A Multi-Measure Analysis: Evaluating the Sustainability of Polystyrene Waste Mitigation Technologies - Towards A Circular Economy: Sustainable Management

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Abstract - Focus towards SDG13, The universal problem of plastic pollution, fueled by linear production and consumption patterns, poses a climactic threat to human and environmental health. The prevailing waste management infrastructure, over-dependent on land-filling and inefficient recycling, cannot respond effectively to the aggravating crisis. This calls for a paradigm shift towards plastics based on a sustainable, circular economy. This review assesses the waste management hierarchy the prioritization of source reduction, reuse, mechanical recycling, and chemical recycling the foundation of a sustainable approach. This study describes four valuable recycling and re-purposing systems for polystyrene. These include: conversion to plywood composites, concrete/geopolymer systems, chemical depolymerization and conversion into paints and coatings. The paint formulations convert waste PS into coatings with hydrophobic or anti-corrosive properties. Grafting PS gained reactive or polar groups, which can increase the performance of PS waste streams in targeted applications. Although breakthroughs in biodegradable polymers and waste-to-energy technologies provide supporting solutions, ensuring their life-cycle assessment to prevent the emergence of unforeseen consequences is necessary. This analysis ends with the identification of key research frontiers, calling for effective chemical up-cycling and systems-level modeling for decisions on policy and investment. It is necessary to collaborate across scientific, industrial, and governmental communities to move from a plastic waste issue to a sustainable plastics economy.

Key Words: SDG13,Plastic,circular economy,recycle

1.INTRODUCTION

Polystyrene (PS), produced from styrene monomers, is a lightweight, insulating, and easily processed polymer widely used in packaging, construction, and consumer products; however, its expanded form (EPS) is non-biodegradable and persists in land, marine, and waste-management environments, where it accumulates, disrupts disposal systems, and endangers wildlife.[1] The increasing volume of PS waste, together with limited recycling rates, has intensified the global need for sustainable waste-management strategies that align with circular-economy principles. Conventional practices such as landfilling and incineration are now recognized as environmentally and economically unsustainable because they generate greenhouse gases, produce toxic by-products, and eliminate materials that could otherwise be recovered.[2] As a result, recycling pathways that convert PS into value-added materials are receiving growing attention.Mechanical recycling can take discarded rigid plastics (PS) and turn them into something useful, like a type of plywood or board that is lightweight and has moisture-resistant properties which helps to reduce the volume of waste created when the product is thrown away.[3] EPS is also used as a lightweight aggregate for concrete which reduces the overall density of concrete while increasing thermal insulation capability for non-structural applications. [4] Through the process of chemical recycling, especially depolymerization through pyrolysis or along mechanochemical and oxidative pathways, PS is transformed into high purity styrene monomer, a building block in creating new materials through circular material recovery.[5-6] Waste PS materials are also being used in making paints and coatings, where the dissolved PS acts as a binder, and in combination with conductive polymers such as polyaniline can create anti-corrosion systems that rely less on petrochemical-based materials to create these systems. By grafting and polar modifications (recycling PS) create functional groups, thereby enhancing the recycled PS to have improved compatibility, improved mechanical performance, and improved interfaces leading to more potential applications. Challenges still exist in optimizing processes, creating scalable.[7-8]

2.METHOD

Recycling ratios identify both demand, and recycling volumes of PS in the different regions/countries suggested. This global view provides a context for our understanding of the different recycling strategies to address the environmental problem of PS waste.[9] In the next sections, we will describe five ways to recycle PS, each unique in turning waste into products. The methods are Polystyrene into plywood, Polystyrene extrusion method, Polystyrene in concrete and geopolymer materials, Polystyrene depolymerisation and oxidative degradation, Polystyrene in paint formulation.[10]

2.1 Polystyrene into plywood

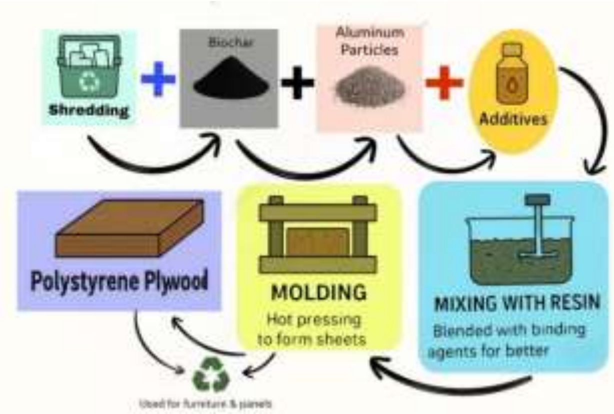


Figure 1 : Polystyrene into plywood process

The creation of sustainable composites has been driven by concerns about plastic pollution and deforestation.[11] Polystyrene-bound wood composites (PBWCs) combine waste Expanded Polystyrene (EPS) with lignocellulosic fillers to create a composite material that diverts waste from landfills and decreases reliance on virgin plywood and medium-density fibreboard (MDF).[12-13] By recycling EPS within a closed-loop economy framework, these products reduce both environmental burdens associated with the disposal of wood waste (such as sawdust, wood shavings, and agricultural waste) and support a closed-loop economy for plastic.[14-15] Because PBWCs use bio-based fillers that can be sourced from rice husk, bamboo, and coconut shell, they provide a sustainable alternative to plywood and MDF for use in the construction, furniture, and automotive industries.[16,19] Analyses of life-cycle data demonstrate that PBWCs have a lower carbon footprint than competitive products and through an optimisation of the EPS-to-filler ratio, PBWCs have improved physical characteristics (mechanical and dimensional stability). [14-15] The method for creating EPS binders involves the use of solvent-based processes (acetone, toluene, gasoline, or bio-based d-limonene) to reduce the weight of the EPS (to ~40% of the binder weight).[20-22] The filler materials are then added to the binder and, after being machined into boards, may be subjected to optional heat treatment. By the use of compatibilisers, such as silane and maleic anhydride, the ability of PBWCs to adhere to one another is increased and their mechanical strength, processability, and shelf life are extended.

Rule of Mixtures (Elastic Modulus)

$$E_c = V_f E_f + V_m E_m$$

E_c → Modulus of the composite

Vf → Volume fraction of the fiber

Ef → Modulus of the fiber

Vm → Volume fraction of the matrix

Em → Modulus of the matrix

Kelly–Tyson Short Fiber Model

$$\boldsymbol{\sigma_{c} = \sigma_{m} (1 - V_{f}) + 2 \tau V_{f} (l/d)}$$

σc → Tensile strength of the composite
σm → Tensile strength of the matrix

Vf → Volume fraction of the fiber
τ → Interfacial shear stress between fiber and matrix
l → Fiber length
d → Fiber diameter
l/d → Aspect ratio of the fiber

Water Absorption

$$\mathbf{WA(\%) = (m_{wet} - m_{dry}) / m_{dry} \times 100}$$

mwet → Mass of the sample after water immersion
mdry → Mass of the dry sample
WA(%) → Percentage of water absorbed

Porosity

$$\Pi(\%) = (m_3 - m_1) / (m_3 - m_2) \times 100$$

m1 → Mass of dry sample
m2 → Mass of sample suspended in water
m3 → Mass of water-soaked sample
Π(%) → Porosity percentage

Evaporation Rate

$$\Delta E(\%) = (m_j - m_f) / m_f \times 100$$

mj → Initial mass before drying
mf → Final mass after drying
ΔE(%) → Percentage of mass lost due to evaporation

Flexural Properties

$$MOR = 3\ F\ L / (2\ b\ d^2)$$
$$MOE = L^3\ m / (4\ b\ d^3)$$

F → Applied load
L → Support span length
b → Width of the specimen
d → Thickness of the specimen

Table 1. Effect of Processing Parameters on PS-Based Composites

Parameter	Range	Observed Effect
Die Temperature	150–220 °C	Cell size ↑ 80–300 µm; density ↓ 0.45 → 0.22 g/cm³
Screw Speed	40–120 rpm	Viscosity ↓ 10–35%; cell size ↓ 200 → 90 µm
Blowing Agent	0.5–5 wt%	Expansion ratio ↑ 5× → 25×; porosity ↑ 20–70%
Cooling Rate	5–20 °C/s	Cell size ↓ 30–50%; dimensional stability ↑ 10–20%

2.2 Polystyrene in Concrete

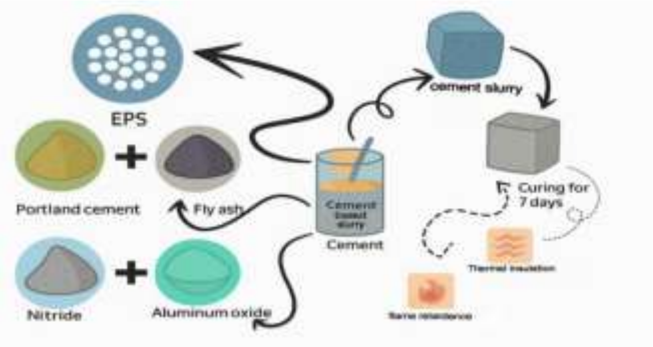


Figure 2 : Polystyerene Concrete Process

Expanded polystyrene (EPS), a non-biodegradable plastic with a reported half-life exceeding 650 years, has gained increasing attention for incorporation into concrete and geopolymer systems as a sustainable recycling pathway.[23-25] Using Expanded Polystyrene (EPS) reduces the density of concrete and reduces the thermal conductivity of concrete while enhancing the ability to handle and insulate concrete, but the mechanical strength of concrete generally decreases without making mix adjustments or adding bonding agents. In an experiment it was found that using 0% - 30% milled EPS within a concrete mixture containing a total of 1:1.59:3.14 ratio of materials and with a W/C ratio of 0.38 produced decreasing values of Slump (that is 14.55 mm to 3.80 mm) and Compressive Strength (i.e. 20.25 Mpa to 6.89 Mpa), with optimal performance seen at between 5% to 10% addition of EPS as the Flexural Strength, and Tensile Strength were maintained. However, the peak in Split Tensile Strength (2.28 Mpa) was observed at the 10% of added EPS.[26] Water absorption (1.11% - 2.56%) remained within an acceptable range with a minimum value being seen at the 20% level of EPS used. The results of this study indicate that lower amounts of EPS in a mixture will provide a more balanced mix in relation to the weight, while higher levels of EPS will provide better thermal insulation properties, and no structural integrity, when compared to conventional concrete. In addition to producing conventional concrete, EPS can be chemically changed or depolymerised creating geopolymers or light weight aggregate which assist with resource conservation and a lower carbon footprint when produced in accordance with Circular Economy practices.[27]

Linear regression equation describing the effect of EPS dosage (%) on compressive strength (MPa)

$y = -0.4476x + 19.543 (R2 = 0.9861)$

y = compressive strength (MPa)

x = EPS dosage (%)

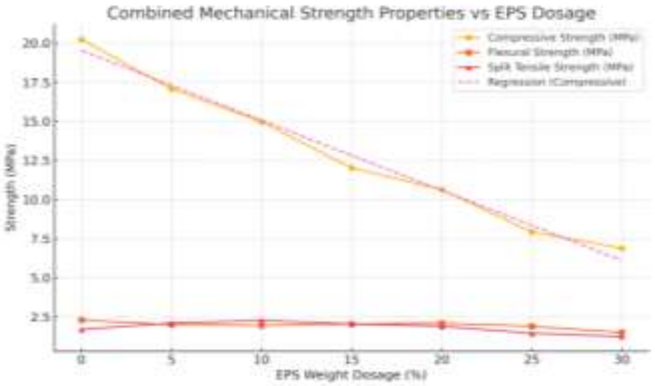


Figure 3. Effect of EPS Weight Dosage on Compressive, Flexural, and Split Tensile Strengths of Concrete.

The combined strength profile supports that increasing amounts of EPS correspond to decrease in the compressive strength as depicted by the decreasing trendline and positive relationship between the two variables shown on the combined strength profile via regression analysis. The strength properties flexural and split-tensile both show slight improvements at low EPS contents (5-10%); however, as the amount of EPS increases beyond 5% and decreases the overall matrix rigidity and the interlock of aggregations, the flexural and split-tensile strengths will also decrease as described above. Therefore, the overall conclusion is that there are compact benefits associated with the tensile strength of EPS at low levels of replacement. However, the mechanical characteristics of the composite were negatively impacted by the increase in porosity due to a reduction of structural density resulting in greater amounts of EPS.[27]

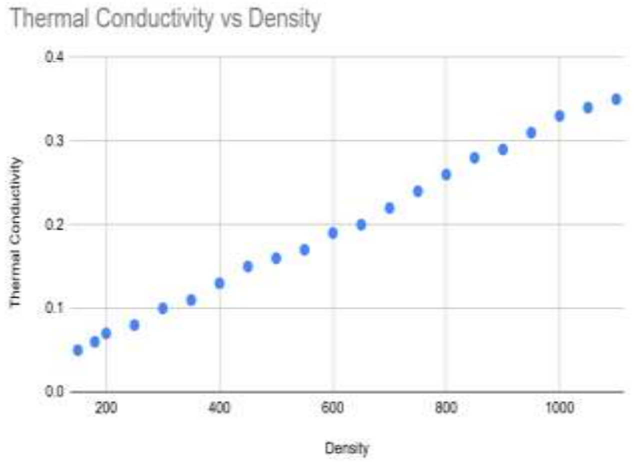


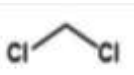
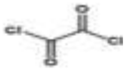
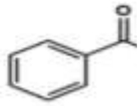
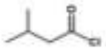
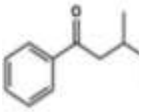
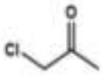
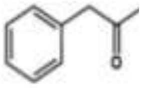
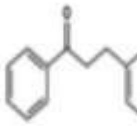
Figure 4. Variation of Thermal Conductivity with Increasing Material Density.

Thermal conductivity increases with increasing density in a near-linear fashion from about 0.05 W/m·°C at a density of 150 kg/m³ up to about 0.35 W/m·°C when the density is 1,100 kg/m³. The results reflect the expected results of using EPS in concrete. With increasing use of EPS by reducing the density of the concrete or creating more voids within it, they will provide a better (higher) thermal insulation rating but will conduct less heat (lower thermal conductivity).[26]

2.3 Polystyrene Depolymerisation

Polystyrene (PS), has expedited the search for practical and sustainable recycling options. Traditional recycling (or mechanical recycling) is limited in scope, as it depends on reuse and the cycling of the material, while retaining some limited material qualities, due to many plastics being contaminated or too degraded. In the case of polystyrene, structural integrity is usually lost through constantly being subjected to mechanical processing. This has led to an increased interest in the chemical recycling methods, and depolymerization, which can directly reduce PS waste into its original monomeric forms, such as styrene. Recovering monomers advances not only recycling performance, quality, and efficacy, but it also enhances the prospects for a circular economy through less dependence on virgin raw materials or fossil fuels.[34]

TABLE 2 : DEPOLYMERISATION PRODUCTS

Additives (Structure)	**Reaction Conditions (°C)**	**Product (Structure)**	**Yield (%)**	**Applications**	**Reference**
	25		83	Fragrance, pharmaceutical	28
	25		84	Cosmetic, pharmaceutical	29
	25		89	Cosmetic, pharmaceutical	30
	25		96	Synthetic intermediates	31
	80		52	Amphetamines precursor	32
	80		98	Artificial sweeteners precursor	33

Depolymerization methods are one such option to recycle PS waste - depolymerization methods can break the polymer chains down into useful smaller monomers. Depolymerization offers higher quality recycling as chemical recycling performs better than mechanical recycling. Consequently, depolymerization has the potential to create pure monomer solutions from polystyrene which can be re-polymerized into new products with the same quality of virgin materials. This is crucial to working towards a world with a more viable and sustainable model for the management of plastics waste.

2.4 Paint Formulation from Waste Polystyrene:

Figure 5: POLYSTYERENE PAINT FORMULATION PROCESSES

Polystyrene (PS) in expanded polystyrene (EPS) causes persistent pollution, yet recent work shows waste EPS can be converted into useful coating materials because of its good adhesion, low water absorption, and film-forming behaviour.[35] Emulsion paints from EPS (dissolved in D-limonene or methyl acetate) give good hardness and water resistance but limited weather durability.[35] Solvent-based EPS coatings (xylene, toluene, methyl acetate) offer higher hardness, abrasion resistance, and improved adhesion.36 Thermo-catalytic processing yields solvent fractions (50 g feed → 47–51 mL for thermocol; 39–43 mL for acrylic), and bio-based solvents like carrot, olive, pine, and rose oils provide safer alternatives to aromatic solvents, supporting greener PS-based paint systems.[37]

Volume reduction percentage calculation for EPS during vapor-phase treatment

Volume Reduction $\% = (IV - FV)/IV \times 100$

- Using the reported values $IV = 6250mL$ and $FV = 310mL$:
- Volume removed = $6250 - 310 = 5940mL$
- Fraction removed = $(5940/6250 = 0.9504)$
- Volume reduction ≈ **95%** the vapor-phase step collapses ~95% of EPS bulk, easing handling and preparing feedstock for catalytic conversion.

Table 3: Influence of catalysts on liquid recovery and residue formation from polymer feedstocks

Raw Material	Catalyst	Liquid (mL)	Residue (g)	Reference
Thermocol	Silica–Alumina	50–51	3–4	35
Thermocol	$BaCO_3$	48–50	3–6	35
Thermocol	$CaCO_3$	47–48	6	35
Acrylic	Silica–Alumina	43	11–12	35
Acrylic	$BaCO_3$	40–41	12–14	35
Acrylic	$CaCO_3$	39	13–15	35

Enhancement of PS by Grafting and Polar Modification

In polymer science, grafting and polar modification are being used more frequently to modify properties while capitalizing on base polymer benefits. Grafting results in the attachment of polymer side chains to backbones, permitting the compatibility of chemically different components, and boosting performance in biocompatible materials/frankly immiscible mixtures/thermoplastic elastomers for application in medical devices articles. Functional groups are introduced by polar modification to change the wettability and compatibility as well as adsorption. In combination, these methods open up new possibilities for novel materials with specific properties.There are many ways to demonstrate efforts of successful grafting and polar modification and each strategy has advantages and disadvantages.

One-Pot Radical Grafting of Polystyrene with Aliphatic Polyester:

Simple one-pot method to make styrene grafted with poly(β-propiolactone) chains by polymerizing styrene and β-propiolactone at 120 °C.[38] Styrene polymerized faster, creating sites on the backbone for β-PL chains to attach. Successful grafting was confirmed by NMR, GPC, and hydrolysis. The copolymers displayed distinct phase behavior, including two glass transition temperatures (–18°C and ~103°C) and a melting point for poly(β-PL). The materials can be used for specialized applications thanks to this simple method that eliminates the need for multiple steps and gives control over thermal properties.

Grafted polybutadiene chains in functionalized SIS copolymers:

Reactive polybutadiene chains to graft long polybutadiene (PB) chains and create epoxide-functionalized SIS triblock copolymers. With PB grafts increasing the soft diene part's flexibility and epoxidation raising the surface polarity, the procedure enhanced both polarity and flexibility.[39] These materials are useful as thermoplastic elastomers with tunable flexibility and surface properties.

Polar-modified polystyrene adsorbent for removing polar contaminants like salicylic acid:

The material was made by crosslinking and amination of a glycidyl methacrylate–DVB copolymer, introducing polar amide and hydroxyl groups that enhanced surface polarity. This increased affinity for polar molecules, allowing over 90% of salicylic acid to be removed in under an hour**.** The adsorbent also showed good reusability, making it promising for practical water purification applications.[40] Electron-beam irradiation of PVDF generates radicals on the polymer backbone, enabling styrene grafting to form PVDF-g-PS copolymers with enhanced dielectric properties. Grafted films show a dielectric constant up to ~90 at 100 Hz with minimal loss, reduced crystallinity, improved interfacial polarization, higher breakdown strength, and increased surface hydrophobicity. Process optimization is key to maximizing grafting efficiency and electrical performance. These findings highlight the potential of PVDF-g-PS copolymers for energy storage and high-performance capacitor applications.[41]

3.1 Gaps and future research directions

The studies presented here display incredible progress in grafting and polar modification, but there few areas that should be further explored to be able to completely exploit these techniques:

Controlling Grafting Heterogeneity and Distribution:

There are a few examples in the literature which suggest a greater number of grafted points will be possible when initially adding a higher monomer feed ratio, but spatial distribution and uniformity of grafts along the backbone of the network are critical to ensure uniform properties of the material. More sophisticated techniques will be necessary to effectively map and control the placement of grafts in 2-d and/or 3-d space at the nanoscale, especially for bulk grafting techniques.[43]

Long Term Stability and Durability of Modified Properties: For applications which are utilising some form of adsorption or dielectrics, there will be a thorough review to quantify the long-term stability of any introduced polar groups, and/or grafted chains in a variety of environmental conditions. This includes various pH environments, temperature changes, and mechanical stresses. The degradation (razor based or other possible mechanisms) of grafted materials over time (potentially many years) does not seem to receive much coverage.[44]

Scalability and Economic Viability: Several of the new grafting technologies, including electron beam radiation to induce grafting or some specific multi-step chemical reactions, may not scale up for industrial use at acceptable cost. It would be beneficial to investigate other green and more economically viable initiation processes, or solvent systems, that are appropriate for large-scale synthesis.[45]

Predictive Modelling of Structure-Property Relationships:

Challenges such as homopolymer formation, steric hindrance, and backbone changes reduce grafting efficiency and purity. Controlling these issues can minimize side reactions and improve structural stability.[46]

3.2 CHALLENGES IN COMMERCIALIZATION

TABLE 4 : CHALLENGES IN COMMERCIALIZATION OF EXPANDED POLYSTYRENE

Property	Value	Challenge	Reference
Density	10–35 kg/m³	Bulky and costly to transport & store	[65]
Melting Point	210–249 °C	High energy demand in recycling	[65]
Water Solubility	Insoluble	Persists in environment and hard to degrade	[65]
Solubility in Solvents	Soluble in non-polar solvents	Requires hazardous solvents in recycling	[65]
Thermal Conductivity	0.033 W/m·K	Resists thermal breakdown and slow processing	[65]
Specific Heat	1.3 kJ/kg·K	More heat needed during processing	[65]
Decomposition	Years to decay	Non-biodegradable and microplastic formation	[65]
Water Absorption	0.03–0.1 (ASTM)	Hydrophobic and environmental persistence	[65]

A major barrier to commercializing PS recycling technologies in high variability in the chemical makeup of PS waste . Expanded and foamed PS products often contain additives such a flame retardants , stabilizers, and colorants the remain locked with the material throughout its life cycle[42]. When this mixed waste enters recycling streams, these additives interfere with melting and reprocessing, causing instability and unpredictable behaviour during manufacturing. For industries that rely on consistent material performance, this chemical variability increases purification costs and makes companies hesitant to adopt recycled PS for high value products.

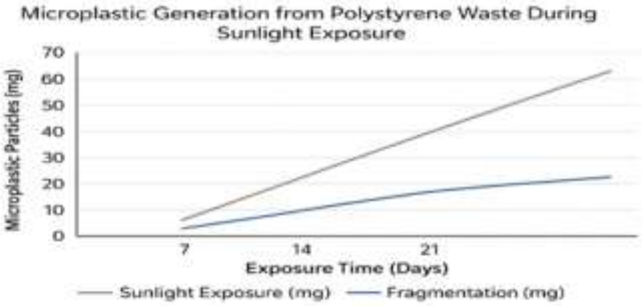


Figure 6:SUNLIGHT INDUCED MICROPLASTIC FORMATION

Another challenge stems from fragile physical structure of expanded polystyrene (EPS) EPS tents to crumble into micro and nanosized fragments when exposed to sunlight, heat , or mechanical stress [43]. Once fragmented, the materials becomes extremely lightweight and difficult to handle, raising transportation costs and recycling technologies difficult and limit progress toward economically sustainable solution.These tiny particles disperse easily in air, soil and water, which leads to contamination and increase the effort requirement to prepare the waste for recycling.

Commercial progress is further slowed by the low recover rate of PS worldwide.

Because PS is light, bulky, and easily contaminated, it is often neglected in household waste sorting. As a result, only a very small fraction is collected and recycled compared with other polymers [44]. This irregular and insufficient supply of clean ps waste make it difficult for industries to operate recycling plants at stable, economically viable capacities.

Regulatory requirements also create major hurdles, particularly for food contact application

. Research has shown that styrene monomers and oligomers can migrate from PS packaging into food under certain storage conditions [48]. Similar behaviour has been reported for styrene oligomers [49] and for nanocomposite-based PS packaging systems [50]. Because of these findings, recycled PS must undergo extensive testing and compliance checks before it can be approved for food packaging. This adds time, cost, and uncertainty to commercial development.

Another significant limitation is need for specialized multilayer barrier system. Studies indicate that the recycled PS cannot be safely used for food packing without protective functional layer to prevent chemical migration [46]. Producing these multilayer materials requires advanced equipment and strict quality control, which increases initial investment and slow industrial adoption

Finally, commercialization is hindered by poor segregation of PS waste at the household level. In many places, PS is mixed with food residues, liquids, and general trash due to weak waste-sorting practices [51]. Such contamination requires additional washing, drying, and sorting before recycling can begin, raising operational costs and reducing the quality of recovered material.

Together, these challenges chemical variability, physical fragility, low recovery rates, regulatory constraints, specialized processing needs, and contamination issues make large-scale commercialization of PS recycling technologies difficult and limit progress toward economically sustainable

3.3: COST ECONOMICS AND ENVIRONMENTAL ASSESMENT

TABLE 5:COMPARISON OF POLYSTYRENE RECYCLING PATHWAYS

Application	Data	Commercial Meaning	**Refernce**
Chemical Depolymerization	80 - 90% styrene yield	High monomer recovery and strong economic value	[61]
Gypsum PS Composite Boards	15 - 20% lower thermal conductivity	Better insulation and high demand in construction markets	[54]
Low VOC PS Paints	Up to 40% reduction in VOC emissions	Meets environmental regulations and high commercialization potential	[57]
PS Concrete Aggregates	Density reduced from 2400 kg/m³ - 1200-1400 kg/m³	Lightweight concrete and cost effective non-structural products	[58-60]
Water Absorption	0.03–0.1 (ASTM)	Hydrophobic and environmental persistence	

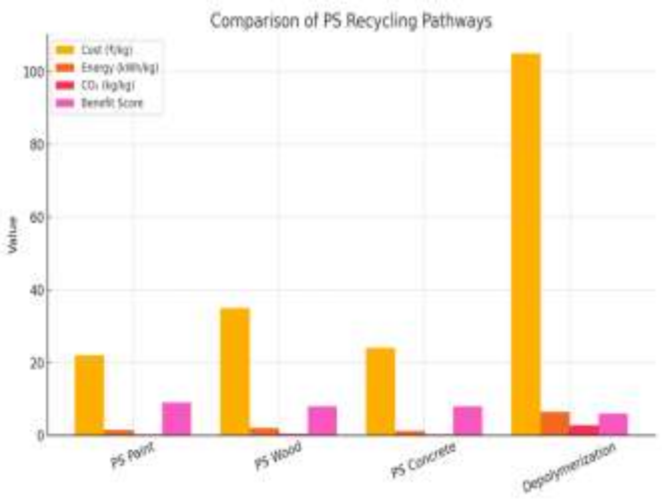


Figure 7 : COMPARATIVE ANALYSIS OF PS RECYCLING

The economic and environmental performance of polystyrene recycling depends on how well each method converts waste into useful materials and how suitable the recycled products are for different applications.Among the available options, the most relevant pathways are the production of PS based paints, PS wood composites, PS lightweight concrete and chemical depolymerization.

Chemical recycling remains the most expensive route. Xu and Sun [52] explain that these processes need strict control of temperature, specialised catalysts and advanced reaction systems. These requirements raise both the initial investment and the daily operating cost.This makes chemical recycling difficult to adopt in regions that do not have strong industrial infrastructure. Even with these challenges, the products obtained from chemical conversion are of high value and support a circular use of resources by turning waste back into usable chemicals.On the other hand, paints made with recycled PS are one of the most affordable options. Paints that use waste expanded PS along with agricultural fillers reduce the amount of new binder needed during production, which lowers the cost considerably [56]. These paints also emit fewer volatile organic compounds, giving them better environmental performance and allowing them to meet modern green building requirements [57]. Because of their low cost and simple manufacturing steps, PS based paints are considered one of the most practical uses of PS waste.

A similar cost advantage is seen in PS lightweight concrete. When PS beads replace natural aggregates, the density of concrete drops from the usual value of around 2400 kilogram per cubic metre to nearly half of that amount. This reduction in weight decreases transportation expenses and lowers handling effort at construction sites[58]. Studies show that this type of concrete works well for non structural parts of buildings, including internal walls and prefabricated units [60]. Although additives may be needed to improve strength, the overall savings gained from lighter raw materials usually outweigh this requirement.

Depolymerization is a method that produces high quality chemicals, but it is the most energy demanding pathway. Catalytic systems used by Kumar and colleagues have shown high recovery of styrene, often between eighty and ninety percent [61]. However, the process requires high temperatures, careful catalyst regeneration and clean feedstock.Pyrolysis units also operate at temperatures between four hundred and fifty and six hundred degrees Celsius, which further increases energy use [62]. This makes the method attractive from a resource recovery point of view but harder to justify economically unless renewable energy is available.

Environmental assessments show clear differences among the four pathways. PS based paints and PS concrete have low emissions and generate very few hazardous by products. They also divert large amounts of PS waste away from landfills.Their environmental burden mainly comes from the processing of fillers and the curing of the product. In contrast, chemical recycling needs much more energy and therefore has a larger carbon footprint when powered by fossil fuels. However, recent catalytic advances have improved conversion efficiency and reduced the amount of unwanted by products formed during chemical recovery of PS [64].

Conclusion

To sum everything up, waste polystyrene recycling is a feasible strategy to tackle one of the biggest environmental issues of our time polystyrene pollution. Polystyrene accumulates rapidly in landfills and oceans, and is a non-biodegradable material, potentially leaving permanent damage to the environment. Converting waste polystyrene to useful products, especially paint, can reduce the potential environmental impact and result in useful products that can be sold on the market. The conversion of waste polystyrene into paint not only supports a sustainable agenda but has advantages compared to traditional paints. By using inventive recycling technologies such as using waste polystyrene as the binder compound, and incorporating environment friendly additives (for example, D-limonene) the outcome can be paints that have good adhesion, opacity, waterproofing, and more. In addition, the use of grafting to change the polarity of polystyrene holds significant promise to allow the recycled polystyrene to have better compatibility with waterborne paints, and lessen the use of toxic solvents and ultimately improve the paint performance and durability as well. These scientific advancements in polymer chemistry and materials sciences inform waste polystyrene's opportunity to be developed into high-performance coatings, an alternate solution that provides a step towards environmental sustainability and economic opportunity. The innovative paint to be developed potentially offers a unique way to create an essential product from waste material, making polystyrene recycling appealing for future industrial use. Further, scientific investigation into grafting and other modifying methods will unlock the potential of recycled polystyrene for a sustainable use that allows for waste elimination and high-quality paint production.

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