Waste Reduction Model (WARM)

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EPA's Waste Reduction Model (WARM) Overview

- Created in 1998 to offer high-level estimates of potential greenhouse gas (GHG) emissions reductions, energy savings, and economic impacts from waste management options.
- Estimates impacts from baseline and alternative waste management options, including:
  - Source reduction, recycling, anaerobic digestion, combustion, composting and landfilling.
- Models 60 materials commonly found in MSW and C&D debris, including plastics.

WARM Stakeholders

Municipal and state government employees

- Understand and compare potential solid waste management options

Students and educators

- Elementary school to higher education

Industry groups

- Commodity/material specific groups provide data and use the tool

Waste reduction and waste management groups

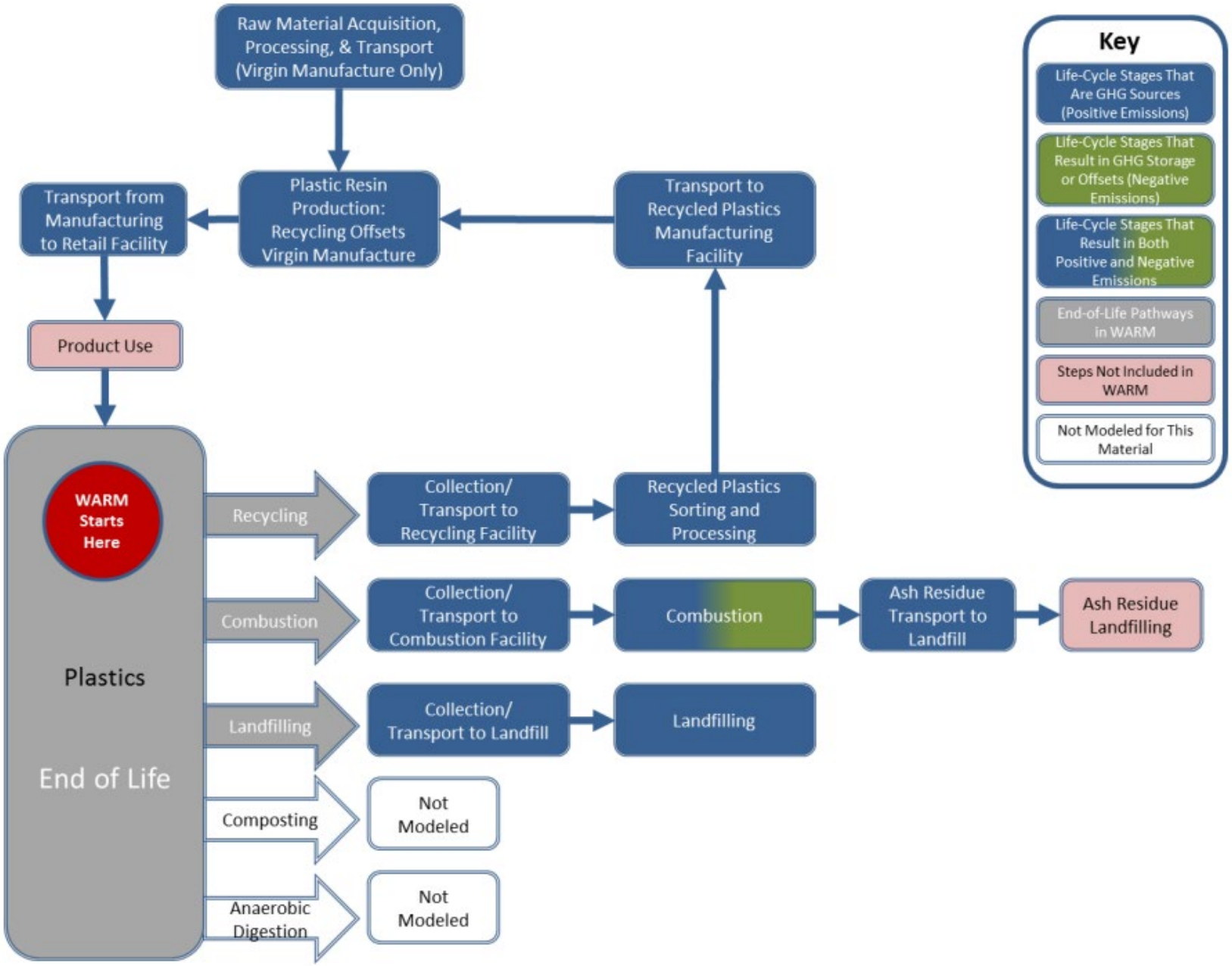
- Composting council, recycling organizations, etc.

Plastics modeled:

- HDPE
- LDPE
- PET
- LLDPE
- PP
- PS
- PVC
- Mixed Plastics

(40% HDPE, 60% PET)

Exhibit 5-1: Life Cycle of Plastics in WARM[37]

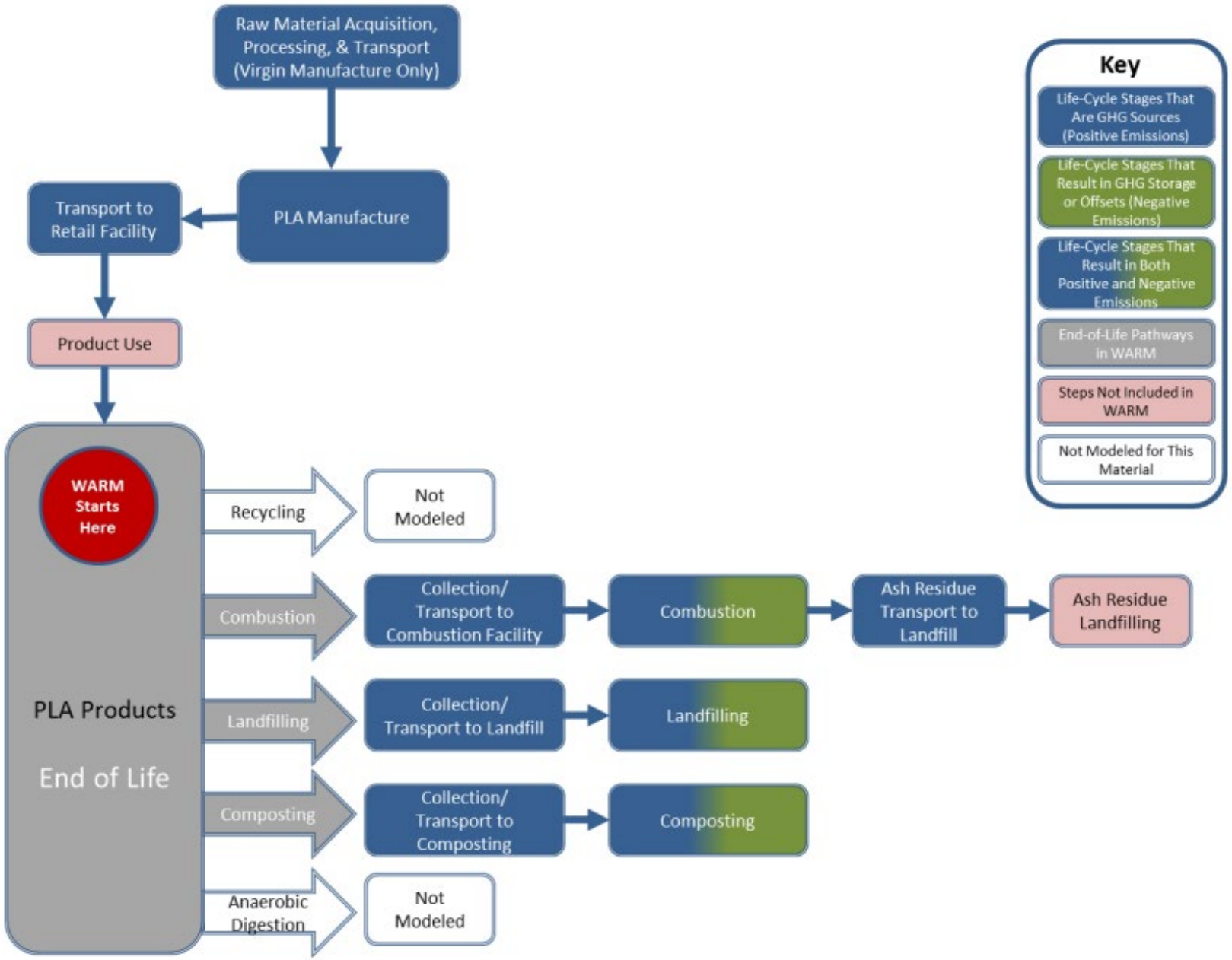


https://www.epa.gov/sites/default/files/2020-12/documents/warm_containers_packaging_and_non-durable_goods_materials_v15_10-29-2020.pdf

Biobased polymer: PLA

- Can be composted, unlike other plastics categories
- Recycling not modeled

Exhibit 4-1: Life Cycle of PLA in WARM



Plastics Emission Factors

Per Ton Estimates of GHG Emissions for Baseline and Alternative Management Scenarios							
Material	GHG Emissions per Ton of Material Produced (MTCO2E)	GHG Emissions per Ton of Material Source Reduced (MTCO2E)	GHGEmissions per Ton of Material Recycled (MTCO2E)	GHG Emissions per Ton of Material Landfilled (MTCO2E)	GHG Emissions per Ton of Material Combusted (MTCO2E)	GHG Emissions per Ton of Material Composted (MTCO2E)	GHG Emission per Ton of Material Anaerobically Digested (MTCO2E)
HDPE	1.42	-1.42	-0.76	0.02	1.29	NA	NA
LDPE	1.8	-1.8	NA	0.02	1.29	NA	NA
PET	2.17	-2.17	-1.04	0.02	1.24	NA	NA
LLDPE	1.58	-1.58	NA	0.02	1.29	NA	NA
PP	1.52	-1.52	-0.79	0.02	1.29	NA	NA
PS	2.5	-2.5	NA	0.02	1.65	NA	NA
PVC	1.93	-1.92	NA	0.02	0.66	NA	NA
Mixed Plastics	1.87	-1.87	-0.93	0.02	1.26	NA	NA
PLA	2.45	-2.45	NA	-1.64	-0.63	-0.09	NA

Plastics Management: Source Reduction

Choosing displacement of "current mix" or 100% virgin changes source reduction emission factors

Exhibit 5-6: Source Reduction Emission Factors for Plastics ($MTCO_2E$/Short Ton)

Material	Raw Material Acquisition and Manufacturing for Current Mix of Inputs	Raw Material Acquisition and Manufacturing for 100% Virgin Inputs
HDPE	(1.42)	(1.52)
LDPE	(1.80)	(1.80)
PET	(2.17)	(2.21)
LLDPE	(1.58)	(1.58)
PP	(1.52)	(1.54)
PS	(2.50)	(2.50)
PVC	(1.93)	(1.93)
Mixed Plastics	(1.87)	(1.94)

Plastics Management: Recycling

- WARM models plastics at resin level (e.g., not bottles/other end uses).
- Recycling is modeled as closed loop, resin-to-resin.
- Recycled input credit: difference between manufacturing virgin and recycled resin.

Exhibit 5-11: Recycling Emission Factor for Plastics ($MTCO_2E$/Short Ton)

Material[a]	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Materials Management Emissions	Recycled Input Credit[a] Process Energy	Recycled Input Credit[b] – Transportation Energy	Recycled Input Credit[b] – Process Non-Energy	Forest Carbon Storage	Net Emissions (Post-Consumer)
HDPE	–	–	(0.59)	(0.01)	(0.15)	–	(0.76)
LDPE	NA	NA	NA	NA	NA	NA	NA
PET	–	–	(0.59)	(0.01)	(0.15)	–	(1.04)
LLDPE	NA	NA	NA	NA	NA	NA	NA
PP	–	–	(0.65)	0.02	(0.16)	–	(0.70)
PS	NA	NA	NA	NA	NA	NA	NA
PVC	NA	NA	NA	NA	NA	NA	NA
Mixed Plastics	–	–	(0.70)	0.01	(0.24)	–	(0.93)

Note: Negative values denote net GHG emission reductions or carbon storage from a materials management practice.
– = Zero emissions.
[a] Recycling emission factors are only available for HDPE, PET, and PP due to LCI data availability.
[b] Includes emissions from the initial production of the material being managed.

Plastics Management: Combustion

- Emissions based on carbon content of plastics and % of that carbon converted to CO2 during combustion.
- Utility offsets: uses assumptions of plastic energy content, combustion system efficiency and national average grid electricity generation emissions.

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	Utility Emissions	Steel Recovery Offsets	Net Emissions (Post-Consumer)
HDPE	–	0.01	2.79	–	(1.52)	–	1.29
LDPE	–	0.01	2.79	–	(1.51)	–	1.29
PET	–	0.01	2.04	–	(0.80)	–	1.24
LLDPE	–	0.01	2.79	–	(1.51)	–	1.29
PP	–	0.01	2.79	–	(1.51)	–	1.29
PS	–	0.01	3.01	–	(1.37)	–	1.65
PVC	–	0.01	1.25	–	(0.60)	–	0.66
Mixed Plastics	–	0.01	2.34	–	(1.09)	–	1.26

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

Plastics Management: Landfilling

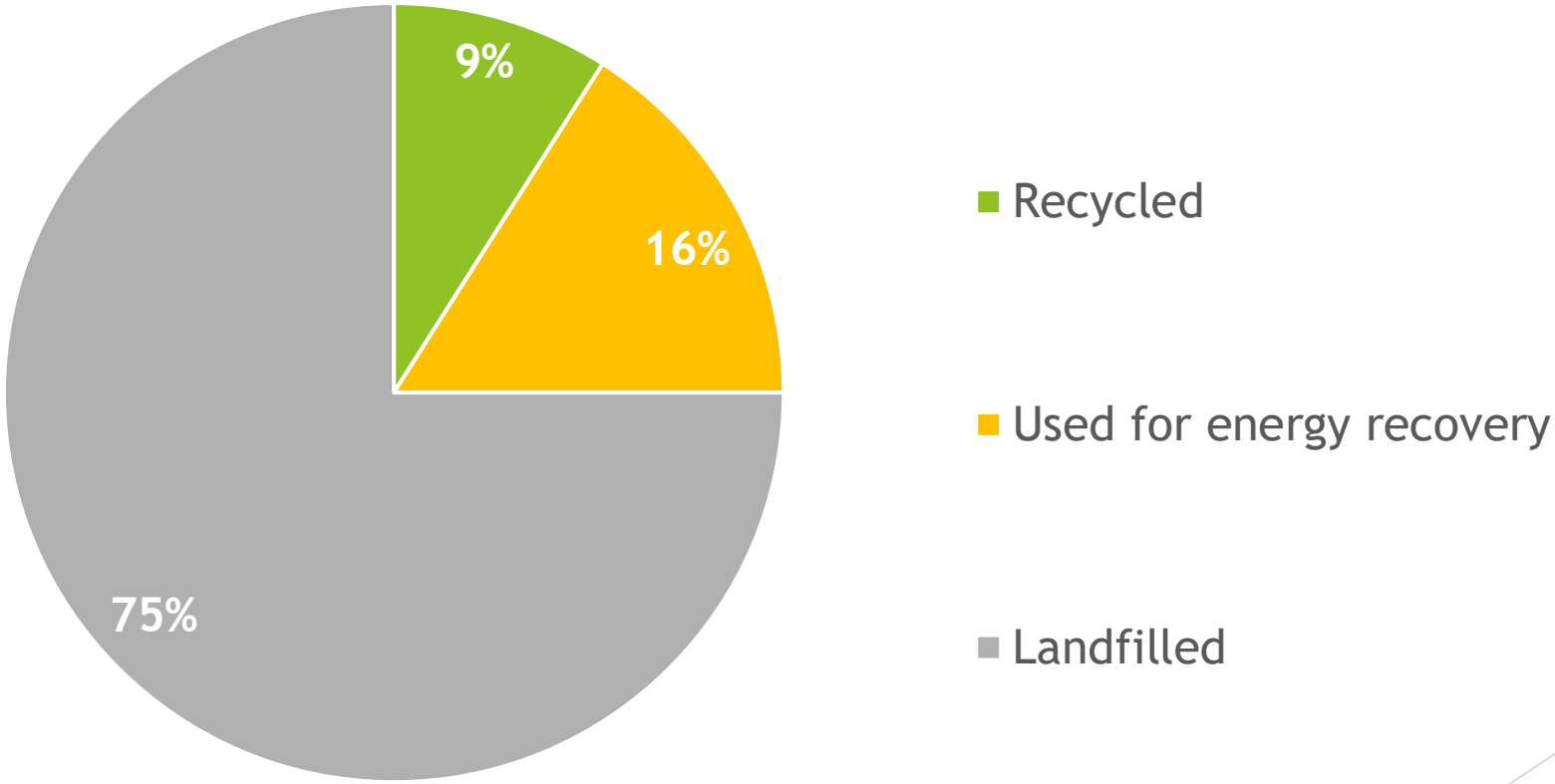
- Only emissions associated with landfilling plastics are transportation to landfill.
- Carbon is not biodegradable, so no CH4 emissions or capture.
- Doesn't count as carbon storage because fossil-fuel-derived.

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

Management of plastic waste in the United States

EPA's Facts and Figures about Materials, Waste, and Recycling report estimated 35.68 million tons of plastic waste generated in 2018



These estimates do not account for littering or other mismanagement

U.S. Plastics in MSW (2018)

	Current Plastics Waste Management (tons)*	GHG (Million MTCO2e, est.)**	Energy (million BTU, est.)**	Labor (million hrs, est.)**	Wages (million USD)**	Taxes (million USD)**
Recycling	3,090,000 (8.7%)	(3)	(108)	185	$4,106	$674
Combustion with energy recovery	5,620,000 (15.8%)	7	(76)	8	$259	$96
Landfilled	26,970,000 (75.6%)	0.5	7	37	$1,244	$462

*Estimates on managed plastics waste come from EPA's Facts and Figures report.
** Estimates are based on using the WARM factors and include emission and energy offsets.

Future Plastics Work in WARM

Add Reuse pathway (for plastics reuse).

Preliminary scoping complete; potential FY24 work.

Add Textiles category (nylon and polyester).

Preliminary scoping complete; potential FY24 work.

Add Chemical Recycling pathway (plastics only).

Potential FY24 scoping.

Plans to Expand Impact Categories

Potential FY24 scoping.

Align with MSW DST and Peer Review

Potential FY24 scoping.

WARM Resources

Documentation chapters

Containers, Packaging, and Non-Durable Good Materials Chapter

Main page: epa.gov/warm

Thank You!

For more information:
epa.gov/warm

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