenic	2.30E-07	kg/tonne	
Barium	7.50E-07	kg/tonne	
Benzaldehyde	6.50E-05	kg/tonne	
Benzene, ethyl-	1.10E-03	kg/tonne	
Beryllium	7.50E-08	kg/tonne	

Cadmium	3.05E-07	kg/tonne	
Chromium	2.85E-07	kg/tonne	
Chromium VI	2.40E-08	kg/tonne	
Copper	1.40E-06	kg/tonne	
Lead	4.45E-07	kg/tonne	
Manganese	3.45E-06	kg/tonne	
Nickel	1.50E-06	kg/tonne	
Particulates, < 10 µm	1.35E-02	kg/tonne	
Selenium	2.45E-07	kg/tonne	
Xylene	1.35E-03	kg/tonne	
Zinc	3.40E-06	kg/tonne	

Combustion of fuels for drying and heating raw materials contribute to process emissions. For the following emissions to air, use the maximum value between either the US EPA data (Table 15) or calculated emission estimates based on natural gas combustion (Table 16).

Table 15. Asphalt plant emissions to air, kg/tonne of asphalt

Emission to air	Quantity	Unit	Source
Acetaldehyde	1.60E-4	kg/tonne	US EPA 2004 reported values
Benzoapyrene	-	kg/tonne	
Benzene	1.40E-4	kg/tonne	
Butane	-	kg/tonne	
Methane	3.70E-3	kg/tonne	
Carbon monoxide	2.00E-1	kg/tonne	
Carbon dioxide	1.85E1	kg/tonne	
Acetic acid	-	kg/tonne	
Formaldehyde	3.70E-4	kg/tonne	
Mercury	2.05E-7	kg/tonne	
Dinitrogen monoxide	-	kg/tonne	
Nitrogen oxides	1.25E-2	kg/tonne	
PAH	-	kg/tonne	
Particulates, <2.5µm	4.15E-3	kg/tonne	
Pentane	-	kg/tonne	
Propane	-	kg/tonne	
Propionic acid	-	kg/tonne	
Sulfur dioxide	2.30E-3	kg/tonne	
Dioxins	-	kg/tonne	
Toluene	5.00E-4	kg/tonne	

Table 16. Asphalt plant emissions to air, kg/MJ of natural gas combusted

Emission to air	Quantity	Unit	Source
Acetaldehyde	0.000000001	kg/MJ	Emission in kg per MJ of natural gas use - from ecoinvent v2.2 process for Natural gas, burned in industrial furnace >100kW/RER U
Benzoapyrene	1.00E-11	kg/MJ	
Benzene	0.0000004	kg/MJ	
Butane	0.0000007	kg/MJ	
Methane	0.000002	kg/MJ	
Carbon monoxide	0.0000021	kg/MJ	
Carbon dioxide	0.056	kg/MJ	
Acetic acid	0.00000015	kg/MJ	
Formaldehyde	0.0000001	kg/MJ	
Mercury	3.00E-11	kg/MJ	
Dinitrogen monoxide	0.0000001	kg/MJ	
Nitrogen oxides	0.0000179	kg/MJ	
PAH	0.00000001	kg/MJ	
Particulates, <2.5µm	0.0000002	kg/MJ	
Pentane	0.0000012	kg/MJ	
Propane	0.0000002	kg/MJ	
Propionic acid	0.00000002	kg/MJ	
Sulfur dioxide	0.00000055	kg/MJ	
Dioxins	3.00E-17	kg/MJ	
Toluene	0.0000002	kg/MJ	

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY TABLES

The US EPA 2004 tables on the following pages show the default emission factors that form the basis for calculating emission factors for asphalt production processes.

Relevant default emissions are indicated with an orange outline:

Note: To convert from lb/ton to kg/Mg, multiply by 0.5.

Table 11.1-1. PARTICULATE MATTER EMISSION FACTORS FOR BATCH MIX HOT MIX ASPHALT PLANTS[a]

	Filterable PM				Condensable PM[b]				Total PM			
Process	PM[c]	EMISSION FACTOR RATING	PM-10[d]	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING	PM[e]	EMISSION FACTOR RATING	PM-10[f]	EMISSION FACTOR RATING
Dryer, hot screens, mixer[g] (SCC 3-05-002-45, -46, -47)												
Uncontrolled	32[h]	E	4.5	E	0.013[j]	E	0.0041[j]	E	32	E	4.5	E
Venturi or wet scrubber	0.12[k]	C	ND	NA	0.013[m]	B	0.0041[n]	B	0.14	C	ND	NA
Fabric filter	0.025[p]	A	0.0098	C	0.013[m]	A	0.0041[n]	A	0.042	B	0.027	C

[a] Factors are lb/ton of product. SCC = Source Classification Code. ND = no data. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.
[b] Condensable PM is that PM collected using an EPA Method 202, Method 5 (analysis of "back-half" or impingers), or equivalent sampling train.
[c] Filterable PM is that PM collected on or before the filter of an EPA Method 5 (or equivalent) sampling train.
[d] Particle size data from Reference 23 were used in conjunction with the filterable PM emission factors shown.
[e] Total PM is the sum of filterable PM, condensable inorganic PM, and condensable organic PM.
[f] Total PM-10 is the sum of filterable PM-10, condensable inorganic PM, and condensable organic PM.
[g] Batch mix dryer fired with natural gas, propane, fuel oil, waste oil, and coal. The data indicate that fuel type does not significantly effect PM emissions.
[h] Reference 5.
[j] Although no data are available for uncontrolled condensable PM, values are assumed to be equal to the controlled value measured.
[k] Reference 1, Table 4-19. Average of data from 16 facilities. Range: 0.047 to 0.40 lb/ton. Median: 0.049 lb/ton. Standard deviation: 0.11 lb/ton.
[m] Reference 1, Table 4-19. Average of data from 35 facilities. Range: 0.00073 to 0.12 lb/ton. Median: 0.0042 lb/ton. Standard deviation: 0.024 lb/ton.
[n] Reference 1, Table 4-19. Average of data from 24 facilities. Range: 0.000012 to 0.018 lb/ton. Median: 0.0026 lb/ton. Standard deviation: 0.0042 lb/ton.
[p] Reference 1, Table 4-19. Average of data from 89 facilities. Range: 0.0023 to 0.18 lb/ton. Median: 0.012 lb/ton. Standard deviation: 0.033 lb/ton.

** Fabric filter is standard technology on most Australian asphalt plants*

Table 11.1-2. SUMMARY OF PARTICLE SIZE DISTRIBUTION FOR BATCH MIX DRYERS, HOT SCREENS, AND MIXERS[a]

EMISSION FACTOR RATING: E

Particle Size, µm[b]	Cumulative Mass Less Than or Equal to Stated Size (%)[c]		Emission Factors, lb/ton	
	Uncontrolled[d]	Fabric Filter	Uncontrolled[d]	Fabric Filter
1.0	ND	30[e]	ND	0.0075[e]
2.5	0.83	33[e]	0.27	0.0083[e]
5.0	3.5	36[e]	1.1	0.0090[e]
10.0	14	39[f]	4.5	0.0098[f]
15.0	23	47[e]	7.4	0.012[e]

[a] Emission factor units are lb/ton of HMA provided. Rounded to two significant figures. SCC 3-05-002-45, -46, -47. ND = no data available. To convert from lb/ton to kg/Mg, multiply by 0.5.
[b] Aerodynamic diameter.
[c] Applies only to the mass of filterable PM.
[d] References 23, Table 3-36. The emission factors are calculated using the particle size data from this reference in conjunction with the filterable PM emission factor shown in Table 11.1-1.
[e] References 23, Page J-61. The emission factors are calculated using the particle size data from this reference in conjunction with the filterable PM emission factor shown in Table 11.1-1.
[f] References 23-24. The emission factors are calculated using the particle size data from these references in conjunction with the filterable PM emission factor shown in Table 11.1-1.

Table 11.1-5. EMISSION FACTORS FOR CO, CO_2, NO_x, AND SO_2 FROM BATCH MIX HOT MIX ASPHALT PLANTS[a]

Process	CO[b]	EMISSION FACTOR RATING	CO_2[c]	EMISSION FACTOR RATING	NO_x	EMISSION FACTOR RATING	SO_2[c]	EMISSION FACTOR RATING
Natural gas-fired dryer, hot screens, and mixer (SCC 3-05-002-45)	0.40	C	37[d]	A	0.025[e]	D	0.0046[f]	E
No. 2 fuel oil-fired dryer, hot screens, and mixer (SCC 3-05-002-46)	0.40	C	37[d]	A	0.12[g]	E	0.088[h]	E
Waste oil-fired dryer, hot screens, and mixer (SCC 3-05-002-47)	0.40	C	37[d]	A	0.12[g]	E	0.088[h]	E
Coal-fired dryer, hot screens, and mixer[j] (SCC 3-05-002-98)	ND	NA	37[d]	A	ND	NA	0.043[k]	E

[a] Emission factor units are lb per ton of HMA produced. SCC = Source Classification Code. ND = no data available. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] References 24, 34, 46-47, 49, 161, 204, 215-217, 282, 370, 378, 381. The CO emission factors represent normal plant operations without scrutiny of the burner design, operation, and maintenance. Information is available that indicates that attention to burner design, periodic evaluation of burner operation, and appropriate maintenance can reduce CO emissions. Data for dryers firing natural gas, No. 2 fuel oil, and No. 6 fuel oil were combined to develop a single emission factor because the magnitude of emissions was similar for dryers fired with these fuels.

[c] Emissions of CO_2 and SO_2 can also be estimated based on fuel usage and the fuel combustion emission factors (for the appropriate fuel) presented in AP-42 Chapter 1. The CO_2 emission factors are an average of all available data, regardless of the dryer fuel (emissions were similar from dryers firing any of the various fuels). Based on data for drum mix facilities, 50 percent of the fuel-bound sulfur, up to a maximum (as SO_2) of 0.1 lb/ton of product, is expected to be retained in the product, with the remainder emitted as SO_2.

[d] Reference 1, Table 4-20. Average of data from 115 facilities. Range: 6.9 to 160 lb/ton. Median: 32 lb/ton. Standard deviation: 22 lb/ton.

[e] References 24, 34, 46-47.

[f] References 46-47.

[g] References 49, 226.

[h] References 49, 226, 228, 385.

[j] Dryer fired with coal and supplemental natural gas or fuel oil.

[k] Reference 126.

Table 11.1-6. EMISSION FACTORS FOR TOC, METHANE, AND VOC FROM BATCH MIX HOT MIX ASPHALT PLANTS[a]

Process	TOC[b]	EMISSION FACTOR RATING	CH_4[c]	EMISSION FACTOR RATING	VOC[d]	EMISSION FACTOR RATING
Natural gas-fired dryer, hot screens, and mixer (SCC 3-05-002-45)	0.015[e]	D	0.0074	D	0.0082	D
No. 2 fuel oil-fired dryer, hot screens, and mixer (SCC 3-05-002-46)	0.015[e]	D	0.0074	D	0.0082	D
No. 6 fuel oil-fired dryer, hot screens, and mixer (SCC 3-05-002-47)	0.043[f]	E	0.0074	D	0.036	E

[a] Emission factor units are lb per ton of HMA produced. SCC = Source Classification Code. ND = no data available. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.
[b] TOC equals total hydrocarbons as propane, as measured with an EPA Method 25A or equivalent sampling train plus formaldehyde.
[c] References 24, 46-47, 49. Factor includes data from natural gas- and No. 6 fuel oil-fired dryers. Methane measured with an EPA Method 18 or equivalent sampling train.
[d] The VOC emission factors are equal to the TOC factors minus the methane emission factors; differences in values reported are due to rounding.
[e] References 24, 46-47, 155.
[f] Reference 49.

Table 11.1-9. EMISSION FACTORS FOR ORGANIC POLLUTANT EMISSIONS FROM BATCH MIX HOT MIX ASPHALT PLANTS[a]

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. Nos.
	CASRN	Name			
Natural gas- or No. 2 fuel oil-fired dryer, hot screens, and mixer with fabric filter (SCC 3-05-002-45,-46)	Non-PAH Hazardous Air Pollutants[b]				
	75-07-0	Acetaldehyde	0.00032	E	24,34
	71-43-2	Benzene	0.00028	D	24,34,46, 382
	100-41-4	Ethylbenzene	0.0022	D	24,46,47,49
	50-00-0	Formaldehyde	0.00074	D	24,34,46,47,49,226,382
	106-51-4	Quinone	0.00027	E	24
	108-88-3	Toluene	0.0010	D	24,34,46,47
	1330-20-7	Xylene	0.0027	D	24,46,47,49
		Total non-PAH HAPs	0.0075		

		PAH HAPs			
	91-57-6	2-Methylnaphthalene[c]	$7.1x10^{-5}$	D	24,47,49
	83-32-9	Acenaphthene[c]	$9.0x10^{-7}$	D	34,46,226
	208-96-8	Acenaphthylene[c]	$5.8x10^{-7}$	D	34,46,226
	120-12-7	Anthracene[c]	$2.1x10^{-7}$	D	34,46,226
	56-55-3	Benzo(a)anthracene[c]	$4.6x10^{-9}$	E	46,226
	50-32-8	Benzo(a)pyrene[c]	$3.1x10^{-10}$	E	226
	205-99-2	Benzo(b)fluoranthene[c]	$9.4x10^{-9}$	D	34,46,226
	191-24-2	Benzo(g,h,i)perylene[c]	$5.0x10^{-10}$	E	226
	207-08-9	Benzo(k)fluoranthene[c]	$1.3x10^{-8}$	E	34,226
	218-01-9	Chrysene[c]	$3.8x10^{-9}$	E	46,226
	53-70-3	Dibenz(a,h)anthracene[c]	$9.5x10^{-11}$	E	226
	206-44-0	Fluoranthene[c]	$1.6x10^{-7}$	D	34,46,47,226
	86-73-7	Fluorene[c]	$1.6x10^{-6}$	D	34,46,47,226
	193-39-5	Indeno(1,2,3-cd)pyrene[c]	$3.0x10^{-10}$	E	226
	91-20-3	Naphthalene	$3.6x10^{-5}$	D	34,46,47,49,226
	85-01-8	Phenanthrene[c]	$2.6x10^{-6}$	D	34,46,47,226
	129-00-0	Pyrene[c]	$6.2x10^{-8}$	D	34,46,226
		Total PAH HAPs	0.00011		
		Total HAPs	0.0076		
		Non-HAP organic compounds			
	100-52-7	Benzaldehyde	0.00013	E	24
	78-84-2	Butyraldehyde/ isobutyraldehyde	$3.0x10^{-5}$	E	24
	4170-30-3	Crotonaldehyde	$2.9x10^{-5}$	E	24
	66-25-1	Hexanal	$2.4x10^{-5}$	E	24
		Total non-HAPs	0.00019		

Table 11.1-11. EMISSION FACTORS FOR METAL EMISSIONS FROM BATCH MIX HOT MIX ASPHALT PLANTS[a]

Process	Pollutant	Emission Factor, lb/ton	Emission Factor Rating	Reference Numbers
Dryer, hot screens, and mixer[b] (SCC 3-05-002-45,-46,-47)	Arsenic[c]	$4.6x10^{-7}$	D	34, 40, 226
	Barium	$1.5x10^{-6}$	E	24
	Beryllium[c]	$1.5x10^{-7}$	E	34, 226
	Cadmium[c]	$6.1x10^{-7}$	D	24, 34, 226
	Chromium[c]	$5.7x10^{-7}$	D	24, 34, 226
	Hexavalent chromium[c]	$4.8x10^{-8}$	E	34, 226
	Copper	$2.8x10^{-6}$	D	24, 34, 226
	Lead[c]	$8.9x10^{-7}$	D	24, 34, 226
	Manganese[c]	$6.9x10^{-6}$	D	24, 34, 226
	Mercury[c]	$4.1x10^{-7}$	E	34, 226
	Nickel[c]	$3.0x10^{-6}$	D	24, 34, 226
	Selenium[c]	$4.9x10^{-7}$	E	34, 226
	Zinc	$6.8x10^{-6}$	D	24, 34, 226

[a] Emission factor units are lb/ton of HMA produced. Emissions controlled by a fabric filter. SCC = Source Classification Code. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Natural gas-, propane-, No. 2 fuel oil-, or waste oil-/drain oil-/No. 6 fuel oil-fired dryer. For waste oil-/drain oil-/No. 6 fuel oil-fired dryer, use a lead emission factor of $1.0x10^{-5}$ lb/ton (References 177 and 321, Emission factor rating: E) in lieu of the emission factor shown.

[c] Arsenic, beryllium, cadmium, chromium, hexavalent chromium, lead, manganese, mercury, nickel, and selenium are HAPs as defined in the 1990 CAAA.