NATIONAL ASPHALT PAVEMENT ASSOCIATION

Product Category Rules (PCR)

For Asphalt Mixtures: Annex I

Prescribed Secondary Data Sources

January 31, 2017

Validity Period: Through January 2022

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Prescribed Secondary Data Sources

In choosing the datasets, the first priority was transparency. To meet this transparency goal, the prescribed datasets must be publicly available at no cost. This was demanded by the public agencies who would request and use the EPDs published under this PCR. Cost and a lack of transparency of data sources have been noted as barriers to adoption of other existing EPD programs.

Unfortunately, many of the available open data sources include some datasets that are more than 10 years old. As a result, per the request of the technical reviewers, the LCA results using the datasets prescribed were compared to LCA results using a proprietary dataset to further assess the data quality (Mukherjee, 2016). Although specific values for the calculated potential environmental impacts differed, the LCA using open data proved generally in line with the trends identified with proprietary data.

Further Explanation — Choice of Data Sources

Data sources prescribed are publicly available and freely accessible to ensure transparency. Use of the prescribed data source will ensure comparability among EPDs developed using this PCR by limiting any variability due to differences in the upstream data within the system boundary

1. Secondary Data Sources for Asphalt Binder and Energy Sources

Module references are to Figure 2 in the PCR. Secondary data quality assessment per Section 12 of the PCR follows.

NREL U.S. LCI: *Crude oil, at refinery with electricity dummy processes estimated by GREET 2013.*

1. Impacts of all co-products of crude oil refining, including extraction, refining, and storage. The co-products of interest to this PCR include gasoline, diesel, residual fuel oil, and asphalt binder. A combination of mass and economic allocation is used to allocate relative impacts of the crude oil refining process across the different co-products. Refers to processes in Module A1:1.
2. Transportation of crude oil from well to refinery and transportation of all co-products of refining (excepting for asphalt binder) from the refinery to the asphalt mixture plant. This will be based on secondary data sources, from existing public U.S. LCI data. Refers to processes in Module A2:1.

NREL U.S. LCI: *Natural gas combusted in industrial boiler with electricity dummy processes estimated by GREET 2013.*

1. Impacts associated with the extraction and production of natural gas. Refers to processes in Module A1:2.

Electricity: Based on Argonne National Laboratory (2015) GREET 2013, emissions and energy use in Electricity tab; line losses assumed to be 6.5% as per GREET 2013. Note: Tables 1a and 1b include average U.S. energy mix data. The PCR requires the use of data from the local eGRID subregion in which the plant is located.

1. Impacts associated with the production of electricity and transmission to asphalt mixture plant. Refers to processes in item A1:4.

Table 1a: Power Plant Energy Use and Emissions: per MMBtu of Electricity Available at User Sites

	Stationary Use: U.S. Mix
Energy Use: Btu	***Total (Btu/MMBtu)***
Residual oil	29302.23521
Natural gas	529490.8756
Coal	1419257.122
Biomass	14082.41653
Nuclear	217437.774
Other energy sources	104289.5883
Emissions: grams	***g/MMBtu***
VOC	3.413323958
CO	36.13841307
NO_x	194.2071307
PM_{10}	45.1780429
$PM_{2.5}$	31.83058815
SO_x	480.370154
CH_4	2.629685648
N_2O	2.389911051
CO_2	175923.7538

Table 1b: U.S. Electricity Mix

Source of Electricity (U.S. average)	**Btu/kWh**
Residual oil (non-renewable)	1.00E+02
Natural Gas (non-renewable)	1.81E+03
Coal — Bituminous (non-renewable)	4.38E+03
Coal — Lignite (non-renewable)	2.13E+02
Biomass	4.81E+01
Nuclear (non-renewable)	7.42E+02
Hydroelectric	2.39E+02
Geothermal	1.40E+01
Wind	8.70E+01
Solar PV	1.11E+00
Other (Biogenic Waste, Pumped Storage, etc.)	1.45E+01

ID	Process	Age	Geography	Sources
A1:1, A2:1	NREL U.S. LCI: Crude oil, at refinery	2003	USA	Franklin Associates 2003 Data Details for Petroleum Refining
				U.S. EPA 2002 Inv. of U.S. GHG Emissions and Sinks: 1990–2000 CH_4 Emissions from Petroleum Systems
				Energy Information Administration 2001 Annual Energy Review 2001, Refinery Input and Output
				World Bank Group 1998 Petroleum Refining, Pollution Prevention and Abatement Handbook.
				Oak Ridge National Laboratory 1996 Estimating Externalities of Oil Fuel Cycles.
				Association of Oil Pipelines 2000 Association of Oil Pipelines Annual Report 2000
				1986 ASTM-IP Petroleum Measurement Tables
				U.S. EPA 1995 AP 42, Chapter 5, Petroleum Refining.
A1:2	NREL U.S. LCI: Natural gas combusted in industrial boiler	2003	USA	Franklin Associates 2003 Data Details for Natural Gas Industrial Combustion
				Center for Transportation Research, Argo 2000 GREET Version 1.6
				EPA 1998 AP-42 Emission Factors. External Combustion Sources. Section 1.4 — NG Combustion
				U.S. EPA 1998 Study of Haz Air Pol Emis from Elec Utility Steam Gen Units V1 EPA-453/R-98-004a
				U.S. EPA Office of Solid Waste and Emerg 1999 Rep. to Congress on Wastes from the Combustion of Fossil Fuels EPA 530-R-99-010.
				Assumption by Franklin Associates on fossil-fuel fired boiler systems

ID	Process	Age	Geography	Sources
A1:4	Electricity — line loss of 6.5% with U.S. average energy mix	2013	USA Region specific	GREET 2013

2. Asphalt Binder Allocation

Until a public secondary data source for asphalt binder is published and prescribed on the NAPA EPD Program website, the NREL U.S. LCI Crude oil, at refinery using a combination of mass and economic allocation at the refinery, which is in accordance to the procedure defined by Yang (2014) and outlined in Table 2, shall be used.

Table 2: Allocation for Asphalt Binder (Yang, 2014)

Co-products U.S. Average	Allocation Factors	Mass Yield Fractions	Economic Allocation Coefficient
LPG	0.76	0.03	0.02
Finished motor gasoline	1.31	0.42	0.53
Kerosenes	1.21	0.09	0.10
Distillate fuel oil	1.2	0.21	0.25
Residual fuel oil	0.65	0.05	0.03
Special napthas	0.99	0.05	0.04
Lubricants	3.14	0.05	0.09
Petroleum coke	0.14	0.06	0.01
Asphalt and road oil	0.5	0.04	0.02

Note: The allocation factors are defined as the ratio of the economic *Allocation Coefficient*, that is the price weighted average yield of each co-product, to the *Mass Yield Fraction*. Based on the mass yields of the co-products and the known allocation factors, the economic allocation coefficients were derived. The relevant numbers have been illustrated in Table 2. (Mass Yield Fraction and Economic Allocation Coefficient numbers may not add up to 1 due to rounding.) The economic allocation coefficients were used to develop an inventory for asphalt binder based on the *NREL U.S. LCI Crude oil, at refinery* data. An inventory for distillate fuel oil was also constructed the same way.

3. Secondary Data Sources for Aggregates

Module references are to Figure 2 in the PCR. Secondary data quality assessment per Section 12 of the PCR follows.

Data sources from Life Cycle Inventory of Portland Cement Concrete, SN3011 (Marceau et al., 2007).

1. Impacts associated with the mining, extraction, and production of aggregate. Refers to processes in item A1:3.

Table 3: Source: Life Cycle Inventory of Portland Cement Concrete, Report No. SN3011 (Marceau et al., 2007).

Energy used to produce sand and gravel:					
Fuel or Electricity	**Total Energy Used**		**Energy/Ton Aggregate**		
	Amount	**MBtu**	**Amount**	**Btu/ton**	**kJ/metric ton**
Distillate (light) grade Nos. 1, 2, 4, & light diesel fuel, gallon	58,959,600	8,177,697	0.0562	7,793	9,060
Residual (heavy) grade Nos. 5 and 6 & heavy diesel fuel, gallon	13,234,200	1,981,160	0.0126	1,888	2,200
Gas (natural, manufactured, and mixed), Mcf	1,400,000	1,437,800	0.0013	1,370	1,590
Gasoline used as a fuel, gallon	5,700,000	712,500	0.0054	679	790
Electricity purchased, 1000 kWh	2,525,053	8,615,481	0.0024	8,210	9,550
Total		**20,924,638**		**19,940**	**23,190**
Energy used to produce coarse aggregate from crushed stone:					
Fuel or Electricity	**Total Energy Used**		**Energy/Ton Aggregate**		
	Amount	**MBtu**	**Amount**	**Btu/ton**	**kJ/metric ton**
Coal, ton	43,000	903,516	0.0000275	577	670
Distillate (light) grade Nos. 1, 2, 4, & light diesel fuel, gallon	145,811,400	20,224,041	0.0932	12,920	15,030
Residual (heavy) grade Mos. 5 and 6 & heavy diesel fuel, gallon	22,663,200	3,392,681	0.0145	2,167	2,520
Gas (natural, manufactured, and mixed), Mcf	5,400,000	5,545,800	0.00345	3,543	4,120
Gasoline used as a fuel, gallon	14,700,000	1,837,500	0.00939	1,174	1,370
Electricity purchased, 1000 kWh	4,627,887	15,790,350	0.00296	10,088	11,730
Total		**47,693,888**		**30,469**	**35,440**

ID	Process	Age	Geography	Sources
A1:3	Mining extraction and production of aggregate	2007	USA	Life Cycle Inventory of Portland Cement Concrete, Report No. SN3011 (Marceau et al., 2007)

4. Secondary Data Sources for Transportation

Module references are to Figure 2 in the PCR. Secondary data quality assessment per Section 12 of the PCR follows.

Transportation, NREL U.S. LCI

1. Transportation of asphalt binder from refinery/terminal to plant. Distances and transportation method will be based on primary data collected for each plant. Refers to processes in Module A2:2. NREL datasets per possible transportation method are as follows:
    a. *Transport, barge average fuel mix.*
    b. *Transport, combination truck diesel powered.*
    c. *Transport, train diesel powered.*
2. Transportation of virgin aggregate from quarry to the asphalt mixture plant. Distances and transportation method will be based on primary data collected for each plant. Refers to processes in item A2:3. NREL datasets per possible transportation method are as follows:
    a. *Transport, barge average fuel mix.*
    b. *Transport, combination truck diesel powered.*
    c. *Transport, train diesel powered.*
3. Transportation of recycled materials such as RFO, RAP and RAS to the asphalt mixture plant. Distances will be based on primary data collected for each plant. Refers to processes in Module A2:4. NREL datasets per possible transportation method is as follows:
    a. *Transport, combination truck diesel powered.*

ID	Process	Age	Geography	Sources
A2:2	NREL U.S. LCI: Transport, train diesel powered	2003	USA	Franklin Associates 2003 Data Details for Locomotive Transportation (Diesel)
				Center for Transportation Research, Argo 2001 GREET Version 1.6
				unspecified 9999 Based on assumption by Franklin Associates.
				Association of American Railroads 2002 Railroad Facts 2002.

ID	Process	Age	Geography	Sources
A2:3, A2:4	NREL U.S. LCI: Transport, combination truck diesel powered	2003	USA	Franklin Associates 9999 Data Details for Combination Truck Transportation (Diesel)
				Center for Transportation Research, Argo 9999 GREET Version 1.6
				unspecified 9999 Based on assumption by Franklin Associates.
A2:3, A2:4	NREL U.S. LCI: Transport, barge, average fuel mix	2007	USA	James Littlefield 2007
	NREL U.S. LCI: Transport, barge, diesel powered	2003	USA	Franklin Associates 2003
				Center for Transportation Research, Argo 2001
				unspecified 9999 Based on assumption by Franklin Associates.
	NREL U.S. LCI: Transport, barge, residual fuel oil powered	2006	USA	Franklin Associates 2006
				Center for Transportation Research, Argo 2001
				unspecified 9999 Based on assumption by Franklin Associates.

Asphalt Mix Additives and Modifiers

5. Various asphalt-mix additives and modifiers with the current status of data availability

Materials that are less than 1% of the total mass inputs for the model (excluding fuel), but which are considered environmentally relevant include chemical additives and polymers such as those listed below. As there are data gaps in their publicly available life cycle inventories, these materials will be included in the analysis as soon as reliable and transparent sources become available. These data gaps must be clearly noted on the EPD as prescribed in Section 16.a.vii.

Table 4. Asphalt Mix Additives and Modifiers

Type	Generic Examples	Public Inventory Data
Antistrip Agents	Amines	None at this time
	Hydrated lime	NREL
Fibers: Natural	Cellulose	None at this time
	Mineral	
	Rock wool	
Fibers: Synthetic	Fiberglas	
	Polyester	
	Polypropylene	
Mineral Fillers	Crushed fines	PCA
	Fly ash	Cutoff rule
	Lime	NREL
	Portland cement	PCA
Miscellaneous	Silicones (prevent foaming in the asphalt tank) (added by refiners)	None at this time
Plastic	Ethylene acrylate copolymer	None at this time
	Ethylene propylene copolymers (EPM)	
	Ethylene propylene diene (EPDM)	
	Ethylene-vinyl acetate (EVA)	
	Polyethylene	
	Polyolefins	
	Polypropylene	
	Polyvinyl chloride (PVC)	
Polymer Blends	Blends of plastic and rubber polymers	None at this time
Recycling Agents	Hydrocarbon recycling oils	None at this time
	Refined engine oil bottoms (REOB)	
	Vacuum tower asphalt extenders	

Type	Generic Examples	Public Inventory Data
Rubber	Natural rubber	None at this time
Natural Latex	Styrene-butadiene rubber (SBR)	
Synthetic Latex	Polychloroprene latex	
Block Copolymer	Styrene-isoprene-styrene (SIS)	
	Styrene-butadiene-styrene (SBS)	
Waste Materials	Ground tire rubber (GTR)	None at this time
	Roofing shingles (RAS)	Mukherjee (2016)

References

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