Product Category Rules (PCR)

For Asphalt Mixtures

Version 0.4
June 1, 2016
Validity Period: Through [Month] 2021
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1. General Information

a. This product category rule (PCR) is intended for U.S. companies (including companies operating in the federal district and territories) seeking Environmental Product Declarations (EPDs) for asphalt mixtures.

b. The PCR was prepared by members of the PCR Development Working Group (see Appendix A) in accordance with the following guidelines and underlying life cycle assessment (LCA):
   i. National Asphalt Pavement Association (NAPA) Environmental Product Declaration Program’s General Program Instructions;
   ii. Guidance for Product Category Rule Development, v 1.0 (see Conformity Assessment Form in Appendix B); and
   iii. Life Cycle Assessment of Asphalt Mixtures in Support of an Environmental Product Declaration (Mukherjee, 2016).

c. The development of this PCR was funded by the State Asphalt Pavement Associations and the National Asphalt Pavement Association.

d. The PCR is in conformance with the requirements of the following standards:
   i. International Organization for Standardization (ISO) 14025:2006 Environmental Labels and Declarations — Type III Environmental Declarations — Principles and Procedures;
   ii. ISO 14040:2006 Environmental Management — Life Cycle Assessment — Principles and Framework; and

e. The PCR references the following standards:
   i. European Committee for Standardization (CEN) EN 15804:2012 Sustainability of Construction Works — Environmental Product Declarations — Core Rules for the Product Category of Construction Products; and

f. This document is valid through [TBD] 2021.
   i. Review of PCR will begin four years from date of publication, or sooner if circumstances warrant an earlier review.

2. Identification of Program Operator

a. The Program Operator is the National Asphalt Pavement Association based in Lanham, Maryland, United States of America.

b. NAPA is a 501(c)(6) non-profit organization. It is the only trade association exclusively representing the interests of asphalt pavement material producers and paving contractors on the national level with Congress, governmental agencies, and other
national trade and business organizations. NAPA supports an active research program designed to answer questions about environmental issues and to improve the quality of asphalt pavements and paving techniques used in the construction of roads, streets, highways, parking lots, airports, and environmental and recreational facilities. The association provides technical, educational, and marketing materials and information to its members, and supplies technical information to users and specifiers of paving materials. The association, which counts more than 1,100 companies among its members, was founded in 1955.

c. The general program instructions and program contact information can be accessed at http://www.asphaltpavement.org/EPD.

3. PCR Review

a. To ensure conformance with the ISO standards this PCR underwent a public comment period and was reviewed by third-party review panel.

b. Third-Party ISO Reviewer Panel:
   i. Joep Meijer, theRightenvironment
   ii. Christoph Koffler, thinkstep
   iii. John T. Harvey, University of California, Davis

c. Open Consultation Period:
   i. The first draft for stakeholder comments was published on June 1, 2016, and was open for public consultation for 30 days.
   ii. A list of stakeholders who provided comments or who were invited to provide comments is found in Appendix C.
   iii. More than [TBD] comments were received and integrated into this version.
   iv. A summary of the comments received and the PCR Development Working Group’s response is found in Appendix D.

4. PCR Purpose

a. This PCR is being developed to accommodate the use and implementation of Type III EPDs that will provide the basis for comparing cradle-to-gate environmental impacts for the production of asphalt mixtures in the United States, including the federal district and territories.
   i. This PCR is valid for business-to-business EPDs for asphalt mixtures from cradle to gate.
   ii. Per the NAPA General Program Instructions, producers who develop an EPD in accordance with this PCR maintain sole ownership and have sole responsibility and liability for their EPDs.
iii. EPDs compliant with this program may be used as a data input for pavement life cycle assessments to compare the environmental impacts of different asphalt pavement alternatives only.

Further Explanation — Life Cycle Inventory Data

To minimize variances resulting from differences in choice of secondary data sources, all life cycle inventory data is prescribed in this PCR. Therefore, EPDs compliant with this PCR reflect only differences in primary data such as plant energy use, material use, and plant emissions. This provides an effective approach to compare the environmental impacts of the processes used in the production of asphalt mixtures.

b. This PCR is based upon the “Product Category Rules for Preparing an Environmental Declaration for Product Group Asphalt and Crushed Stone (NPCR 18)” published by The Norwegian EPD Foundation in November 2010. Primary differences between this document and NPCR 18 are as follows:

i. Geography: North America;
ii. Environmental Impact Methods: Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) 2.1; and
iii. Data Sources: Prescribed upstream inventories.

c. Harmonization with other EPD programs: Currently no PCRs exist for asphalt mixture constituent materials. Efforts will be made in the future to maintain harmonization efforts undertaken by the Asphalt Institute, the international trade association of petroleum asphalt producers, manufacturers and affiliated businesses.

5. Definitions

a. General LCA definitions are provided in the referenced ISO standards.

b. Definitions\(^1\) specific to this PCR are as follows:

i. Aggregate — a collective term for mineral materials that vary in size and source, such as sand, gravel and crushed stone, used with a binding medium, such as liquid asphalt cement, to form asphalt mixtures or other compound materials.

ii. Asphalt — also called “bitumen.” A dark brown or black cement-like residuum obtained from the distillation of suitable crude oils or derived from naturally occurring deposits. Used to produce liquid asphalt binder.

iii. Asphalt baghouse fines — dust particles captured from the exhaust gases of asphalt mixing plants.

iv. Asphalt mixture — a plant-produced composite material of aggregates, liquid asphalt binder, and other materials. The mixture may contain varying quantities of recycled materials as a substitute for virgin materials, including reclaimed

\(^1\) Definitions are based on those provided in ASTM D8-13b Standard Terminology Relating to Materials for Roads and Pavements.
asphalt pavement (RAP) and recycled asphalt shingles (RAS). See Table E1 in Appendix E for a list of other material additives.

v. Equivalent single-axle loads (ESALs) — Wheel loads of various magnitudes and repetitions (“mixed traffic”) converted to an equivalent number of standard loads that a pavement is expected to encounter.

vi. Fibers — cellulose, mineral fibers, or synthetic fibers added to asphalt mixtures to improve cracking resistance and stabilize the binding structure.

vii. Fines — a collective term for the smallest aggregate components, generally those that pass through a ⅜-inch sieve or No. 4 sieve. Aggregates larger than ⅜ inch are referred to as “coarse aggregates.”

viii. Foaming — a warm-mix asphalt technology that injects a small amount of water into an asphalt mixture to aid the coating of aggregate with liquid asphalt while reducing the temperatures at which the material is mixed and placed on the road.

ix. Ground tire rubber (GTR) — scrap tires that are ground to small particles and added as a modifier to liquid asphalt binder or to asphalt mixtures to supplement a portion of the fine aggregate.

x. Hydrated lime — a dry white powder consisting essentially of calcium hydroxide (Ca(OH)₂) that is added to improve the moisture susceptibility of asphalt mixes. Hydrated lime is processed by adding water to crushed lime (water accounts for approximately 1% of raw hydrate).

xi. Lime — a mineral derived from heating (calcining) limestone, which is added to improve the moisture susceptibility of asphalt mixes.

xii. Liquid antistrip — additive added to liquid asphalt binder to improve the moisture susceptibility of asphalt mixes.

xiii. Liquid asphalt binder — also called “liquid asphalt” or “asphalt cement.” A highly viscous liquid or semi-solid residue from petroleum refining used as the principal binding agent in asphalt mixtures. Asphalt binders may include materials added to modify its original properties.

xiv. Load spectrum — distribution of wheel loads characterized by number of axles, configuration, and weight that a pavement is expected to encounter.

xv. Polymer additives — Elastomers and plastomers used to modify liquid asphalt binder to provide special properties. See Table E1 in Appendix E for a list of specific polymer additives.

xvi. Primary data — any data item directly observed and collected.

xvii. Reclaimed asphalt pavement (RAP) — removed and/or reprocessed pavement materials containing liquid asphalt binder and aggregates. RAP is typically generated by milling machines in rehabilitation projects or a special crushing plant that breaks down large pieces of discarded hot- or warm-mix asphalt pavement.

xviii. Recycled fuel oil (RFO) — waste oil that is reprocessed to be used as a substitute energy source.

xix. Recycled asphalt shingles (RAS) — asphalt shingle manufacturer waste or asphalt shingles removed during re-roofing or roof removal projects that are
ground into fine particles to be added to asphalt mixtures as a replacement of a portion of virgin liquid asphalt binder and fines.

xx. Recycling agents — are hydrocarbon materials designed to restore aged (oxidized) liquid asphalt binder from RAP and/or RAS to the requirements of current asphalt cement specifications for asphalt mixes.

xxi. Secondary data — data inventories from other sources that have not been directly observed.

xxii. Warm-mix additives — a variety of chemical additives that allow producers of asphalt mixtures to lower temperatures at which the material is mixed and placed on the road and improve compaction.

xxiii. Warm-mix asphalt technologies — methods that allow asphalt mixtures allowable to be compacted at lower temperatures than conventional asphalt mixtures, e.g., warm-mix additives or foaming.

6. Acronyms

a. General LCA acronyms are provided in the referenced ISO standards.

b. Acronyms specific to this PCR are as follows:

i. AASHTO: American Association of State Highway and Transportation Officials

ii. Btu: British thermal unit

iii. CO₂e: Carbon dioxide equivalents

iv. EPD: Environmental product declaration

v. ESALs: Equivalent single-axle loads

vi. GTR: Ground tire rubber

vii. GREET: Greenhouse gases, Regulated Emissions, and Energy use in Transportation

viii. HMA: Hot-mix asphalt

ix. kWh: Kilowatt hour

x. LCA: Life cycle assessment

xi. LCI: Life cycle inventory

xii. Mcf: One thousand cubic feet

xiii. MMBtu: One million British thermal units

xiv. NAPA: National Asphalt Pavement Association

xv. NREL: National Renewable Energy Laboratory

xvi. PCA: Portland Cement Association

xvii. PCR: Product category rules

xviii. RAP: Reclaimed asphalt pavement

xix. RAS: Recycled asphalt shingles

xx. RFO: Recycled fuel oil
7. **Life Cycle Assessment: Product Scope**

a. This PCR addresses UNSPSC — United Nations Standard Products and Services — Code 30111509: Asphalt Based Concrete. An asphalt mixture is defined as a plant-produced composite material of aggregates, liquid asphalt binder, and other materials.

i. The mixture may contain varying quantities of waste materials as a substitute for virgin materials, as well as chemical additives and modifiers which will be included as and when appropriate inventory data becomes available.

ii. Table E1 in Appendix E lists various asphalt-mix additives and modifiers with the current status of data availability.

b. The asphalt mix shall be described in accordance to the product specifications under which it is purchased, as well as production information.

i. Product specifications include, but are not limited to, the AASHTO M323-04 Standard Specification for Superpave Volumetric Design and the traffic volume in ESALs or load spectrum of the pavement for which the mixture is intended to be used.

ii. Production information declared shall include the company name, asphalt plant, the production temperature range, and the type of warm-mix technology (chemical or foaming) used, if any.

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**Further Explanation — Asphalt Production Temperature**

Reducing production temperatures can reduce energy requirements and thus lower the environmental impact of asphalt production. Different plants achieve temperature reductions in different ways; however, the use of RAP and/or polymer-modified asphalts can place a limit on how low temperatures can be reduced. This creates significant variability in the actual temperatures at which asphalt mixtures are produced. Therefore, no differentiation is made between a “hot” asphalt mixture and a “warm” asphalt mixture; instead, for each asphalt mixture, the plant production temperature will be declared in the EPD.

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8. **Life Cycle Assessment: Declared Unit**

a. 1 short ton of asphalt mixture (liquid asphalt binder and aggregate combined).

9. **Life Cycle Assessment: System Boundaries**

a. The system boundaries for the study are established in Figures 1 and 2.

b. This PCR accounts for processes that are within the bounds of phases A1: Raw Material Supply, A2: Transport, and A3: Manufacturing (Figure 1).

c. The scope of the underlying life cycle assessment of the asphalt mixture (Mukherjee, 2016) is strictly cradle-to-gate, with the gate being defined as the point at which the asphalt mixture is transferred from the silo at an asphalt plant to the truck for transport to consumer.
d. All inputs and outputs to the unit processes identified must be included in the calculation (Figure 2).

e. The items are referenced using the phase and associated number on the list. Hence, A1:2 refers to item 2 in phase A1.

**Processes in Phase A1: Material Supply, Mining, and Production**

Data for all these processes will be based on secondary data sources, from existing public U.S. LCI data. The following impacts are included:

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 bitumen. An economic allocation (Yang, 2014) is used to allocate the relative impacts of the crude oil refining process across the different co-products.

2. Impacts associated with the extraction and production of natural gas used as burner fuel.

3. Impacts associated with the mining, extraction, and production of aggregate.

4. Impacts associated with the production of electricity and transmission to asphalt plant.

5. Impacts associated with bio-fuels, if used, at the plant.

6. Impacts associated with the recycled/reclaimed materials such as RAP/RAS. See section 14: Allocation.

**Processes in Phase A2: Transport to Plant**

Transportation distances of raw materials to the plant are considered to be primary data. Transportation distances that are part of upstream processes, involving transport of a raw material through the supply chain before it arrives to the plant, are considered part of the secondary data.

1. Transportation of crude oil from well to refinery and transportation of all co-products of refining (except for liquid asphalt binder) from the refinery to the asphalt plant. This will be based on secondary data, from existing public U.S. LCI data sources.

2. Transportation of crude oil from well to refinery and transportation of all co-products of refining (except for liquid asphalt binder) from the refinery to the asphalt plant. This will be based on secondary data, from existing public U.S. LCI data sources.

3. Transportation of liquid asphalt binder from the refinery to the asphalt plant. It is assumed that the liquid asphalt binder is directly sourced from a refinery, not a terminal. This will be based on primary data collected for each plant.

4. Transportation of virgin aggregate from source to the asphalt plant. This will be based on primary data collected for each plant.

5. Transportation of recycled materials such as RFO, RAP, and RAS to the asphalt plant. This will be based on primary data collected for each plant.
Figure 1. Diagram of designations of modular information used for life cycle assessments for pavements (adapted from CEN EN 15978:2011). This PCR's boundaries are in the box outlined in orange, covering phase A1–A3.
Figure 2. Diagram of the system boundaries and data types.
Processes in Phase A3: Plant Operations

All data collected for this part of the system will be directly based on plant operations and will be considered primary data.

1. Energy (fuel and electricity) used at the plant for the mix production process, including:
   a. Off-road equipment used in moving aggregate and other related mobile equipment used on site for the production of asphalt mixtures.
   b. Burner used for the drying of aggregates.
   c. Burner used for secondary purposes (heating exhaust gases).
   d. Heating of asphalt binder in storage tanks.
   e. Movement of aggregate and liquid binder through the plant and mixing process.
   f. Asphalt mixture storage in silos and liquid asphalt binder in tanks.
   g. Processing of RAP and RAS completed at the plant site.
   h. Additive addition completed at the plant, e.g., chemical antistrip or hydrated lime, warm mix, recycling agents, etc.

2. Outputs from plant:
   a. Total amount of asphalt mixture produced at the plant. Production is defined by total tonnage of asphalt mixture sold.
   b. Total amount of water used on the plant for dust control and/or for foaming. No differentiation is made between water used for dust control and water used for foaming.
   c. Total plant emissions from stack.
   d. Total quantity of baghouse fines not closed-loop recycled 100% in the plant.

10. Life Cycle Assessment: Cutoff Criteria

a. All inputs and outputs to a unit process for which data are available must be included in the calculation. Data gaps may be filled by conservative assumptions with average or generic data. Any assumptions for such choices shall be documented.

b. In case of insufficient input data or data gaps for a unit process, the cutoff criteria shall be 1% of the total primary energy usage and 1% of the total mass input of that unit process. The total sum of neglected input flows shall not exceed 5% of energy usage and mass. Conservative assumptions in combination with plausibility considerations and expert judgment can be used to demonstrate compliance with these criteria.

c. The total sum of neglected impacts shall not exceed 5% of energy usage and mass. This applies particularly to material and energy flows known to have the potential to cause significant emissions into air and water or soil during the life cycle of the product; it also applies to processes that are known to be resource intensive. Conservative assumptions
in combination with plausibility considerations and expert judgment can be used to
demonstrate compliance with these criteria.

d. Materials that are less than 1% of the total mass input but 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. This may include, but not limited to, the following:

i. Liquid antistrips, recycling agents, and warm-mix chemical additives;

ii. Ground tire rubber and energy used for recycling rubber; and

iii. Polymers in binder, broken down into two classes of chemicals: elastomers or
rubbers, such as styrene-butadiene-styrene (SBS), and plastomers.

11. **Life Cycle Assessment: Excluded from System Boundary**

a. Upstream impacts of extraction, production, and manufacturing of any material that is
not consumed in the production of the asphalt mixture is considered to be part of the
plant infrastructure and is therefore explicitly excluded from the system boundary. These
include:

i. The asphalt mixture production equipment and machinery and its upkeep and
maintenance, including lubricants and any other substance used to facilitate the
smooth functioning of the plant;

ii. Machinery for the recycling of RAP and RAS;

iii. Solar panels or any other alternative energy apparatus that is used to substitute
traditional energy sources at the plant;

iv. General management, office, and headquarter operations; and

v. Personnel at the plant or their commuting to and from the plant.

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**Further Explanation — Excluded from System Boundary**

Given the goal of the EPD program — to facilitate comparison of environmental impacts of products
in the same category — the environmental impacts from the construction and maintenance of the
plant and equipment infrastructure and consumables are excluded from the system boundaries as
asphalt producers use similar capital goods to produce the same product. Hence, capital goods are
considered non-essential to the comparison and are not relevant in regards to the decisions that will
be supported by the EPDs. This also includes consumables (lubricants and conveyor belts) used in
operating and maintaining the equipment.

**12. Data Quality**

a. Age — Data should be no more than 10 years old, unless verified that it is unchanged.

b. Representativeness — Data should represent the technology in use.
c. Geography — Data should represent the proper geographical region.
   i. Local data when available, and then regional or national data.
   ii. Alternative data sources modified with the local energy mix may be used.

d. Precision — Data must be reported to no more than two significant figures.

e. Units — Both English and metric units may be used.

f. Completeness — Must include all data within the defined system boundaries as noted in this PCR.

g. Uncertainty — Shall evaluate any assumptions and primary data through sensitivity analysis as noted in this PCR.

### 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 boundaries.

### 13. Life Cycle Inventory

a. Primary data should be reported in accordance with the following requirements:

   i. Time Period: All data reported must be reflective of plant production over a period of 12 consecutive months, within the last five years.

   ii. Documents on File: Primary data reported should be based on utility and energy bills, production records, and other similar documents, all of which should be on file and easily accessible.

   iii. Correctness Check: Sensitivity analysis of energy consumption per ton should be used to assess the accuracy of the primary data collected. Primary data should follow statistical trends identified in the underlying LCA by Mukherjee (2016). These trends will be used to create checks and balances to insure data quality, and identify possible errors or anomalies in reporting. Data reported by plants that do not fall within the error margins based on these trends should be checked for reporting errors or explained.

   iv. Generic vs. Specific Data: All data reported for a plant must be specific to that plant.

   v. Data Gaps: Efforts should be made to ensure gaps in primary data collection are limited to only those items for which a predetermined scenario has been provided (Items 13 and 14 in the below listing of data to be reported).

   vi. The following data must be reported:

      a) Total asphalt produced at the plant, reported in U.S. short tons.

      b) Total electricity

         1) Line power use in kWh, based on the energy production mix for the region in which the plant is located
2) Solar power in kWh
3) Wind power in kWh
4) Other renewable energy
c) Generator energy
  1) Diesel fuel in gallons
  2) Biofuels in gallons
  3) Other?
d) Plant burner energy (primary)
  1) Natural gas use in Mcf or MMBtu
  2) Propane used in gallons
  3) Diesel fuel in gallons
  4) RFO in gallons
  5) Biofuels in gallons
e) Plant burner energy (secondary)
  1) Natural gas use in Mcf or MMBtu
  2) Propane used in gallons
  3) Diesel fuel in gallons
  4) RFO in gallons
  5) Biofuels in gallons
f) Hot oil heater energy
  1) Natural gas use in Mcf or MMBtu
  2) Propane used in gallons
  3) Diesel fuel in gallons
  4) RFO in gallons
  5) Biofuels in gallons
g) Mobile equipment energy
  1) Diesel fuel use in gallons
  2) Natural gas use in Mcf or MMBtu
  3) Other?
h) Aggregate used in production in U.S. short tons
i) Asphalt binder used in production in U.S. short tons
j) One-way distances travelled to plant for asphalt binder and aggregate
   (both virgin and recycled), expressed in U.S. short-ton miles
k) Water used in gallons
l) Stack emissions from plant in pounds
Pre-determined scenarios: For parameters that may be difficult to estimate or collect primary data, the following estimates are used:

- **m)** Default energy requirements for processing of RAP/RAS is 0.1 gallon/U.S. short ton or 0.4 kWh/U.S. short ton
- **n)** Distance travelled by RAP/RAS to plant is 50 miles

**Further Explanation — Plant Waste**

There are no hazardous waste materials on site. No waste material is produced, as all material at the plant is completely recycled.

b. Secondary data shall be prioritized as follows:

- i. Product-specific EPDs.
- ii. Industry-average EPDs.
- iii. Freely available public datasets. The following prescribed data sources must be used (see Appendix F for assessment of data quality):

**NREL U.S. LCI: Crude oil, at refinery.**

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. An economic allocation is used to allocate relative impacts of the crude oil refining process across the different co-products.
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 plant. This will be based on secondary data sources, from existing public U.S. LCI data.

**NREL U.S. LCI: Natural gas combusted in industrial boiler.**

1. Impacts associated with the extraction and production of natural gas. Refers to processes in item A1:2.
Data sources from PCA 2007 life cycle inventory study

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

Table 1: Source: Life Cycle Inventory of Portland Cement Concrete, Report #3011 (Portland Cement Association, 2007).

<table>
<thead>
<tr>
<th>Fuel or Electricity</th>
<th>Total Energy Used</th>
<th>Energy/Ton Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount MBtu</td>
<td>Amount Btu/ton kJ/metric ton</td>
</tr>
<tr>
<td>Distillate (light) grade Nos. 1, 2, 4, &amp; light diesel fuel, gallon</td>
<td>58,959,600</td>
<td>0.0562/ 7,793/ 9,060</td>
</tr>
<tr>
<td>Residual (heavy) grade Nos. 5 and 6 &amp; heavy diesel fuel, gallon</td>
<td>13,234,200</td>
<td>0.0126/ 1,888/ 2,200</td>
</tr>
<tr>
<td>Gas (natural, manufactured, and mixed), Mcf</td>
<td>1,400,000</td>
<td>0.0013/ 1,370/ 1,590</td>
</tr>
<tr>
<td>Gasoline used as a fuel, gallon</td>
<td>5,700,000</td>
<td>0.0054/ 679/ 790</td>
</tr>
<tr>
<td>Electricity purchased, 1000 kWh</td>
<td>2,525,053</td>
<td>0.0024/ 8,210/ 9,550</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20,924,638</strong></td>
<td><strong>19,940/ 23,190</strong></td>
</tr>
</tbody>
</table>

Energy used to produce coarse aggregate from crushed stone:

<table>
<thead>
<tr>
<th>Fuel or Electricity</th>
<th>Total Energy Used</th>
<th>Energy/Ton Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount MBtu</td>
<td>Amount Btu/ton kJ/metric ton</td>
</tr>
<tr>
<td>Coal, ton</td>
<td>43,000</td>
<td>0.0000275/ 577/ 670</td>
</tr>
<tr>
<td>Distillate (light) grade Nos. 1, 2, 4, &amp; light diesel fuel, gallon</td>
<td>145,811,400</td>
<td>0.0932/ 12,920/ 15,030</td>
</tr>
<tr>
<td>Residual (heavy) grade Mos. 5 and 6 &amp; heavy diesel fuel, gallon</td>
<td>22,663,200</td>
<td>0.0145/ 2,167/ 2,520</td>
</tr>
<tr>
<td>Gas (natural, manufactured, and mixed), Mcf</td>
<td>5,400,000</td>
<td>0.00345/ 3,543/ 4,120</td>
</tr>
<tr>
<td>Gasoline used as a fuel, gallon</td>
<td>14,700,000</td>
<td>0.00939/ 1,174/ 1,370</td>
</tr>
<tr>
<td>Electricity purchased, 1000 kWh</td>
<td>4,627,887</td>
<td>0.00296/ 10,088/ 11,730</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>47,693,888</strong></td>
<td><strong>30,469/ 35,440</strong></td>
</tr>
</tbody>
</table>
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 and average U.S. energy mix used.

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

Table 2a: Power Plant Energy Use and Emissions: per MMBtu of Electricity Available at User Sites

<table>
<thead>
<tr>
<th>Energy Use: Btu</th>
<th>Stationary Use: U.S. Mix (Btu/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual oil</td>
<td>29302.23521</td>
</tr>
<tr>
<td>Natural gas</td>
<td>52940.8756</td>
</tr>
<tr>
<td>Coal</td>
<td>1419257.122</td>
</tr>
<tr>
<td>Biomass</td>
<td>14082.4653</td>
</tr>
<tr>
<td>Nuclear</td>
<td>217437.774</td>
</tr>
<tr>
<td>Other energy sources</td>
<td>104289.5883</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emissions: grams</th>
<th>g/MMBtu</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC</td>
<td>3.413323958</td>
</tr>
<tr>
<td>CO</td>
<td>36.13841307</td>
</tr>
<tr>
<td>NOx</td>
<td>194.2071307</td>
</tr>
<tr>
<td>PM_{10}</td>
<td>45.1780429</td>
</tr>
<tr>
<td>PM_{2.5}</td>
<td>31.83058815</td>
</tr>
<tr>
<td>SOx</td>
<td>480.370154</td>
</tr>
<tr>
<td>CH_{4}</td>
<td>2.62965648</td>
</tr>
<tr>
<td>N_{2}O</td>
<td>2.389911051</td>
</tr>
<tr>
<td>CO_{2}</td>
<td>175923.7538</td>
</tr>
</tbody>
</table>

Table 2b: U.S. Electricity Mix

<table>
<thead>
<tr>
<th>Source of Electricity (U.S. average)</th>
<th>Btu/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual oil (non-renewable)</td>
<td>1.00E+02</td>
</tr>
<tr>
<td>Natural Gas (non-renewable)</td>
<td>1.81E+03</td>
</tr>
<tr>
<td>Coal — Bituminous (non-renewable)</td>
<td>4.36E+03</td>
</tr>
<tr>
<td>Coal — Lignite (non-renewable)</td>
<td>2.13E+02</td>
</tr>
<tr>
<td>Biomass</td>
<td>4.81E+01</td>
</tr>
<tr>
<td>Nuclear (non-renewable)</td>
<td>7.42E+02</td>
</tr>
<tr>
<td>Hydroelectric</td>
<td>2.39E+02</td>
</tr>
<tr>
<td>Geothermal</td>
<td>1.40E+01</td>
</tr>
<tr>
<td>Wind</td>
<td>8.70E+01</td>
</tr>
<tr>
<td>Solar PV</td>
<td>1.11E+00</td>
</tr>
<tr>
<td>Other (Biogenic Waste, Pumped Storage, etc.)</td>
<td>1.45E+01</td>
</tr>
</tbody>
</table>
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 item 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 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 plant. Distances will be based on primary data collected for each plant. Refers to processes in item A2:4. NREL datasets per possible transportation method is as follows:
   a. Transport, combination truck diesel powered.

14. Allocation

a. Allocation must follow ISO 14044, which states:
   i. Allocation should be avoided, wherever possible.
   ii. If allocation cannot be avoided, inputs and outputs of the system should be partitioned based on physical relationships before other alternative relationships, such as economic, are used.

Further Explanation — RAP Allocation

An economic allocation is not being used for materials like RAP because the supply of RAP is independent of the quantity being used in an asphalt plant. Asphalt plants do not typically buy RAP — infrequently, they do — and therefore are not creating a demand for it. Typically, RAP arrives at a plant from milling and maintenance operations without a payment for receiving or depositing the material. In situations when the volume of RAP being produced is much higher than what is used at a plant, plants sometimes charge contractors to deposit RAP to help control the size of their stockpiles. It can be safely argued that RAP is not being produced to meet a demand created by asphalt plants.
b. Recycled/reclaimed materials, such as RAP, RAS, GTR, and RFO must use the cutoff method.
   
i. The upstream impacts associated with recycled/reclaimed materials’ previous life cycles, including production/manufacturing, transport and use, are excluded from the system boundary.
   
ii. Impacts associated with the processes involved in recycling materials for use in the asphalt mixture are considered part of the system boundary. Hence, the included processes are:
   
a) Impacts of crushing RAP or grinding RAS and transportation to plant;
   
b) Impacts of recycling motor oil and other non-traditional fuels such as cooking oil and bio-fuels; and
   
c) Impacts for producing crumb rubber from waste tires.
   
c. Liquid asphalt binder, a co-product of the petroleum refining process, shall use an economic allocation at the refinery, which is in accordance to the procedure defined by Yang (2014) and outlined in Table 3.

<table>
<thead>
<tr>
<th>Co-products</th>
<th>Allocation Factors</th>
<th>Mass Fractions</th>
<th>Economic Allocation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPG</td>
<td>0.76</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Finished motor gasoline</td>
<td>1.31</td>
<td>0.42</td>
<td>0.53</td>
</tr>
<tr>
<td>Kerosenes</td>
<td>1.21</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>Distillate fuel oil</td>
<td>1.2</td>
<td>0.21</td>
<td>0.25</td>
</tr>
<tr>
<td>Residual fuel oil</td>
<td>0.65</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>Special napthas</td>
<td>0.99</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Lubricants</td>
<td>3.14</td>
<td>0.05</td>
<td>0.09</td>
</tr>
<tr>
<td>Petroleum coke</td>
<td>0.14</td>
<td>0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>Asphalt and road oil</td>
<td>0.5</td>
<td>0.04</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**Note:** The allocation factors are defined as the ratio of the economic Allocation Co-efficient, that is the price weighted average yield of each co-product, to the Mass Yield. 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 3. (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.

15. **Life Cycle Impact Assessment**

a. The impact assessment method to be used is TRACI 2.1 with normalization based in US-2008, potentials reported on a per-year basis.

i. Normalization scheme US-CA 2008/2005 shall be used.

ii. Environmental impact indicators to be reported per declared unit are:
a) Global warming potential (GWP), in kilograms of CO$_2$e
b) Depletion potential of the stratospheric ozone layer (ODP), in kilograms of CFC-11 equivalents
c) Acidification potential of land and water resources (AP), in kilograms of SO$_2$ equivalents
d) Eutrophication potential (EP), in kilograms of N equivalents
e) Photochemical Ozone Creation/Smog potential (POCP), in kilograms of O$_3$ equivalents.
f) Depletion of abiotic resources (fossil)

b. The energy reporting in the EPD shall be as follows:

i. Total Primary Energy: include process all fossil fuels, measured in MMBtu, Lower Heating Value (LHV), and expressed as MJ per declared unit of the asphalt mixture.

ii. The energy for each asphalt mix is calculated using the heating values (LHV) in Table 4.

<table>
<thead>
<tr>
<th>LHV</th>
<th>MJ/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude oil</td>
<td>43.05</td>
</tr>
<tr>
<td>Gasoline</td>
<td>44.15</td>
</tr>
<tr>
<td>Diesel</td>
<td>42.91</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>40.87</td>
</tr>
<tr>
<td>LPG</td>
<td>46.28</td>
</tr>
<tr>
<td>Kerosene</td>
<td>43.69</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>119.95</td>
</tr>
<tr>
<td>Coal</td>
<td>25.75</td>
</tr>
<tr>
<td>Natural gas</td>
<td>45.86</td>
</tr>
</tbody>
</table>

iii. Total Electric: based on electricity used at plant, measured in kWh, and expressed as MJ per declared unit of the asphalt mixture. The mix of renewable and non-renewable sources of the energy will be specified depending on the eGrid region in which the electricity is generated.

iv. Total Plant Process Energy: the energy used in the asphalt mixture production process, expressed in MJ/declared unit of the asphalt mixture.

v. Total Feedstock Energy: The feedstock energy associated with the liquid asphalt binder will be reported to comply with ISO 14040/44 but shall not be included in the total energy used as the embodied energy is never accessed.
Further Explanation — Feedstock Energy

It is unlikely the embodied energy of the liquid asphalt binder will ever be released, as the asphalt mixture will not be used as a source of fuel beyond the life of the pavement. Hence, feedstock energy will be reported separately. Because the use of the liquid asphalt binder in the mixture helps avoid the burden of further refining the residuum through energy and emissions-intensive processes like cracking and hydro-treating, and effectively sequesters the energy from the carbon cycle, it should not be counted as part of the environmental burden of the asphalt mixture.

16. EPD Format

a. The following items must be included in the EPD (See appendix G for template).
   i. Information about asphalt mix producer (including company name, plant name/identification, location, and contact person and phone number).
   ii. Product Description, including description of application, UNSPSC, product contents, produce specification, production temperature range, warm-mix technology used if applicable, and an optional graphic.
   iii. Reference to this PCR and the name of the Program Operator.
   iv. Period of validity.
   v. Third-party verification with contact information for the validator, confirming that the EPD conforms to this PCR.
   vi. Life Cycle Assessment Information:
      a) Diagram of life cycle stages included and the system boundaries (Figure 1 and Figure 2).
      b) Table of impact indicator results with the following note: “The life cycle impact assessment results are relative expressions and do not predict actual impacts on category endpoints, the exceeding of thresholds, safety margins, or risks.”
      c) Feedstock Energy note: “Feedstock energy is reported separately as the asphalt mixture will not be used as a source of fuel beyond the life of the pavement. In fact, the use of the liquid asphalt binder in the mixture helps avoid the burden of further refining it through energy- and emissions-intensive processes. Therefore, it should not be counted negatively in the environmental burden of the asphalt mixture.”
   vii. Summary of Limitations:
      a) List data gaps due to additives — fibers, crumb rubbers (if it is added at a plant), liquid antistrips, recycling agents, stabilizers, etc.
      b) An EPD for an asphalt mixture that uses a modified liquid asphalt binder must include the following statement: “This mix uses a [polymer/GTR/polymer + GTR] modified liquid asphalt binder. The upstream impacts associated with the process of extraction, manufacturing/production, and transportation of the materials
used in the modification process have not been accounted for in this EPD.”

c) An EPD for an asphalt mixture that uses RAS, must include the following statement: “The impact of recycling asphalt shingles was estimated using data for processing reclaimed asphalt pavement. The source of the shingles (tear off or factory rejects) is not being accounted.”
References


## Appendix A: PCR Development Working Group

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daniel T. Crago, P.E.</td>
<td>Environmental &amp; Quality Control Manager</td>
<td>Valley Asphalt Corp.</td>
</tr>
<tr>
<td>Ronald A. Sines, P.E.</td>
<td>Vice President, Asphalt Performance</td>
<td>Oldcastle Materials</td>
</tr>
<tr>
<td>Jon E. Callahan</td>
<td>Operations Manager</td>
<td>Palmer Paving Corporation</td>
</tr>
<tr>
<td>Everett Crews, Ph.D.</td>
<td>Director of Research and Development</td>
<td>Ingevity</td>
</tr>
<tr>
<td>Joe P. Mahoney, Ph.D.</td>
<td>William M. And Marilyn M. Conner Professor</td>
<td>University of Washington</td>
</tr>
<tr>
<td>Meagan Sylvia, LEED AP, REM</td>
<td>Director of Environmental Services</td>
<td>The Lane Construction Corp.</td>
</tr>
<tr>
<td>Mark S. Buncher, Ph.D., P.E.</td>
<td>Director of Engineering</td>
<td>Asphalt Institute</td>
</tr>
<tr>
<td>Darrell Cass, P.E.</td>
<td>Federal Aid Project Manager</td>
<td>MnDOT</td>
</tr>
<tr>
<td>Gina Ahlstrom</td>
<td>Team Leader-Pavement Design and Analysis</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>Randy Bowman, P.E.</td>
<td>Sustainability Director</td>
<td>City of Columbus</td>
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Appendix B: Conformity Assessment Form

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Appendix C: Stakeholders

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## Appendix E: Asphalt Mix Additives and Modifiers

### Table E1. Asphalt Mix Additives and Modifiers

<table>
<thead>
<tr>
<th>Type</th>
<th>Generic Examples</th>
<th>Public Inventory Data</th>
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<tr>
<td>Mineral fillers</td>
<td>Crushed fines</td>
<td>PCA</td>
</tr>
<tr>
<td></td>
<td>Lime</td>
<td>NREL</td>
</tr>
<tr>
<td></td>
<td>Portland cement</td>
<td>PCA</td>
</tr>
<tr>
<td></td>
<td>Fly ash</td>
<td>Cutoff rule</td>
</tr>
<tr>
<td>Rubber</td>
<td>Natural rubber</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Styrene-butadiene rubber (SBR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polychloroprene latex</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Styrene-isoprene-styrene (SIS)</td>
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<tr>
<td></td>
<td>Styrene-butadiene-styrene (SBS)</td>
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<td>Plastic</td>
<td>Polyethylene</td>
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<tr>
<td></td>
<td>Polypropylene</td>
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</tr>
<tr>
<td></td>
<td>Ethylene acrylate copolymer</td>
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<tr>
<td></td>
<td>Ethylene-vinyl acetate (EVA)</td>
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</tr>
<tr>
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<td>Polyvinyl chloride (PVC)</td>
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<tr>
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<td>Ethylene propylene copolymers (EPM)</td>
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</tr>
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<td></td>
<td>Ethylene propylene diene (EPDM)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polylefins</td>
<td></td>
</tr>
<tr>
<td>Polymer blends</td>
<td>Blends of plastic and rubber polymers</td>
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<tr>
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<td>Polyester</td>
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<td>Fiberglas</td>
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<td></td>
<td>Cellulose</td>
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<tr>
<td>Recycling agents</td>
<td>Hydrocarbon recycling oils</td>
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<td>Refined Engine Oil Bottoms (REOB)</td>
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<td></td>
<td>Vacuum Tower Asphalt Extenders</td>
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</tr>
<tr>
<td>Antistrip agents</td>
<td>Amines</td>
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</tr>
<tr>
<td></td>
<td>Hydrated Lime</td>
<td>NREL</td>
</tr>
<tr>
<td>Waste materials</td>
<td>Roofing shingles</td>
<td>Mukherjee (2016)</td>
</tr>
<tr>
<td></td>
<td>Ground Tire Rubber</td>
<td>None at this time</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Silicones (prevent foaming in the asphalt tank) (refiners add)</td>
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### Appendix F: Secondary Data Quality Assessment

<table>
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<th>Process</th>
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<th>Geography</th>
<th>Sources</th>
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<td>Association of Oil Pipelines 2000 Association of Oil Pipelines Annual Report 2000</td>
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<td>1986 ASTM-IP Petroleum Measurement Tables</td>
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<td>Center for Transportation Research, Argo 2000 GREET Version 1.6</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Assumption by Franklin Associates on fossil-fuel fired boiler systems</td>
</tr>
<tr>
<td>ID</td>
<td>Process</td>
<td>Age</td>
<td>Geography</td>
<td>Sources</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------------</td>
<td>------</td>
<td>----------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
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<td>A1:4</td>
<td>Electricity — line loss of 6.5% with U.S. average energy mix</td>
<td>2013</td>
<td>USA Region specific</td>
<td>GREET 2013</td>
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<td></td>
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<td>USA</td>
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</tbody>
</table>

In choosing the datasets, the first priority was transparency. To meet this transparency goal, the prescribed datasets must be publically 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.
Appendix G: EPD Template

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