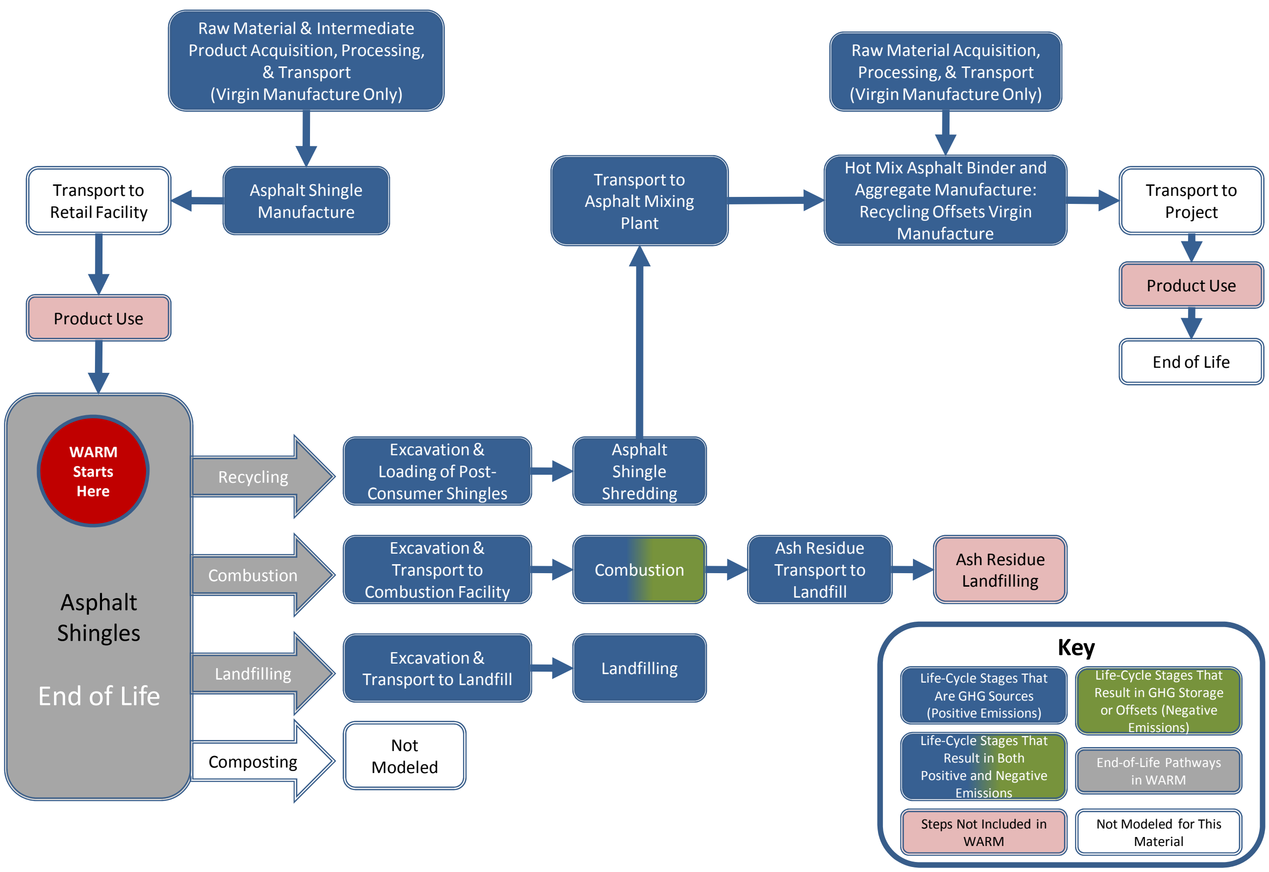
ASPHALT SHINGLES

1. INTRODUCTION TO WARM AND ASPHALT SHINGLES

This chapter describes the methodology used in EPA's Waste Reduction Model (WARM) to estimate streamlined life-cycle greenhouse gas (GHG) emission factors for asphalt shingles beginning at the waste generation reference point.[1] The WARM GHG emission factors are used to compare the net emissions associated with asphalt shingles in the following four waste management alternatives: source reduction, recycling, combustion and landfilling. Exhibit 1 shows the general outline of materials management pathways for asphalt shingles in WARM. For background information on the general purpose and function of WARM emission factors, see the Introduction & Overview chapter. For more information on Source Reduction, Recycling, Combustion and Landfilling, see the chapters devoted to those processes.

Exhibit 1: Life Cycle of Asphalt Shingles in WARM



Asphalt shingles are used as a roofing material and are typically made of a felt mat saturated with asphalt. Small rock granules are added to one side of the shingle in order to protect against natural elements such as sun and rain. Depending on whether the shingle base is organic or fiberglass, the granules are composed of asphalt cement (19 to 36 percent by weight, respectively), a mineral stabilizer like limestone or dolomite (8 to 40 percent), and sand-sized mineral granules (20 to 38 percent), in

[1] EPA would like to thank Dr. Kimberly Cochran of EPA for her efforts in improving these estimates.

addition to the organic or fiberglass felt backing (2 to 15 percent). The asphalt that is used in shingles is considerably harder than the asphalt used in pavement. According to the EPA, the United States manufactures and disposes of an estimated 11 million tons of asphalt shingles per year (NERC, 2007).

The material composition and production process is different for paper felt-based and fiberglass-based shingles. The majority of post-consumer asphalt shingle waste is generated at residential sites, while the remaining asphalt shingles waste is generated at non-residential sites (CMRA, 2007a). Additionally, our research indicates that 82 percent of the residential shingle market is fiberglass and the market share is growing (HUD, 1999). Therefore, WARM uses the fiberglass-based asphalt shingle emission factor as the factor for asphalt shingles, rather than using two separate emission factors for fiberglass- and paper felt-based shingles.

2. LIFE-CYCLE ASSESSMENT AND EMISSION FACTOR RESULTS

The life-cycle boundaries in WARM start at the point of waste generation, or the moment a material is discarded, as the reference point, and only consider upstream GHG emissions when the production of new materials is affected by materials management decisions. Recycling and source reduction are the two materials management options that impact the upstream production of materials, and consequently are the only management options that include upstream GHG emissions. For more information on evaluating upstream emissions, see the chapters on Recycling, and Source Reduction.

WARM does not consider composting for asphalt shingles. As Exhibit 2 illustrates, all of the GHG sources and sinks relevant to asphalt shingles in this analysis are contained in the raw materials acquisition and manufacturing (RMAM) and materials management sections of the life cycle assessment.

Exhibit 2: Asphalt Shingles GHG Sources and Sinks from Relevant Materials Management Pathways

MSW Management Strategies for Asphalt Shingles	**GHG Sources and Sinks Relevant to Asphalt Shingles**		
	Raw Materials Acquisition and Manufacturing	**Changes in Forest or Soil Carbon Storage**	**End of Life**
Source Reduction	**Offsets** • Avoided production of primary raw materials • Avoided secondary processing to manufacture shingles • Avoided transportation of raw materials	NA	NA
Recycling	**Offsets** • Avoided production of virgin asphalt binder and aggregate • Avoided transportation for virgin asphalt binder and aggregate	NA	**Emissions** • Excavating, loading, shredding post-consumer shingles • Transport to HMA mixing plant
Composting	Not applicable since asphalt shingles cannot be composted		
Combustion	NA	NA	**Emissions** • Emissions from combustion in cement kiln **Offsets** • Avoided refinery fuel gas typically used in cement kilns
Landfilling	NA	NA	**Emissions** • Transport to C&D landfill • Landfilling machinery

NA = Not applicable.

WARM analyzes all of the GHG sources and sinks outlined in Exhibit 2 and calculates net GHG emissions per short ton of asphalt shingles inputs. For more detailed methodology on emission factors, please see the sections below on individual waste management strategies. Exhibit 3 outlines the net GHG emissions for asphalt shingles under each materials management option.

Exhibit 3: Net Emissions for Asphalt Shingles under Each Materials Management Option ($MTCO_2E$/Short Ton)

Material/Product	Net Source Reduction (Reuse) Emissions for Current Mix of Inputs	Net Recycling Emissions	Net Composting Emissions	Net Combustion Emissions	Net Landfilling Emissions
Asphalt Shingles	-0.20	-0.09	NA	-0.34	0.04

Note: Negative values denote net GHG emission reductions or carbon storage from a materials management practice.
NA = Not applicable.

3. RAW MATERIALS ACQUISITION AND MANUFACTURING

For asphalt shingles, GHG emissions associated with raw materials acquisition and manufacturing are (1) GHG emissions from energy used during the raw materials acquisition and manufacturing processes, (2) GHG emissions from energy used to transport raw materials, and (3) non-energy GHG emissions resulting from manufacturing processes.[2] For virgin asphalt shingles, process energy GHG emissions result from the manufacture of the main raw materials used in the manufacturing of asphalt shingles, including the fiberglass mat carrier sheet, the asphalt binder and coating, mineral surfacing and the stabilizer or filler. Process energy GHG emissions also include the actual roof shingles manufacturing process, which is a continuous process on an assembly line consisting of a dry and wet accumulator, coating, cooling/drying, shingle cutting and roll winder that builds the shingles from the raw materials (Athena, 2000). Transportation emissions are generated from transportation associated with raw materials, during manufacture and during transportation to the retail facility. EPA assumes that non-energy process GHG emissions from making asphalt shingles are negligible.

The RMAM calculation in WARM also incorporates "retail transportation," which incorporates the average truck, rail, water and other-modes transportation emissions required to transport asphalt shingles from the manufacturing facility to the retail/distribution point, which may be the customer or a variety of other establishments (e.g., warehouse, distribution center, wholesale outlet). The energy and GHG emissions from retail transportation are presented in Exhibit 4. Transportation emissions from the retail point to the consumer are not included. The miles travelled fuel-specific information is obtained from the 2007 *U.S. Census Commodity Flow Survey* (BTS, 2007) and from *Greenhouse Gas Emissions from the Management of Selected Materials* (EPA, 1998).

Exhibit 4: Retail Transportation Energy Use and GHG Emissions

Material/Product	Average Miles per Shipment	Transportation Energy per Short Ton of Product (Million Btu)	Transportation Emission Factors ($MTCO_2E$/ Short Ton)
Asphalt Shingles	388	0.42	0.03

4. MATERIALS MANAGEMENT METHODOLOGIES

This analysis considers the source reduction, recycling, landfilling and combustion pathways for materials management of asphalt shingles.

[2] Process non-energy GHG emissions are emissions that occur during the manufacture of certain materials and are not associated with energy consumption.

Reclaimed asphalt shingles can be used to offset the production and transport of both aggregate and binder. Greenhouse gas savings are realized for source reduction, recycling and combustion, while landfilling has a slightly positive emission factor due to the emissions from transportation to the landfill and operation of landfill equipment. It is interesting to note that the GHG savings for combustion are greater than for any other waste management alternative. This is because the asphalt shingles have significantly high energy content (BTU per ton) due to the asphalt cement coating. Asphalt shingles that are combusted can displace other fuels (i.e., refinery fuel gas) used in cement kilns. This application would prevent the combustion emissions associated with refinery fuel gas and offers significant GHG reduction potential as a waste management alternative to landfilling. This analysis considers source reduction, recycling, combustion and landfilling for materials management of asphalt concrete.

4.1 SOURCE REDUCTION

The type of production process used to produce asphalt shingles depends on whether the asphalt shingle is organic felt-based or fiberglass mat-based. The Athena database contains life-cycle information on both types (organic and fiberglass) of asphalt shingles (Athena, 2000). In general, the production of fiberglass mat-based asphalt shingles is less energy-intensive (and subsequently less GHG-intensive) than the production of organic paper felt-based asphalt shingles. This is because fiberglass mat does not absorb water used throughout the mat production (unlike the organic shingle counterparts). Thus, it is less energy-intensive to form glass mat since the drying of the mat is eliminated as a process step. As discussed earlier, the EPA included only fiberglass shingles in WARM because they make up the majority (82 percent) of the residential shingle market, and the market share is growing (HUD, 1999). The source reduction emission factor for fiberglass asphalt shingles is summarized in Exhibit 5. For more information, please see the chapter on Source Reduction.

Exhibit 5: Source Reduction Emission Factors for Asphalt Shingles ($MTCO_2E$/Short Ton)

Material/Product	Raw Material Acquisition and Manufacturing for Current Mix of Inputs	Raw Material Acquisition and Manufacturing for 100% Virgin Inputs	Forest Carbon Sequestration for Current Mix of Inputs	Forest Carbon Sequestration for 100% Virgin Inputs	Net Emissions for Current Mix of Inputs	Net Emissions for 100% Virgin Inputs
Asphalt Shingles	-0.20	-0.20	NA	NA	-0.20	-0.20

Note: Negative values denote net GHG emission reductions or carbon storage from a materials management practice.
– = Zero emissions.

The GHG benefits of source reduction are calculated as the emissions savings from avoided raw materials acquisition and manufacturing (see section 3) of asphalt shingles produced from a “current mix” of virgin and recycled inputs or from asphalt shingles produced from “100 percent virgin” inputs. For asphalt shingles, the “current mix” is equivalent to the “100 percent virgin” source reduction factor since asphalt shingles are not typically produced using recycled inputs.

Post-consumer emissions are the emissions associated with materials management pathways that could occur at end of life. When source reducing asphalt shingles, there are no post-consumer emissions because production of the material is avoided in the first place, and the avoided asphalt shingles never become post-consumer. Forest carbon storage is not applicable to asphalt shingles, and thus does not contribute to the source reduction emission factor.

4.1.1 Developing the Emission Factor for Source Reduction of Asphalt Shingles

To calculate the avoided GHG emissions for asphalt shingles, EPA first looks at two components of GHG emissions from RMAM activities: process energy and transportation energy GHG emissions. There are no non-energy GHG emissions from asphalt shingles RMAM activities. Exhibit 6 shows the results for each component and the total GHG emission factors for source reduction of asphalt shingles. More information on each component making up the final emission factor is provided below. The methodology for estimating emissions from asphalt shingles manufactured from recycled materials is discussed below in the Recycling section.

Exhibit 6: Raw Material Acquisition and Manufacturing Emission Factor for Virgin Production of Asphalt Shingles ($MTCO_2E$/Short Ton)

(a) Material/Product	(b) Process Energy	(c) Transportation Energy	(d) Process Non-Energy	(e) Net Emissions (e = b + c + d)
Asphalt Shingles	-0.13	-0.07	–	-0.20

Note: Negative values denote net GHG emission reductions or carbon storage from a materials management practice.
– = Zero Emissions.

EPA used data from the Athena Sustainable Materials Institute (2000) to develop a source reduction emission factor for fiberglass shingles. These data include the energy (by fuel type) associated with the production of the primary raw materials as well as secondary processing to manufacture the actual shingles (i.e., the energy associated with the operations at the roofing plant itself). Precombustion energy is not included in Athena (2000) and was subsequently added to the raw process and transportation data fuel breakdown. The process energy used to produce asphalt shingles and the resulting emissions are shown in Exhibit 7.

Exhibit 7: Process Energy GHG Emissions Calculations for Virgin Production of Asphalt Shingles

Material/Product	Process Energy per Short Ton Made from Virgin Inputs (Million Btu)	Process Energy GHG Emissions ($MTCO_2E$/Short Ton)
Asphalt Shingles	2.19	0.13

EPA also used transportation data from the Athena Sustainable Materials Institute (2000) to develop the asphalt shingles source reduction emission factor. These data again include transportation energy associated with the primary raw materials and the manufacturing process itself. The transportation energy used to produce asphalt shingles and the resulting emissions are shown in Exhibit 8.

Exhibit 8: Transportation Energy Emissions Calculations for Virgin Production of Asphalt Shingles

Material/Product	Transportation Energy per Ton Made from Virgin Inputs (Million Btu)	Transportation Emissions ($MTCO_2E$/Short Ton)
Asphalt Shingles	0.58	0.04

Note: The transportation energy and emissions in this exhibit do not include retail transportation, which is presented separately in Exhibit 4.

4.2 RECYCLING

Used or scrap asphalt shingles can be recycled into many types of applications in hot and cold mix asphalt, as an aggregate base for road development, as mulch, as a fuel source, or into new roofing materials (CMRA, 2007a). For more information, please see the chapter on Recycling.

Using asphalt shingles as a component in hot mix asphalt (HMA) is the most common process to which recycled shingles are added. Researchers at the University of Massachusetts have determined that HMA that consists of up to 7 percent recycled asphalt shingles shows no quality differences as compared to virgin HMA (Mallick, 2000). Waste shingles are ground, screened and filtered for contaminants. They are then usually fed into and mixed with aggregate before being added to virgin asphalt binder (CMRA, 2007a). In our analysis, we assume that the ground asphalt shingles displace the production of virgin asphalt binder and aggregate, taking into account the asphalt and aggregate content of the shingles as shown in Exhibit 9.

Exhibit 9: Typical Composition of Asphalt Shingles

Component	Fiberglass Shingles
Asphalt Cement	22%
Fiberglass Felt	15%
Aggregate	38%
Stabilizer/Filler	25%
Total	100%

Source: CMRA, 2007a.

Shingle-to-shingle recycling is a relatively new concept that has not yet been fully developed into any known commercial-scale operation. The biggest challenge with closed-loop recycling of asphalt shingles is conforming to very stringent feedstock product specifications. Also, there is a lack of information and data on shingle-to-shingle recycling practices. Furthermore, there are no known facilities that produce new shingles from either manufacturers' scrap or tear-off material on a commercial basis (CMRA, 2007b). As a result, in developing the recycling emission factor, EPA assumes all recycled shingles are used to displace virgin asphalt binder and aggregate, which is used in the production of HMA.

A "recycled input credit" is calculated for asphalt shingles by assuming that the recycled material avoids—or offsets—the GHG emissions associated with producing virgin asphalt binder and aggregate, taking into account the asphalt and aggregate content of the shingles. GHG emissions associated with management (i.e., collection, transportation and processing) of recycled asphalt shingles are included in the recycling credit calculation. Each component of the recycling emission factor as provided in Exhibit 10 is discussed further in section 4.2.1. For more information on recycling in general, see the Recycling chapter.

Exhibit 10: Recycling Emission Factor for Asphalt Shingles ($MTCO_2E$/Short Ton)

Material/ Product	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Materials Management Emissions	Recycled Input Credit[a] Process Energy	Recycled Input Credit[a] – Transportation Energy	Recycled Input Credit[a] – Process Non-Energy	Forest Carbon Sequestration	Net Emissions (Post-Consumer)
Asphalt Shingles	–	–	-0.11	0.02	–	NA	-0.09

– = Zero emissions.
[a] Includes emissions from the initial production of the material being managed.

4.2.1 Developing the Emission Factor for Recycling of Asphalt Shingles

EPA calculates the GHG benefits of recycling asphalt shingles by calculating the avoided emissions associated with virgin asphalt binder and aggregate that is subsequently used in HMA, after accounting for losses that occur during the recycling process. This difference is called the "recycled input credit" and represents the net change in GHG emissions from process energy and transportation energy in recycling asphalt shingles relative to virgin production of components used in hot mix asphalt.

To calculate each component of the recycling emission factor, EPA follows four steps, which are described in detail below:

Step 1. *Calculate emissions from the recycling of one short ton of asphalt shingles.* The GHG emissions from recycling asphalt shingles are provided in Exhibit 7 and Exhibit 8.

EPA estimates the energy associated with excavating, loading and shredding the post-consumer asphalt shingles using data from Dr. Kimberly Cochran (Cochran, 2006). We assume that the machinery is operated using diesel fuel. The emissions for the process of excavating, loading and shredding the post-consumer asphalt shingles in preparation for use in hot mix asphalt are shown in Exhibit 11.

Exhibit 11: Process Energy GHG Emissions Calculations for Recycled Production of Asphalt Shingles

Material/Product	Process Energy per Short Ton Made from Recycled Inputs (Million Btu)	Energy Emissions ($MTCO_2E$/Short Ton)
Asphalt Shingles	0.04	0.00

EPA assumes that recovered asphalt shingles are transported 40 miles and trucked using diesel fuel. We estimate the avoided transportation energy for offsetting virgin asphalt binder using the data and methodology discussed in the Asphalt Concrete chapter. We obtained transportation energy requirements for the asphalt binder from the Canadian Program for Energy Conservation (Natural Resources Canada, 2005). For the production of virgin crude oil, we obtained transportation data from NREL (2009).

Exhibit 12: Transportation Energy GHG Emissions Calculations for Recycled Production of Asphalt Shingles

Material/Product	Transportation Energy per Ton Made from Recycled Inputs (Million Btu)	Transportation Emissions ($MTCO_2E$/Short Ton)
Asphalt Shingles	0.08	0.01

Step 2. *Calculate GHG emissions for production of components of hot mix asphalt.* Exhibit 13 and Exhibit 14 provide the process and transportation emissions associated with producing hot mix asphalt components.

EPA assumes that the recycled asphalt shingles will avoid the production of virgin asphalt binder and aggregate based on the relative percent virgin asphalt binder and aggregate as shown in Exhibit 9. We estimate the emissions associated with the production of virgin asphalt binder using the data and methodology discussed in the Asphalt Concrete chapter. Specifically, we obtained energy inputs for the manufacturing process of asphalt binder from the Athena Sustainable Materials Institute's *Life Cycle Inventory for Road and Roofing Asphalt*, prepared by Franklin Associates (Athena, 2001). To estimate the emissions associated with virgin production of aggregate, we obtained emission factors discussed in the Concrete chapter for virgin aggregate production.

For example, since fiberglass shingles contain 22 percent "asphalt cement" per short ton, we assume that each ton of recovered asphalt shingles could avoid the production-related GHG emissions of virgin asphalt binder adjusted by this percentage. The "weighted" emission factors in Exhibits 13 and 14 show the avoided GHG emissions associated with using recycled asphalt shingles in hot mix asphalt to displace virgin asphalt binder and aggregate.

Exhibit 13: Process Energy Emissions for Components of Hot Mix Asphalt

Material/Product	Process Energy Emissions ($MTCO_2E$/Short Ton)	Typical Composition as Shown in Exhibit 9 (%)	Weighted Process Energy Emissions ($MTCO_2E$/Short Ton)
Virgin Asphalt Binder	0.55	22%	0.12
Aggregate	0.00	38%	0.00

Exhibit 14: Transportation Energy emissions for Components of Hot Mix Asphalt

Material/Product	Transportation Energy Emissions ($MTCO_2E$/Short Ton)	Typical Composition as Shown in Exhibit 9 (%)	Weighted $MTCO_2E$/Short Ton

Virgin Asphalt Binder	0.05	22%	0.01
Aggregate	0.01	38%	0.01

Step 3. *Calculate the avoided hot mix asphalt emissions using recycled asphalt shingles.* To calculate the GHG emissions implications of recycling one short ton of asphalt shingles, WARM subtracts the virgin asphalt binder and aggregate avoided emissions (calculated in Step 2) from the recycling process emissions (calculated in Step 1) to obtain the GHG savings. These results are shown in Exhibit 15.

Exhibit 15: Differences in Emissions between Recycled and Virgin Asphalt Shingles Manufacture ($MTCO_2E$/Short Ton)

	Product Manufacture Using 100% Virgin Inputs ($MTCO_2E$/Short Ton)			Product Manufacture Using 100% Recycled Inputs ($MTCO_2E$/Short Ton)			Difference Between Recycled and Virgin Manufacture ($MTCO_2E$/Short Ton)		
Material/ Product	**Process Energy**	**Transpor-tation Energy**	**Process Non-Energy**	**Process Energy**	**Transpor-tation Energy**	**Process Non-Energy**	**Process Energy**	**Transpor-tation Energy**	**Process Non-Energy**
Asphalt Shingles	0.13	0.07	–	0.00	0.04	–	-0.13	-0.04	–

Note: Negative values denote net GHG emission reductions or carbon storage from a materials management practice.

Step 4. *Adjust the emissions differences to account for recycling losses.* When any material is recovered for recycling, some portion of the recovered material is unsuitable for use as a recycled input. This portion is discarded either in the recovery stage or in the remanufacturing stage. Consequently, less than 1 short ton of new material generally is made from 1 short ton of recovered material. Material losses are quantified and translated into loss rates. The recycled input credits calculated above are therefore adjusted to account for any loss of product during the recycling process. Since data were unavailable for the losses associated with recovered asphalt shingles, WARM assumes a 7.2 percent loss rate for asphalt shingles recycling based on the average residue percent of throughput across all multi-material material recovery facilities (MRF) (Berenyi, 2007). The differences in emissions from virgin versus recycled process energy and transportation energy are adjusted to account for loss rates by multiplying the final three columns of Exhibit 15 by 92.8 percent, the amount of material retained after losses (i.e., 100 percent input – 7.2 percent lost = 92.8 percent retained).

4.3 COMPOSTING

Due to the nature of the components of asphalt shingles, asphalt shingles cannot be composted and thus WARM does not include an emission factor for the composting of asphalt shingles.

4.4 COMBUSTION

Although the practice of combusting asphalt shingles for energy recovery is established in Europe, asphalt shingles are not usually combusted in the United States (CMRA, 2007a). However, they do contain combustible components, and we therefore developed an emission factor for combustion. For more information on combustion in general, please see the chapter on Combustion.

Since C&D waste is typically not combusted in standard combustion facilities because of various impurities that are present, EPA assumes that asphalt shingles are combusted in cement kilns (CMRA, 2007a). We obtained data on the energy content of asphalt shingles from the Construction Materials Recycling Association (CMRA, 2007a). We used carbon coefficients for oil and lubricants taken from the *U.S. Inventory of Greenhouse Gas Emissions and Sinks* as a proxy to calculate combustion emissions associated with the combustion of fiberglass-based shingles (EPA, 2008b). Similarly, we calculated offset emissions using the carbon coefficients for refinery fuel gas typically used in cement kilns, taking into account the amount of shingles needed to generate a similar amount of energy. Greenhouse gas benefits are shown in Exhibit 16.

Exhibit 16: Components of the Combustion Net Emission Factor for Asphalt Shingles ($MTCO_2E$/Short Ton)

Material	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Transportation to Combustion	CO_2 from Combustion	N_2O from Combustion	Avoided Utility Emissions	Steel Recovery	Net Emissions (Post-Consumer)
Asphalt Shingles	–	0.03	0.65	0.04	-1.05	–	-0.34

Note: Negative values denote net GHG emission reductions or carbon storage from a materials management practice.
– = Zero emissions.

4.4.1 Developing the Emission Factor for Combustion of Asphalt Shingles

Raw Material Acquisition and Manufacturing: Since WARM takes a materials-management perspective (i.e., starting at end-of-life disposal of a material), RMAM emissions are not included for this materials management pathway.

Transportation to Combustion: GHG emissions from transportation energy use were estimated to be 0.04 $MTCO_2E$ for one short ton of asphalt shingles (FAL, 1994).

CO_2 from Combustion and N_2O from Combustion: Carbon coefficients for oil and lubricants are based on the *U.S. Inventory of Greenhouse Gas Emissions and Sinks* as a proxy to calculate combustion emissions associated with the combustion of fiberglass-based shingles in cement kilns (EPA, 2008b). Emissions of N_2O are also included in the combustion factor.

Avoided Utility Emissions: Since asphalt shingles are not typically combusted in waste-to-energy (WTE) combustion facilities, EPA modeled the combustion of asphalt shingles as avoiding the combustion of refinery fuel gas typically combusted in cement kilns. The energy content and carbon content of refinery fuel gas are based on data from the American Petroleum Institute and the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, respectively (API, 2004; EPA, 2008b). Using the energy content per ton of fiberglass shingles in comparison to the energy and carbon content of refinery fuel gas, EPA calculated the avoided GHG emissions associated with combusting fiberglass shingles instead of refinery fuel gas in cement kilns.

Exhibit 17: Avoided Emissions from Combustion of Asphalt Shingles in Cement Kilns

(a)	(b) Energy Content (Million Btu/Short Ton)	(c) Carbon Content (kg C/ Million Btu)[a]	(d) Short Tons of Shingles Required/Short Ton Refinery Fuel Gas	(e) Avoided Emissions ($MTCO_2E$/Short Ton Asphalt Shingles) (e = c adjusted per ton/d)
Refinery Fuel Gas	37.5	32.65	NA	NA
Fiberglass Shingles	8.8	20.24	4.26	1.05

Source: New Mexico Environment Department Solid Waste Bureau, 2010.
NA = Not applicable.
[a] The carbon content for refinery fuel gas is adjusted to mass based on the assumption that 250 gallons of refinery fuel gas weigh 1 ton.

Steel Recovery: There are no steel recovery emissions associated with asphalt shingles because they do not contain steel.

Because transportation and avoided utility emissions are positive emission factors, net GHG emissions for combustion are positive for asphalt shingles.

4.5 LANDFILLING

Landfill emissions in WARM include landfill methane and carbon dioxide from transportation and landfill equipment. WARM also accounts for landfill carbon storage, and avoided utility emissions from landfill gas-to-energy recovery. However, since asphalt shingles do not biodegrade, there are zero emissions from landfill methane, zero landfill carbon storage and zero avoided utility emissions associated with landfilling asphalt shingles. Greenhouse gas emissions associated with RMAM are not included in WARM's landfilling emission factors. As a result, the landfilling emission factor for asphalt shingles is equal to the GHG emissions generated by transportation to the landfill and operating the landfill equipment. For further information, please refer to the chapter on Landfilling. Exhibit 18 provides the net emission factor for landfilling asphalt shingles.

Exhibit 18: Landfilling Emission Factor for Asphalt Shingles ($MTCO_2E$/Short Ton)

Material	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Transportation to Landfill	Landfill CH_4	Avoided CO_2 Emissions from Energy Recovery	Landfill Carbon Sequestration	Net Emissions (Post-Consumer)
Asphalt Shingles	–	0.04	–	–	–	0.04

– = Zero emissions.

5. LIMITATIONS

Although currently EPA does not consider the closed-loop recycling of asphalt shingles (i.e., using recovered asphalt shingles to produce new asphalt shingles), this process is technically feasible. However, many manufacturers have difficulty meeting product specifications when recycled shingles are used as inputs into the production of new asphalt shingles. EPA will consider including closed-loop shingle recycling when data become available for facilities producing new shingles from either manufacturers' scrap or tear-off material on a commercial basis.

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