FACTSHEET

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EPS in Protective Packaging

Lifecycle Performance in Real-World Logistics Applications

Based on: TNO (2025), Environmental Comparison of Protective Packaging Materials

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Introduction

Protective packaging is often discussed in terms of its material identity — recyclable, compostable, fossil-based, or bio-derived. Yet in distribution systems where the environmental cost of product loss is high, performance must be evaluated in terms of what the packaging achieves. The functional role of packaging, particularly its ability to prevent damage during transport, can significantly outweigh material characteristics in determining its environmental profile.

In 2025, the Netherlands Organisation for Applied Scientific Research (TNO) performed a comparative lifecycle assessment of protective packaging materials used in European logistics. The study assessed the climate impact of four packaging types — expanded polystyrene (EPS), expanded polypropylene (EPP), corrugated paperboard, and moulded pulp[1] — in two applications: televisions and washing machines. Each scenario measured greenhouse gas emissions per undamaged product delivered, including contributions from packaging production, transport energy use, and damage-related product loss.

In a sensitivity analysis, TNO explores the impact of damage rates and finds that even marginal increases in damage rates, "*as minor as 0.06 or 0.07 in the damage rate,*"[2] for TVs and for Washing Machines, "*a change of just 0.34 in the damage rate*" impacts the overall conclusion. These findings illustrate that the exclusion of damage rates from packaging LCA's can be a critical flaw in the environmental impact because different materials typically have different protective properties.

Interpretation

The TNO 2025 study supports a system-level interpretation of packaging performance. Materials with low emissions embedded in the packaging do not necessarily result in a low overall impact if they increase transport emissions or lead to higher product damage. Conversely, EPS — despite being fossil-based — performs well when measured by outcome rather than composition. Its low weight, structural resilience, and recyclability in controlled systems contribute to its strong lifecycle performance across both applications studied.

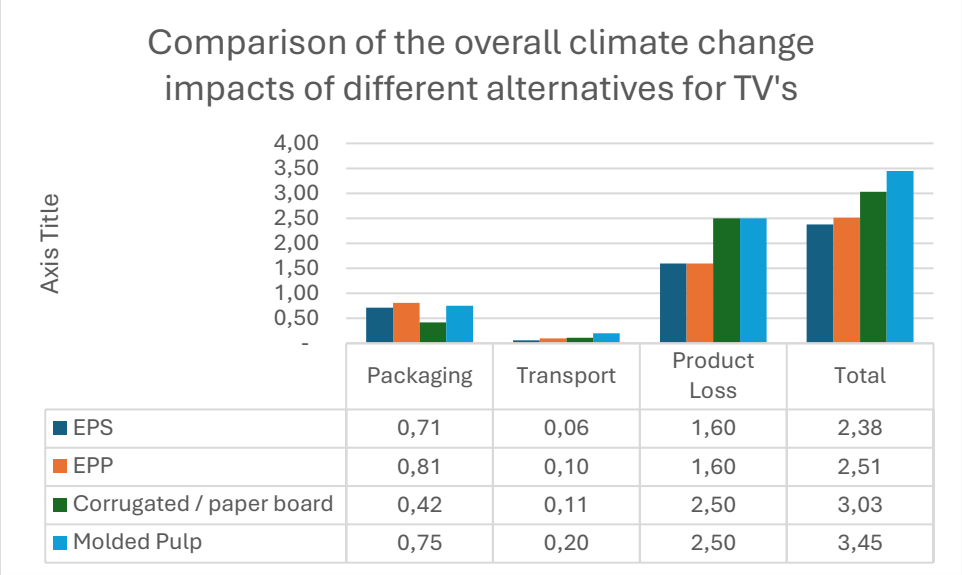
This is not a generalised claim about sustainability. Rather, it is a context-specific conclusion: where protective performance and intact delivery are critical to minimising lifecycle impact, EPS outperforms the tested alternatives in both modelled systems. The relative advantage of EPS against alternative materials increases with the weight of the good that needs protection.

[1] Moulded pulp was excluded from the Washing Machine scenarios, as the material was not able to provide the necessary protection.
[2] TNO. Environmental Comparison of Protective Packaging Materials. Delft: Netherlands Organisation for Applied Scientific Research (TNO), 2025.

Results: Television Scenario

For televisions, all four packaging formats were evaluated. EPS produced the lowest total overall climate impact per delivered unit. While moulded pulp had the lowest packaging emissions, its higher mass and bulk resulted in greater transport emissions. Its higher estimated damage rate also increased the share of product loss in the overall footprint.

The climate impact values per television were as follows:

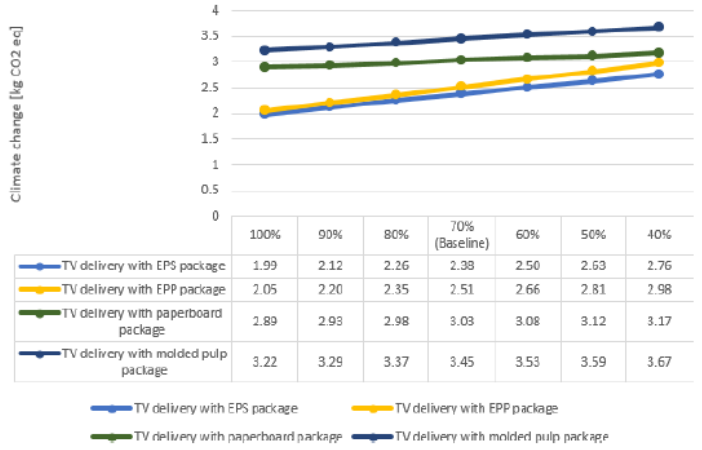


	Packaging	Transport	Product Loss	Total
EPS	0,71	0,06	1,60	2,38
EPP	0,81	0,10	1,60	2,51
Corrugated / paper board	0,42	0,11	2,50	3,03
Molded Pulp	0,75	0,20	2,50	3,45

Figure: Comparison of the overall climate change impacts of different alternatives for TVs[3]

In the LCA, TNO assumed a 70% return rate as well as a 70% recycling rate. However, to evaluate the overall climate impact of the various return/recycling rates, a sensitivity analysis was conducted.

[3] Based on Figure 4.1 in TNO. Environmental Comparison of Protective Packaging Materials. Delft: Netherlands Organisation for Applied Scientific Research (TNO), 2025. P. 19. Totals do not match due to rounding. (Figure 4.1 covers TV and Washing Machines, for ease of reading the data has been split).



	100%	90%	80%	70% (Baseline)	60%	50%	40%
TV delivery with EPS package	1.99	2.12	2.26	2.38	2.50	2.63	2.76
TV delivery with EPP package	2.05	2.20	2.35	2.51	2.66	2.81	2.98
TV delivery with paperboard package	2.89	2.93	2.98	3.03	3.08	3.12	3.17
TV delivery with molded pulp package	3.22	3.29	3.37	3.45	3.53	3.59	3.67

Figure 5.5: The influence of the recycling and reuse return rates on the overall climate change impact of different alternatives for TV

Figure: The influence of the recycling and reuse return rates on the overall climate change impact of different alternatives for TVs.[4]

What is interesting here is that even with a current recycling rate of 40% for EPS[5] a switch to cardboard or moulded pulp with a 100% recycling rate will lead to an increase in Climate Impact.

Results: Washing Machine Scenario

EPS produced the lowest total climate impact in all three impact categories. Hence, it achieves the lowest overall climate impact of all materials, which, relatively speaking, is even better than in the TV case: for example, compared to corrogated paperboard, the use of EPS saves 20% of CO2 emissions over the full life cycle in case of TV packaging and 35% in case of washing machine packaging.

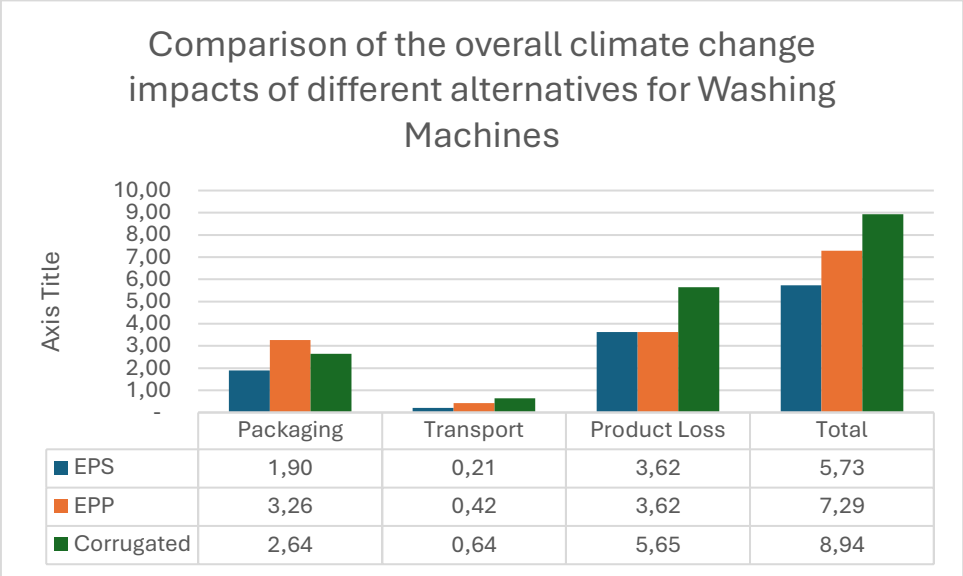
In this scenario, while corrugated board had a lower production and transport impact than that of EPP, the higher damage rate made cardboard have the highest overall climate impact. Again, illustrating the importance of including the damage to the transported materials when examining packaging materials. It is important to highlight that the reported damage rates for corrugated paperboard are conservative estimates. In real-world conditions, the protective performance of corrugated paperboard is often significantly lower, particularly in humid environments, where the material's structural integrity deteriorates rapidly. This has been substantiated by recent studies, including the Electrolux Case Study[6] on EPS packaging, which demonstrated a marked decline in the performance of paper-based packaging under such conditions.

[4] TNO. Environmental Comparison of Protective Packaging Materials. Delft: Netherlands Organisation for Applied Scientific Research (TNO), 2025. P. 31

[5] The EPS-industry's journey towards circularity, 2019, EUMEPS report. https://eumeps.eu/images/website/the-eps-industry-s-journey-towards-circularity-progress-report-final.pdf

[6] Electrolux Sustainability Initiative: https://epsa.org.au/wp-content/uploads/2024/03/Electrolux-Case-Study-On-EPS-Packaging.pdf

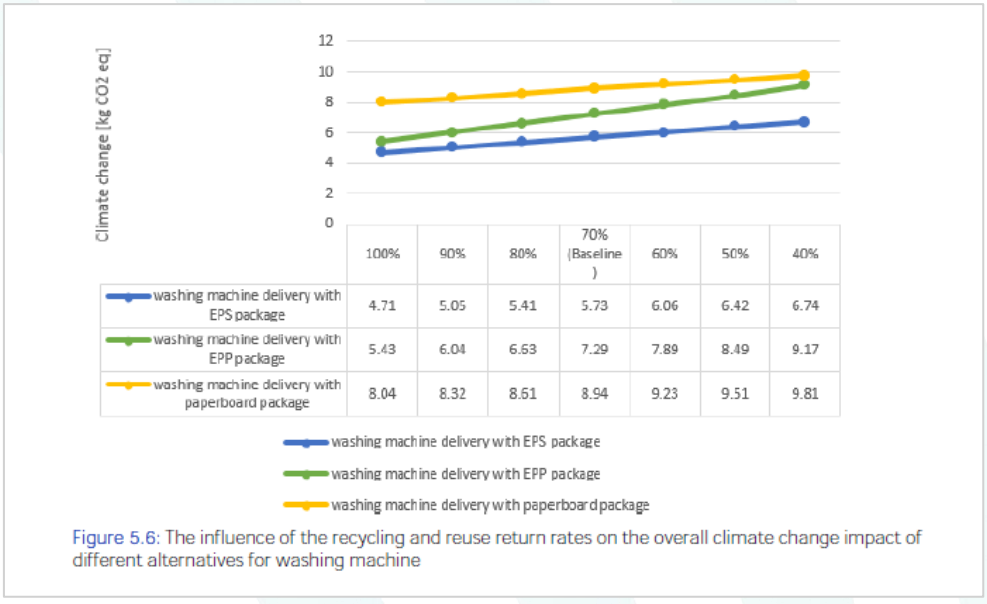
The climate impact values per washing machine were as follows:



	Packaging	Transport	Product Loss	Total
EPS	1,90	0,21	3,62	5,73
EPP	3,26	0,42	3,62	7,29
Corrugated	2,64	0,64	5,65	8,94

Comparison of the overall climate change impacts of different alternatives for Washing Machines.[7]

TNO also did a sensitivity analysis of the reuse/recycling rates for the various packaging solutions. Also, here the conclusion is clear that with a recycling rate of 40%[8] for EPS, a switch to cardboard with a 100% recycling rate will lead to an increase in Climate Impact.



	100%	90%	80%	70% (Baseline)	60%	50%	40%
washing machine delivery with EPS package	4.71	5.05	5.41	5.73	6.06	6.42	6.74
washing machine delivery with EPP package	5.43	6.04	6.63	7.29	7.89	8.49	9.17
washing machine delivery with paperboard package	8.04	8.32	8.61	8.94	9.23	9.51	9.81

Figure 5.6: The influence of the recycling and reuse return rates on the overall climate change impact of different alternatives for washing machine

[7] Based on Figure 4.1 in TNO. Environmental Comparison of Protective Packaging Materials. Delft: Netherlands Organisation for Applied Scientific Research (TNO), 2025. P. 19. Totals do not match due to rounding. (Figure 4.1 covers TV and Washing Machines, for ease of reading the data has been split).

[8] The EPS-industry's journey towards circularity, 2019, EUMEPS report. https://eumeps.eu/images/website/the-eps-industry-s-journey-towards-circularity-progress-report-final.pdf

The influence of the recycling and reuse return rates on the overall climate change impact of different alternatives for washing machine.[9]

Scope and Methodology

The study defines a functional unit as one product delivered intact. All emissions are calculated on a cradle-to-grave basis, incorporating packaging production, logistics emissions, and the climate cost of product replacement in the event of transport damage. This system-boundary approach reflects real delivery conditions more accurately than packaging-focused assessments alone.

The study compares four different packaging materials over multiple delivery cycles, which allows for the comparison of materials that are primarily reused vs. materials primarily recycled.

A central function of packaging is to protect the products that are being transported, and all packaging materials do not have the same cushioning properties. This can lead to different damage rates, which will influence the total environmental impact of the packaging choice.

The TNO study does not assume that damage rates are uniform. If they were to make that assumption, some materials would require substantially more packaging to meet the same cushioning properties, which again impacts the size of the transported box.

Instead, the damage rates were assessed based on operational input from a European manufacturer of white goods. The study applies a damage rate of 0.8 per cent to EPS and EPP and 1.25 per cent to moulded pulp and corrugated board. These values are used in both product systems to estimate the climate impact of damage-induced waste.

Source

TNO. *Environmental Comparison of Protective Packaging Materials*. Delft: Netherlands Organisation for Applied Scientific Research (TNO), 2025.

[9] TNO. Environmental Comparison of Protective Packaging Materials. Delft: Netherlands Organisation for Applied Scientific Research (TNO), 2025. P. 31