Foamed Product Carbon Footprint Study
CO_2(e) Comparison
XLPE vs EPE

(*with supporting documentation*)

14 October 2022

Steve Sopher

JSP

ARPLANK®
Expanded bead foam packaging materials

JSP

Foamed Product Carbon Footprint Study CO_2(e) Comparison XLPE vs EPE

EPE Sustainable Alterative

Compressive Strength was equal at 9 PSI @ 25%, Tear Strength was improved with EPE.

2# XLPE

1.3# EPE

Added Corrugated Recycled EPP base to compliment the EPE Foam

Foamed Product Carbon Footprint Study CO_2(e) Comparison XLPE vs EPE

Foamed Product	Density (pcf)	Weight (lbs/bd-ft)	Carbon Footprint (CO_2e lbs/ft^3)	Carbon Footprint (CO_2e lbs/bd-ft)	Savings (CO_2e lbs/bd-ft)	Savings (CO_2e lbs/truckload)	Savings (CO_2e lbs/million bd-ft)	Savings (Barrels of Oil/truckload)	Savings (Barrels of Oil/million bd-ft)
XLPE (Extruded PE)	2.0	0.167	4.92	0.41					
EPE (Expanded PE)	1.3	0.108	3.22	0.27	0.14	5210	141,333	5.5	148.5

Facts

- ✓ Recycled or Captured CO^2 is used as a blowing agent to expand all ARPLANK EPE products
- ✓ ARPLANK EPE foam products are completely inert and the base resin meets FDA requirements
- ✓ ARPLANK EPE foam products do not contain CFC's, HCFC's, HC's or VOC's
- ✓ ARPLANK EPE foam products meet RoHS and REACH compliance requirements
- ✓ ARPLANK EPE foam products are non-crosslinked and 100% recycle and melt-processable back to the base resin
- ✓ Unlike many other foam products, recycled ARPLANK EPE can be re-expanded to new ARPLANK EPE products
- ✓ Less future energy is required to recycle the foam and corrugated materials
- ✓ Lower product weight reduces shipping weight and both energy (less fuel) cost and carbon footprint for freight carrier

Supporting Documentation for EPE CO_2e Comparison vs. XLPE

U.S. Environmental Protection Agency
Office of Resource Conservation and Recovery

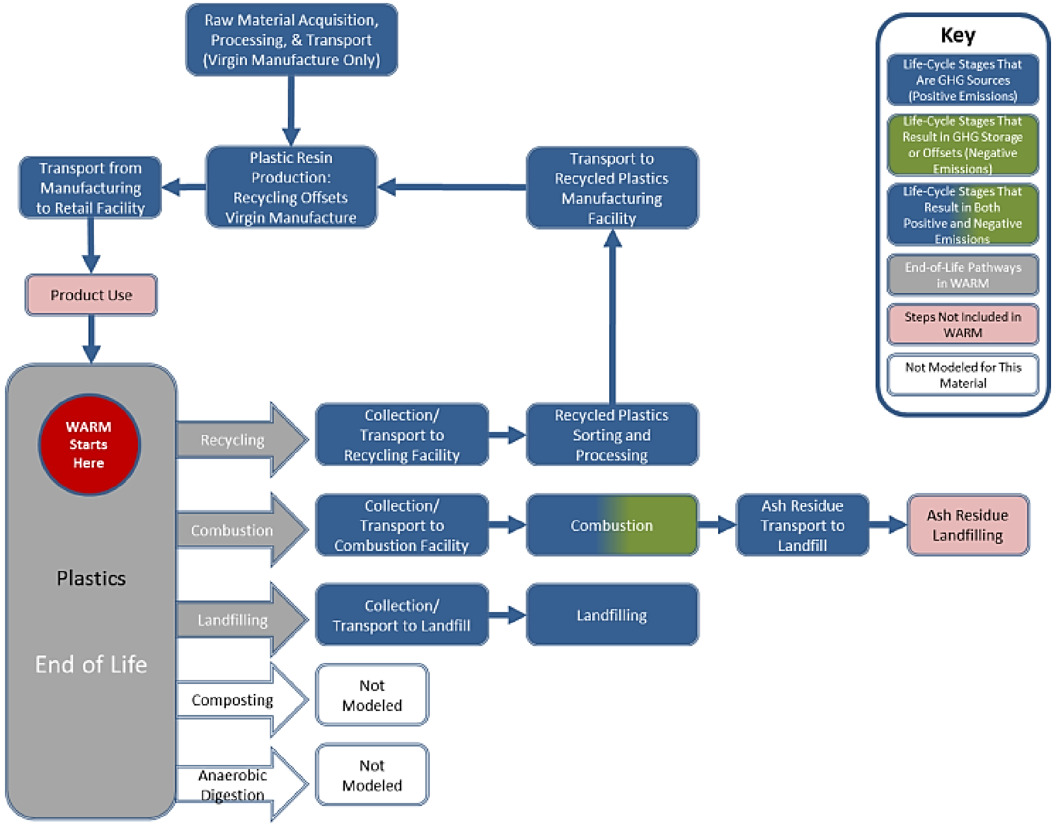
Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)

Containers, Packaging, and Non-Durable Good Materials Chapters

February 2016

Prepared by ICF International
For the U.S. Environmental Protection Agency
Office of Resource Conservation and Recovery

Exhibit 5-1: Life Cycle of Plastics in WARM[39]



Plastics included in WARM are high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyethylene terephthalate (PET), linear low-density polyethylene (LLDPE), polypropylene (PP), general purpose polystyrene (PS), and polyvinyl chloride (PVC).

Page 5-1

Supporting Documentation for EPE CO_2e Comparison vs. XLPE

Exhibit 5-7: Raw Material Acquisition and Manufacturing Emission Factor for Virgin Production of Plastics ($MTCO_2E$/Short Ton)

(a) Material	(b) Process Energy	(c) Transportation Energy	(d) Process Non-Energy	(e) Net Emissions (e = b + c + d)
HDPE	1.18	0.15	0.20	1.53
LDPE	1.40	0.15	0.21	1.76
PET	1.74	0.07	0.39	2.20
LLDPE	1.14	0.15	0.25	1.54
PP	1.17	0.13	0.21	1.51
PS	1.86	0.15	0.45	2.46
PVC	1.68	0.08	0.14	1.90

Exhibit 5-8, Exhibit 5-9, and Exhibit 5-10 provide the calculations for each source of RMAM emissions: process energy, transportation energy and non-energy processes.

Exhibit 5-8: Process Energy GHG Emissions Calculations for Virgin Production of Plastics

Material	Process Energy per Short Ton Made from Virgin Inputs (Million Btu)	Process Energy GHG Emissions ($MTCO_2E$/Short Ton)
HDPE	23.68	1.18
LDPE	27.77	1.40
PET	28.25	1.74
LLDPE	23.04	1.14
PP	23.62	1.17
PS	35.86	1.87
PVC	30.25	1.68

Exhibit 5-9: Transportation Energy Emissions Calculations for Virgin Production of Plastics

Material	Transportation Energy per Short Ton Made from Virgin Inputs (Million Btu)	Transportation Energy GHG Emissions ($MTCO_2E$/Short Ton)
HDPE	2.74	0.15
LDPE	2.79	0.15
PET	1.00	0.07
LLDPE	2.77	0.15
PP	2.36	0.13
PS	2.36	0.15
PVC	1.46	0.08

Note: The transportation energy and emissions in this exhibit do not include retail transportation, which is presented separately in Exhibit 1-6.
– = Zero emissions.

Page 5-7

Exhibit 5-10: Process Non-Energy Emissions Calculations for Virgin Production of Plastics

Material	CO_2 Emissions (MT/Short Ton)	CH_4 Emissions (MT/Short Ton)	CF_4 Emissions (MT/Short Ton)	C_2F_6 Emissions (MT/Short Ton)	N_2O Emissions (MT/Short Ton)	Total Non-Energy Emissions ($MTCO_2E$/Short Ton)
HDPE	0.06	0.01	–	–	–	0.20
LDPE	0.07	0.01	–	–	0.00	0.21
PET	0.27	0.00	–	–	–	0.39
LLDPE	0.11	0.01	–	–	0.00	0.25
PP	0.07	0.01	–	–	0.00	0.21
PS	0.30	0.01	–	–	–	0.45
PVC	0.08	0.00	–	–	–	0.14

– = Zero emissions.

Page 5-8

Supporting Documentation for EPE CO_2e Comparison vs. XLPE

5.4.3 Composting

Because the types of plastics under consideration are not subject to aerobic bacterial degradation, they cannot be composted. As a result, WARM does not consider GHG emissions or storage associated with composting.

5.4.4 Combustion

Because plastic is made from fossil fuels, its combustion is considered an anthropogenic source of carbon emissions. Nitrous oxide (N_2O) emissions can also occur from incomplete combustion of waste but, since the plastic considered here does not contain any nitrogen, there are no N_2O emissions associated with combusting plastic. Also included in the net emission factor for combusting each plastic type are emissions associated with transporting the plastic waste to waste-to-energy (WTE) facilities and emission savings associated with the avoided emissions of burning conventional fossil fuels for utilities. Exhibit 5-15 provides the emission factors for combusting each plastic type and their components.

Page 5-9

Exhibit 5-15: Components of the Combustion Net Emission Factor for Plastics ($MTCO_2E$/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)
HDPE	–	0.01	2.79	–	-1.58	–	1.23
LDPE	–	0.01	2.79	–	-1.57	–	1.24
PET	–	0.01	2.04	–	-0.84	–	1.21
LLDPE	–	0.01	2.79	–	-1.57	–	1.23
PS	–	0.01	2.79	–	-1.57	–	1.23
PP	–	0.01	3.01	–	-1.42	–	1.60
PVC	–	0.01	1.25	–	-0.62	–	0.64
Mixed Plastics	–	0.01	2.32	–	-1.12	–	1.22

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

CO_2 emissions from combusting plastic depend on the carbon content of the plastic and the amount of carbon that is converted to CO_2 during the combustion process. Exhibit 5-16 provides the carbon content of each plastic type modeled in WARM based on its chemical composition; combustion oxidation, or the amount of carbon converted to CO_2 during combustion, which EPA estimates to be 98 percent; and the final resulting CO_2 emissions from combusting each plastic type.

Exhibit 5-16: Plastics CO_2 Combustion Emission Factor Calculation

Material	Carbon Content (%)	Carbon Converted to CO_2 during Combustion (%)	Combustion CO_2 Emissions ($MTCO_2E$/Short Ton)
HDPE	86%	98%	2.79
LDPE	86%	98%	2.79
PET	63%	98%	2.04
LLDPE	86%	98%	2.79
PP	86%	98%	2.79
PS	92%	98%	3.01
PVC	38%	98%	1.25
Mixed Plastics	72%	98%	2.33

Creating energy from waste at WTE facilities offsets part of the required energy production of utility companies. Exhibit 5-17 provides the calculation of utility emissions offsets for plastic combustion by plastic type based on the energy content of each plastic, the combustion system's efficiency, and the emission factor based on the national grid mix associated with a similar amount of energy produced from conventional sources.

Page 5-10

Supporting Documentation for EPE CO_2e Comparison vs. XLPE

Exhibit 5-17: Utility GHG Emissions Offset from Combustion of Plastics

(a) Material	(b) Energy Content (Million Btu per Short Ton)	(c) Combustion System Efficiency (%)	(d) Emission Factor for Utility-Generated Electricity ($MTCO_2E$/ Million Btu of Electricity Delivered)	(e) Avoided Utility GHG per Short Ton Combusted ($MTCO_2E$/Short Ton) (e = b × c × d)
HDPE	40.0	17.8%	0.20	1.44
LDPE	39.8	17.8%	0.20	1.44
PET	21.2	17.8%	0.20	0.77
LLDPE	39.9	17.8%	0.20	1.44
PP	39.9	17.8%	0.20	1.44
PS	36.0	17.8%	0.20	1.30
PVC	15.8	17.8%	0.20	0.57

5.4.5 Landfilling

WARM considers the methane (CH_4) emissions, transportation-related CO_2 emissions and carbon storage that will result from landfilling. Because plastics do not contain biodegradable carbon, they do not generate CH_4 and are not considered to store any carbon when landfilled. The only emissions associated with landfilling plastics are from transportation to the landfill and moving waste in the landfill. Transportation of waste materials results in CO_2 emissions from the combustion of fossil fuels in truck transport. Exhibit 5-18 provides the net emission factor and its components for landfilling each plastic type. For further information on landfilling in general, refer to the Landfilling chapter.

Exhibit 5-18: Landfilling Emission Factors for Plastics ($MTCO_2E$/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 Storage	Net Emissions (Post-Consumer)
HDPE	–	0.02	–	–	–	0.02
LDPE	–	0.02	–	–	–	0.02
PET	–	0.02	–	–	–	0.02
LLDPE	–	0.02	–	–	–	0.02
PP	–	0.02	–	–	–	0.02
PS	–	0.02	–	–	–	0.02
PVC	–	0.02	–	–	–	0.02
Mixed Plastics	–	0.02	–	–	–	0.02

– = Zero emissions.

5.4.6 Anaerobic Digestion

Because of the nature of plastics components, plastics cannot be anaerobically digested, and thus, WARM does not include an emission factor for the anaerobic digestion of plastics.

Page 5-11

Supporting Documentation for EPE CO_2e Comparison vs. XLPE

CO_2e Baseline Numbers per pound (lbsCO_2e/lb) of Polymer Production for US Production

Base Resin for ARPRO EPP = PP – Polypropylene = 1.51 lbsCO_2e/lb
Base Resin for ARPAK EPE = LLDPE – Linear Low Density Polyethylene = 1.54 lbsCO_2e/lb
Base Resin for XLPE = LDPE – Low Density Polyethylene = 1.76 lbsCO_2e/lb
Base Resin for EPS = PS – Polystyrene = 2.46 lbsCO_2e/lb

Process Energy to Foam for ARPRO EPP = 0.87 lbsCO_2e/lb
Process Energy to Foam for ARPAK EPE = 0.94 lbsCO_2e/lb
Process Energy to Foam for XLPE = 0.70 lbsCO_2e/lb
Process Energy to Foam for EPS = 0.53 lbsCO_2e/lb

Foamed Product of ARPRO EPP = 2.38 lbsCO_2e/lb
Foamed Product of ARPAK EPE = 2.48 lbsCO_2e/lb
Foamed Product of XLPE = 2.46 lbsCO_2e/lb
Foamed Product of EPS = 2.99 lbsCO_2e/lb

CO_2e Baseline Number per pound (lbsCO_2e) per 42-gallon barrel of Oil

Average CO_2 coefficient of distillate fuel oil is 952.1 lbs CO_2 per 42-gallon barrel (EPA 2021).