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# Environmental and economic assessment of the reuse of expanded polystyrene (EPS) waste as an aggregate substitute in cement mortar

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**Abstract** This study investigates the feasibility of using expanded polystyrene (EPS) waste collected in coastal areas as a partial substitute for sand in cement mortars, without the need for pre-treatment. Two scenarios were evaluated: (i) direct collection from polluted coastlines and (ii) recovery from existing recycling stations. The environmental assessment was carried out through a life cycle assessment (LCA), while the economic performance was assessed through a life cycle costing (LCC). The results showed that second scenario had approximately 30 % lower environmental impact and significantly lower costs, mainly due to the elimination of the collection phase. Compared to sand, EPS had lower emissions per cubic meter due to its low density. The results confirm that the direct reuse of EPS waste from the coastal areas without pre-treatment is a technically feasible and economically viable solution for non-structural applications. This approach contributes to the reduction of plastic waste and supports the transition to a circular economy in the construction sector.

**Keywords: Marine plastic pollution, EPS waste reuse, sustainable materials, LCA, circular economy.**

## 1. Introduction

Plastic pollution in the oceans is one of the biggest environmental problems of our time, with far-reaching consequences for ecosystems, human health and water quality. One of the main types of plastic waste in the ocean is expanded polystyrene (EPS), a lightweight, non-biodegradable thermoplastic commonly used for packaging, insulation and building materials. Due to its buoyant nature, EPS accumulates in coastal areas and often turns up in marine litter. The main sources of EPS in the sea include inadequate waste disposal, lost fishing gear and urban stormwater runoff (Râpă et al., 2024). EPS is extremely persistent in the environment and takes decades to naturally degrade. During this time, it breaks down into micro- and nanoparticles that can enter the food chain. Although recycling technologies for EPS are being developed worldwide, most of the EPS waste collected from coastal areas remains unused due to surface degradation and contamination (Mumbach et al., 2020). Most industrial applications require clean, homogeneous raw materials, making degraded marine EPS unsuitable. It is therefore often landfilled or stockpiled and is still considered waste even after collection. At the same time, the construction industry is under increasing pressure due to the growing demand for natural sand. With an estimated extraction of over 40 billion tons per year, it is currently the world's most consumed mineral raw material (Bisht, 2021). Sand extraction from riverbeds, floodplains and coastal zones is causing widespread ecological damage such as habitat destruction, biodiversity loss and water pollution (Leal Filho et al., 2021). Even crushed sand from quarries is associated with high carbon emissions (Mishra et al., 2023). This investigation proposes a different approach: the direct use of untreated EPS waste collected in coastal areas as a partial substitute for sand in cement mortar. By avoiding energy-intensive processing, this method aims to reduce the environmental footprint and promote the circular use of degraded materials.

## 2. Materials & Methods

LCA combined with LCC, was applied to evaluate the environmental and economic performance of using EPS waste as a partial substitute for sand in cement mortar. Two scenarios were assessed: direct collection of EPS from polluted coastal areas (Scenario A) and recovery from recycling stations (Scenario B). The LCA was carried out using GaBi software according to the EF 3.1 methodology. A cut-off approach was used in which the environmental impacts of the original EPS production was excluded, as the material was considered as post-consumer waste. The system boundaries included the collection, transportation, processing and incorporation of EPS into mortar. The input data was based on experimental measurements and literature. Emissions were calculated using the Greek electricity mix for 2020. Scenario A included collection at sea and road transportation to a processing plant. Scenario B assumed direct delivery to the plant, eliminating collection and reducing the impact of transportation. The LCA was extended to compare EPS with natural and artificial sand, using production data from either China or Europe (France). Two types of sand were assessed: river-derived sand and crushed sand. Comparisons were made in both kg and m³, considering the much lower density of EPS and the fact that the sand was replaced volumetrically rather than by weight. The data for the sand was taken from international databases and adjusted to the same energy context. In the LCC analysis, costs were captured at each stage, including labour, fuel, maintenance, depreciation and rent. The processing and end-use phases (packaging, storage) were highlighted. Overall, the combined LCA and LCC approach provided a comprehensive assessment of environmental and economic performance and demonstrated that the reuse of untreated marine EPS can be an environmentally and economically viable alternative to sand in non-structural building applications.

## 3. Results

The life cycle assessment (LCA) revealed clear differences between the two scenarios for the use of expanded polystyrene (EPS), as shown in figure 1. In scenario A, the total $CO_2$ emissions reached 0.161 kg $CO_{2eq}$/kg, with the largest share attributable to the processing stages and material transportation. In contrast, the total emissions in scenario B— - in which EPS is already collected at the recycling points— - fell to 0.12 kg $CO_{2eq}$/kg, which is mainly since collection is no longer necessary, and transportation routes are shortened.

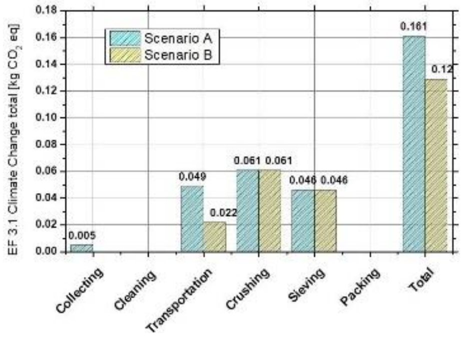


**Figure 1** Climate change impact of Scenarios in kg $CO_{2eqv}$.

The comparison between EPS and sand becomes clearer in figure 2, which shows the $CO_{2eqv}$ emissions per cubic meter ($m^3$) of material. Due to the extremely low density of EPS (~ 20 kg/$m^3$), the emissions per $m^3$ were significantly lower: only 4.03 kg $CO_{2eqv}/m^3$ for EPS, compared to 65.74–83.16 kg $CO_{2eqv}/m^3$ for manufactured and natural sand from China and France. As the replacement of sand in the mortar was done on a volumetric basis, these results confirm the environmental benefit of EPS in the proposed application.

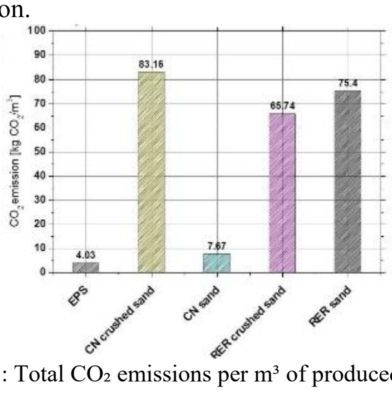


**Figure 2**: Total $CO_2$ emissions per $m^3$ of produced material.

In terms of costs (LCC), figure 3 shows that in Scenario A, more than 50 % of the total cost per kg of EPS is related to shoreline collection. Other important costs are fuel, transportation and maintenance of the ships. Other cost categories (e.g. consumables, handling) contribute less. In contrast, the economic footprint in Scenario B — where collection costs are eliminated — was significantly lower and focused on the processing and packaging phases.

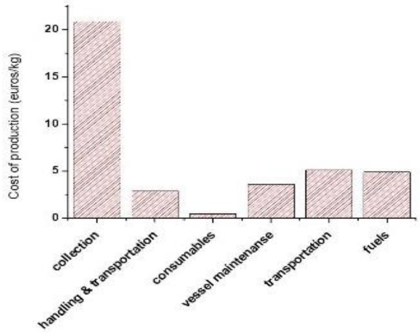


**Figure 3**: Cost of activities for producing 1kg of EPS

## Conclusions

This study demonstrates the potential of using coastal EPS waste as a substitute for sand in cement mortar without the need for pre-treatment. The environmental and economic performance strongly depends on the collection model. Scenario B, where EPS was collected from recycling stations, showed significantly lower emissions and costs compared to Scenario A. Furthermore, when analysed on a volumetric basis, EPS performed better than sand in environmental terms. The results confirm that the direct reuse of coastal EPS is a realistic and sustainable solution for non-structural applications, contributing to the reduction of plastic waste and the promotion of circular economy principles in the construction sector.

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