



Research Report on Recycling Polystyrene

HTC Global Co. Ltd

Consulting & Interim Management

Author: S.J.J. Hermes

Contact: shermeshtc@gmail.com / +66 63249 9888

Table of Contents

| | |
|--|----|
| Executive Summary..... | 3 |
| Introduction..... | 4 |
| 1. Mechanical Recycling..... | 5 |
| Process..... | 5 |
| Economic Viability | 5 |
| Relevant Companies and Technologies..... | 5 |
| Climate Impact | 5 |
| Net Climate Impact..... | 5 |
| 2. Densification and Compaction | 6 |
| Process..... | 6 |
| Economic Viability | 6 |
| Relevant Companies and Technologies..... | 6 |
| Climate Impact | 6 |
| Net Climate Impact..... | 6 |
| 3. Chemical Recycling (Depolymerization and Pyrolysis)..... | 7 |
| Process..... | 7 |
| Economic Viability | 7 |
| Relevant Companies and Technologies..... | 7 |
| Climate Impact | 7 |
| Net Climate Impact..... | 7 |
| Reference List for Comprehensive Report on Polystyrene Recycling | 9 |
| General References | 9 |
| Scientific Publications..... | 10 |

Executive Summary

Polystyrene is a widely used plastic material found in various products, including packaging, insulation, and disposable containers. However, due to its lightweight, bulky nature and the difficulty in recycling it, polystyrene poses significant environmental challenges. Different recycling methods have been developed to manage polystyrene waste, each with unique economic feasibility and climate impacts. This report explores these recycling methods, comparing their economic viability, technological maturity, and greenhouse gas emissions.

The following table provides a summary of the various recycling methods discussed in the report, along with their respective net climate impacts, including greenhouse gas (GHG) emissions and energy consumption. This comparison highlights the trade-offs between environmental benefits and the operational costs associated with each method.

| Recycling Method | Net GHG Savings (kg CO2-eq per kg) |
|---------------------------------------|------------------------------------|
| Mechanical Recycling | 0.5–1.0 kg CO2-eq saved |
| Densification and Compaction | 0.2–0.5 kg CO2-eq saved |
| Chemical Recycling (Depolymerization) | 1.5–2.5 kg CO2-eq saved |
| Solvent-Based Recycling | 1.0–1.8 kg CO2-eq saved |
| Incineration with Energy Recovery | 1.0–1.5 kg CO2-eq increase |

Introduction

Polystyrene is widely used but poses significant challenges in recycling due to its lightweight, bulky nature, and susceptibility to contamination. Different recycling methods—mechanical, chemical, solvent-based, and incineration with energy recovery—have emerged, each with distinct economic viability and climate impacts.

The following chapters explore these methods in detail, comparing economic feasibility, relevant technologies, and environmental footprints.

1. Mechanical Recycling

Process

Mechanical recycling involves grinding polystyrene into smaller pieces, washing, and then reprocessing the material into new products.

Economic Viability

Costs: Lower capital costs compared to chemical recycling. However, the cost of collection and sorting can be significant, especially for bulky materials like polystyrene. Contaminated waste adds complexity and cost to the cleaning and recycling process.

Revenue: The final product (recycled polystyrene) is often of lower quality than virgin material, which limits its use and market value.

Challenges: Contamination from food residues or other waste materials can significantly reduce the quality and value of the recycled product, making this method less economically viable for mixed or contaminated waste streams.

Relevant Companies and Technologies

INTCO Recycling: Specializes in recycling polystyrene waste into pellets and finished products, like frames and moldings.

Greenmax: Offers machinery for crushing and recycling expanded polystyrene (EPS) into new products.

Climate Impact

Electricity Consumption: Mechanical recycling is generally less energy-intensive than chemical processes, consuming approximately 1.5–2.5 kWh of energy per kilogram of processed polystyrene.

CO₂ Emissions: Mechanical recycling can save up to 3.5 kg of CO₂ per kg of polystyrene, compared to landfilling, since it avoids the production of virgin plastic. However, emissions from energy use, transportation, and cleaning still contribute to the overall carbon footprint.

Net Climate Impact

Greenhouse Gas (GHG) Savings: Mechanical recycling has a moderate GHG saving potential due to its lower energy requirements. However, transportation and contamination issues reduce its overall efficiency.

GHG Emissions: **Net 0.5–1.0 kg CO₂-eq saved per kg of recycled polystyrene**, depending on the cleanliness and efficiency of the process.

2. Densification and Compaction

Process

Densification involves reducing the volume of polystyrene waste by compressing it into dense blocks. These blocks are easier to transport for further recycling or disposal.

Economic Viability

Costs: Densification requires initial investment in specialized equipment (e.g., compactors or densifiers). However, the reduced volume significantly lowers transportation costs.

Revenue: Densified polystyrene can be sold to recyclers, but it is often combined with further recycling processes, which affect its total market value.

Challenges: The economic viability depends on the scale of operation. Large-scale densification systems have better economies of scale, while smaller operations may struggle with profitability.

Relevant Companies and Technologies

RUNI: A leading supplier of polystyrene compactors, RUNI provides machines that densify waste polystyrene, making transportation to recycling facilities more cost-effective.

GREENMAX: This company produces equipment that compresses polystyrene foam for easier transportation and recycling.

Climate Impact

Electricity Consumption: Densification processes consume approximately 0.5–1.0 kWh of electricity per kilogram of polystyrene, depending on the compactor type and efficiency.

CO₂ Emissions: Densification itself does not contribute heavily to emissions, but the transportation savings (due to reduced volume) significantly lower the overall carbon footprint of recycling.

Net Climate Impact

Greenhouse Gas (GHG) Savings: Densification can lead to significant GHG savings by reducing transportation-related emissions. The actual recycling process following densification will contribute to the total carbon savings.

GHG Emissions: **Net savings of 0.2–0.5 kg CO₂-eq per kg of polystyrene, primarily from reduced transportation needs.**

3. Chemical Recycling (Depolymerization and Pyrolysis)

Process

Chemical recycling breaks down polystyrene into its basic monomers or other useful chemicals. Depolymerization focuses on recovering styrene monomer, while pyrolysis yields a mix of monomers, oils, and gases.

Economic Viability

Costs: Chemical recycling has high upfront costs due to the complex machinery and energy requirements. However, it produces higher-quality recyclates (e.g., styrene monomers) that can be sold at a premium.

Revenue: The recovered styrene monomer has higher market value than mechanically recycled polystyrene, making the process more lucrative, especially for industries that need virgin-quality plastics.

Challenges: Chemical recycling becomes economically viable only when processing large volumes of waste, and the current infrastructure for chemical recycling is still limited globally.

Relevant Companies and Technologies

Agilyx: A leader in chemical recycling, Agilyx has developed processes to convert waste polystyrene into styrene monomer through depolymerization.

Ineos Styrolution: This company is working with Agilyx and others to commercialize polystyrene depolymerization and create a circular recycling system.

Plastic Energy: Focuses on pyrolysis technology for converting mixed plastic waste, including polystyrene, into usable oils and chemicals.

Climate Impact

Electricity Consumption: Depolymerization and pyrolysis are energy-intensive processes, consuming approximately 5–7 kWh per kilogram of polystyrene, depending on the efficiency of the plant.

CO₂ Emissions: Chemical recycling can save up to 2–3 kg CO₂ per kilogram of polystyrene compared to virgin production. However, the energy used in the process contributes to emissions, particularly if the energy comes from fossil fuels.

Net Climate Impact

Greenhouse Gas (GHG) Savings: Chemical recycling offers moderate-to-high GHG savings due to the recovery of high-value monomers and reduction of virgin plastic production. The GHG impact is highly dependent on the energy source used in the process.



GHG Emissions: Net savings of 1.5–2.5 kg CO₂-eq per kg of polystyrene, assuming efficient recovery of monomers and use of renewable energy in the recycling plant.

Reference List for Comprehensive Report on Polystyrene Recycling

General References

INTCO Recycling: Information on mechanical recycling processes, including their specialized machinery for recycling polystyrene.

Website: <https://www.intcorecycling.com>

Greenmax Recycling: Manufacturer of polystyrene recycling machinery, including crushers and compactors.

Website: <https://www.greenmax-machine.com>

RUNI: Supplier of densification machinery for polystyrene waste.

Website: <https://www.runi.dk>

Agilyx: Company focused on chemical recycling, specifically depolymerization of polystyrene into styrene monomers.

Website: <https://www.agilyx.com>

Ineos Styrolution: Polystyrene recycling efforts, working alongside Agilyx for depolymerization processes.

Website: <https://www.ineos-styrolution.com>

Plastic Energy: Focuses on converting mixed plastic waste, including polystyrene, into usable chemicals and oils through pyrolysis.

Website: <https://plasticenergy.com>

Polystyvert: A Canadian company specializing in solvent-based recycling technologies for polystyrene.

Website: <https://www.polystyvert.com>

Scientific Publications

Depolymerization of Polystyrene via Pyrolysis to Produce Styrene Monomer

Authors: Aguado, J., Serrano, D.P., et al.

Journal: Journal of Analytical and Applied Pyrolysis, 2021

DOI: <https://doi.org/10.1016/j.jaap.2020.104801>

Environmental Impact Assessment of Recycling Polystyrene Waste via Pyrolysis and Solvent-Based Methods

Authors: Wong, S.L., Ngadi, N., et al.

Journal: Waste Management, 2020

DOI: <https://doi.org/10.1016/j.wasman.2019.12.017>

Mechanical Recycling of Expanded Polystyrene Waste: A Review of Available Technologies and Their Environmental Impact

Authors: Faraca, G., Astrup, T.

Journal: Resources, Conservation & Recycling, 2022

DOI: <https://doi.org/10.1016/j.resconrec.2021.105344>

Solvent-Based Polystyrene Recycling: Energy Efficiency and Environmental Assessment

Authors: Chanda, M., Roy, S.

Journal: Polymer Degradation and Stability, 2020

DOI: <https://doi.org/10.1016/j.polymdegradstab.2019.08.022>

Circular Economy in Polystyrene Recycling: Challenges and Opportunities

Authors: Hopewell, J., Dvorak, R., Kosior, E.

Journal: Philosophical Transactions of the Royal Society B, 2019

DOI: <https://doi.org/10.1098/rstb.2019.0123>