Comparative Life Cycle Assessment of Expanded Polystyrene (EPS), Honeycomb, and Molded Pulp Packaging

Introduction

Life Cycle Assessment (LCA) is a critical tool in evaluating the environmental performance of packaging materials. This paper examines the impacts of **Expanded Polystyrene (EPS)**, **Honeycomb**, and **Molded Pulp** packaging based on a recent study conducted using PIQET LCA software1. The results highlight the strengths and weaknesses of each material across multiple environmental indicators, providing a basis for more sustainable packaging decisions.

Overview of Life Cycle Analysis (LCA)

Life Cycle Analysis (LCA) is a methodology for assessing the environmental impacts associated with all stages of a product's life, from raw material extraction to end-of-life disposal. It follows four key phases:

1. **Goal and Scope Definition** – Defines the objective, system boundaries, and functional unit.
2. **Life Cycle Inventory (LCI)** – Collects data on energy and material inputs and outputs.
3. **Life Cycle Impact Assessment (LCIA)** – Evaluates environmental impacts based on categories such as climate change, water use, and energy demand.
4. **Interpretation** – Analyzes results to draw conclusions and support decision-making.

Project Details:

The goal of this project is to compare Atlas Molded Product's baseline material, molded expanded polystyrene (EPS), against two alternative materials. The scenarios to be assessed include EPS, honeycomb, and molded pulp packaging.

Methodology

The LCA follows a **cradle-to-grave** approach, covering raw material extraction, manufacturing, conversion, use, and end-of-life disposal. The functional unit is **1 cubic foot (ft^3)** of packaging material, and the study accounts for different disposal scenarios.

The assumed densities for each scenario are EPS: 1 lb/ft^3, Honeycomb 5.62 lbs/ft^3, and Molded Pulp: 43.75 lbs/ft^3.

All products were assumed to be manufactured in the same location with equivalent transportation distances to the customer.

System Boundaries

The analysis includes:

- **Raw material extraction:** Energy and resource inputs for material production.
- **Conversion:** Manufacturing processes.
- **End-of-life:** Landfilling for EPS and a mix of recycling and landfill for paper-based materials.
- **Country:** USA

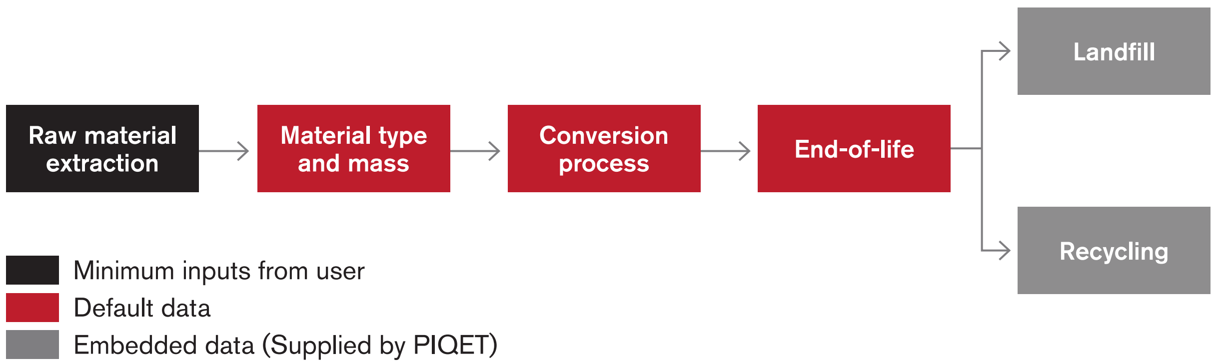

Figure 1: System boundary

End of Life Scenarios:

In Life Cycle Assessment (LCA), the end-of-life (EOL) scenarios evaluate the environmental impacts of how a product is managed after its use. Three common EOL scenarios are recycling, landfill, and waste-to-energy.

- Recycling reduces environmental burdens by diverting materials from disposal and reintroducing them into manufacturing, conserving resources and lowering emissions. Recycling often credits the LCA with avoided impacts from producing virgin materials.
- Landfilling is the most passive EOL option, where waste is buried.
- Waste-to-energy (WTE) involves incinerating waste to produce electricity or heat. It offsets fossil fuel use but releases greenhouse gases and other pollutants.

This study considered that the EOL scenario for EPS was landfilling. A recent independent study conducted by Resource Recycling Systems2 demonstrated that EPS transport packaging is recycled at a rate of 31% so the results from this LCA overstate the impacts as recycling was not considered. Honeycomb and Molded Pulp packaging were considered to be a mix of landfill and recycling using available data.

Impact Categories

The LCA considers key environmental impact categories:

Climate Change (kg CO_2-eq)
Measures climate change impacts from the emission and uptake of CO_2, CO, CH_4, and other GHGs.

Water Use (kL H_2O)
Total of all water used by the processes considered, except turbined water used in hydro generation of electricity.

Cumulative Energy Demand
Calculates total energy use, including fossil, renewable, nuclear, and feedstock energy.

Ozone Depletion
Measures stratospheric ozone depletion from emissions of CFCs, HCFCs, halons, and other ozone-depleting substances

Photochemical Ozone Formation
Measures the photochemical smog potential from sunlight driven reactions with atmospheric gases.

Acidification
Measures the decrease in pH levels of water bodies, which can be caused by human activities or natural processes resulting in forest decline and lake acidification.

Eutrophication (Marine)
Measures nutrient pollution in marine waters, primarily nitrogen-related, affecting coastal and estuarine ecosystems.

Summary of Results - Relative Comparison

The following table compares the relative results on selected indicators for the three materials, where the results are indexed relative to EPS, where EPS=1. Specific impact data is included in Table 2.

Table 1: Relative Life Cycle Impacts

Category	EPS	Honeycomb	Molded Pulp
Climate change kg CO2 eq	1.00	17.21 x EPS	19.42 x EPS
Water use volume kL H2O	1.00	364 x EPS	102 x EPS
Cumulative energy demand MJ LHV	1.00	25.51 x EPS	25.23 x EPS
Ozone Depletion kg CFC-11 eq	1.00	31.28 x EPS	33.33 x EPS
Acidification mol H^+ eq	1.00	27.33 x EPS	30.55 x EPS
Photochemical Ozone Formation kg NMVOC eq	1.00	23.75 x EPS	23.75 x EPS
Eutrophication (Marine) kg N eq	1.00	141.79 x EPS	42.91 x EPS

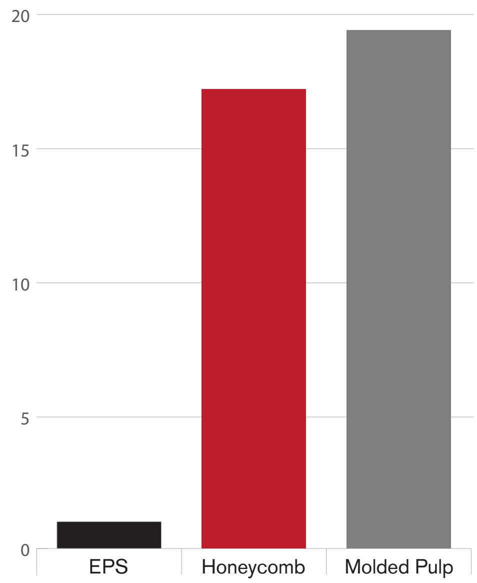

Figure 2: Climate Change comparison (EPS=1)

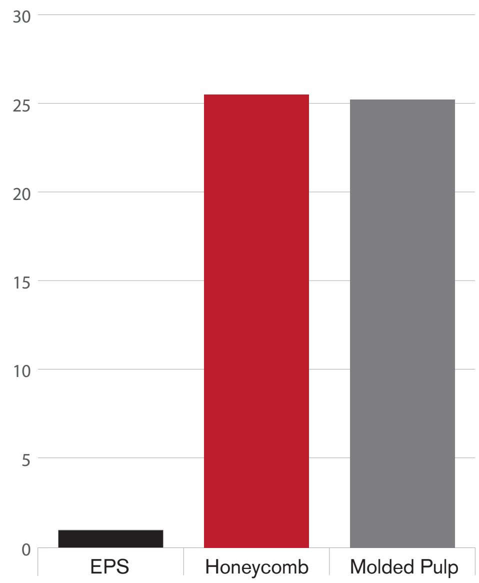

Figure 4: Cumulative Energy Demand comparison (EPS=1)

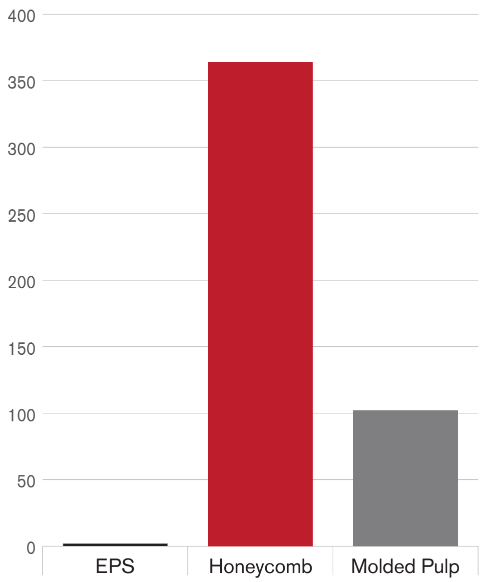

Figure 3: Water Use Volume comparison (EPS=1)

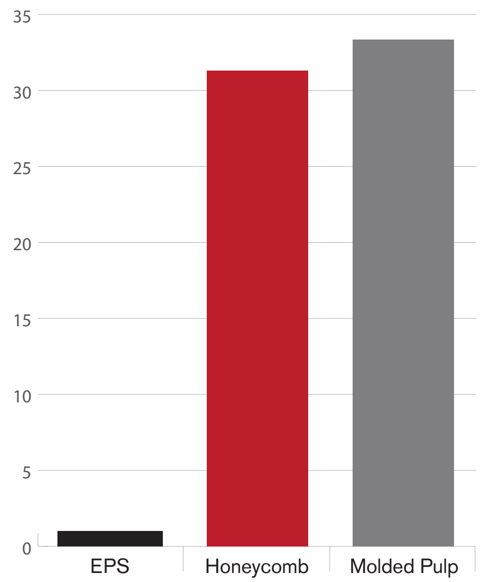

Figure 5: Ozone Depletion comparison (EPS=1)

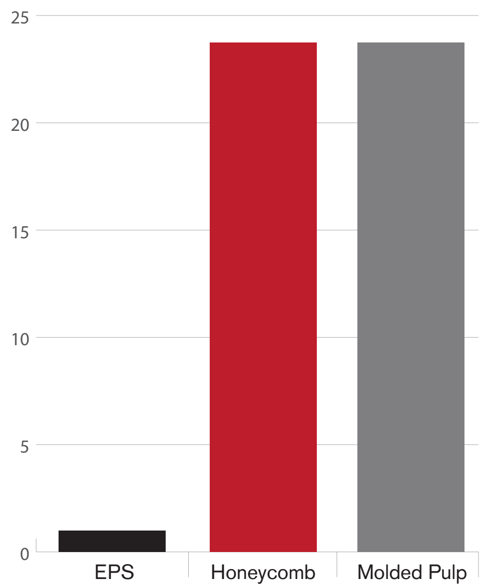

Figure 6: Acidification comparison (EPS=1)

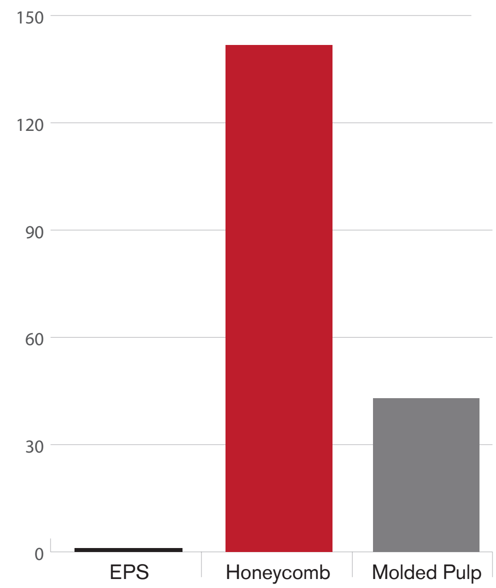

Figure 8: Eutrophication (Marine) comparison (EPS=1)

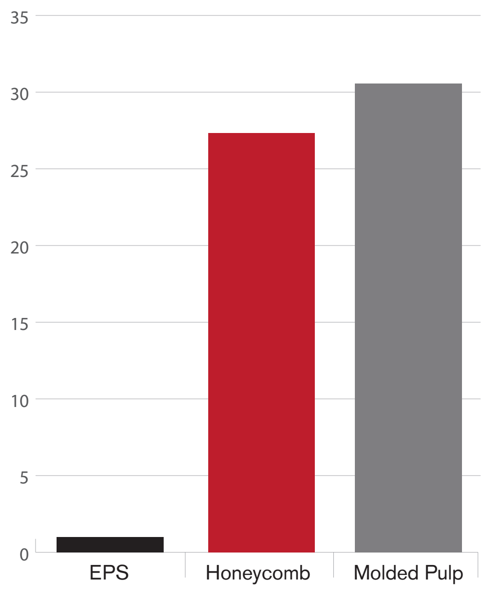

Figure 7: Photochemical Ozone Formation comparison (EPS=1)

Discussion and Implications

While **honeycomb and molded pulp are often perceived to be sustainable alternatives**, their **LCA results indicate substantial environmental trade-offs**. The assumption that paper-based materials are always the best choice must be reconsidered, especially when **water use, energy consumption, and eutrophication impacts** are factored in.

Limitations of the Study

- **Density Differences:** EPS, corrugated board, and molded pulp have different material densities, which should be accounted for when conducting follow up comparison of these products when different volumes are used.

Conclusion

This LCA comparison demonstrates that EPS consistently outperforms paper-based materials in key environmental categories, including carbon footprint, energy use, and water consumption. While recycling rates and disposal methods should be improved, the study challenges the perception that molded pulp and corrugated board are always the superior choice for sustainability.

Software

This study was conducted using the PIQET (Packaging Impact Quick Evaluation Tool) designed to address the environmental impact of packaging in line with the ISO 14040 series. Developed by LCA experts and backed by over 15 years of industry use, PIQET is trusted by leading global companies for confident internal decision-making and credible external reporting. PIQET is underpinned by the leading global LCI database, ecoinvent, which is highly regarded for its transparency and credibility. Learn more at www.piqet.com.

Summary of Results – Specific Material Impacts

The following table provides the specific impact for the selected indicators for the three materials.

Table 2: Life Cycle Impacts

Category	EPS	Honeycomb	Molded Pulp
Climate change kg CO_2 eq	2.4	41.6	47.1
Water use volume kL H_2O	0.1	36.1	9.9
Cumulative energy demand MJ LHV	50.5	1,010	990
Ozone Depletion kg CFC-11 eq x 10^{-8}	6.34	188	201
Acidification mol H^+ eq x 10^{-3}	7.63	170	170
Photochemical Ozone Formation kg NMVOC eq x 10^{-3}	6.28	160	170
Eutrophication (Marine) kg N eq x 10^{-3}	1.36	190	52.5

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