

Assessing the Environmental Footprint of Industrial Packaging

Sk. Tanjim Jaman Supto¹, Ettahad Islam Adib², Dewan Reza Hamid Karzai²

¹ Department of Environmental Research, Nano Research Centre; Sylhet; 3114; Bangladesh

² Department of Industrial and Production Engineering, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh

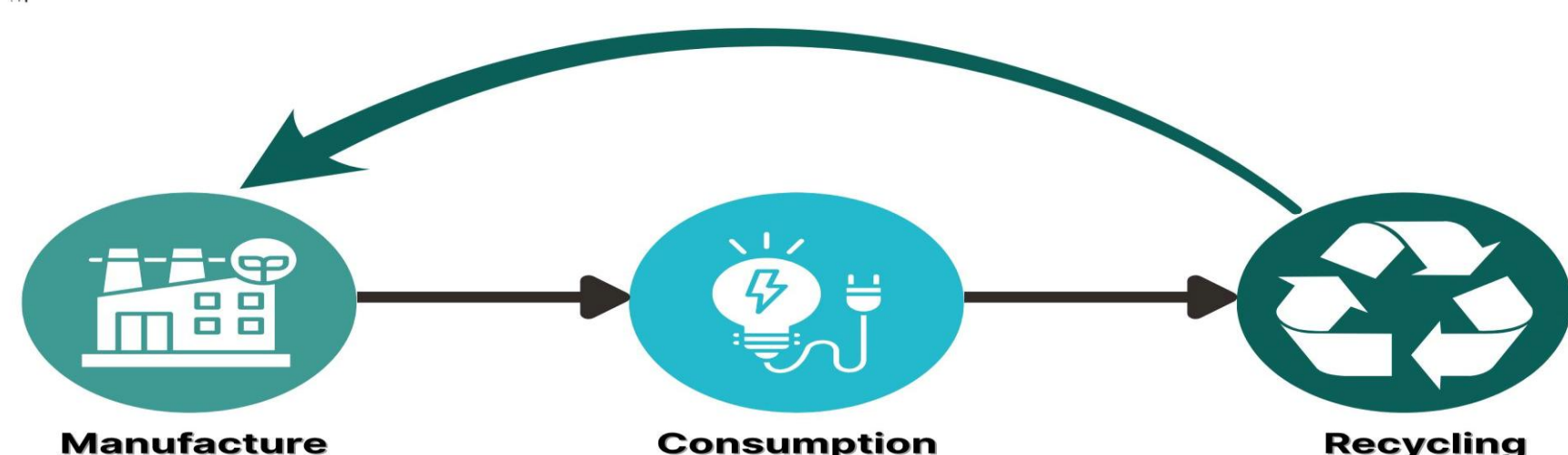
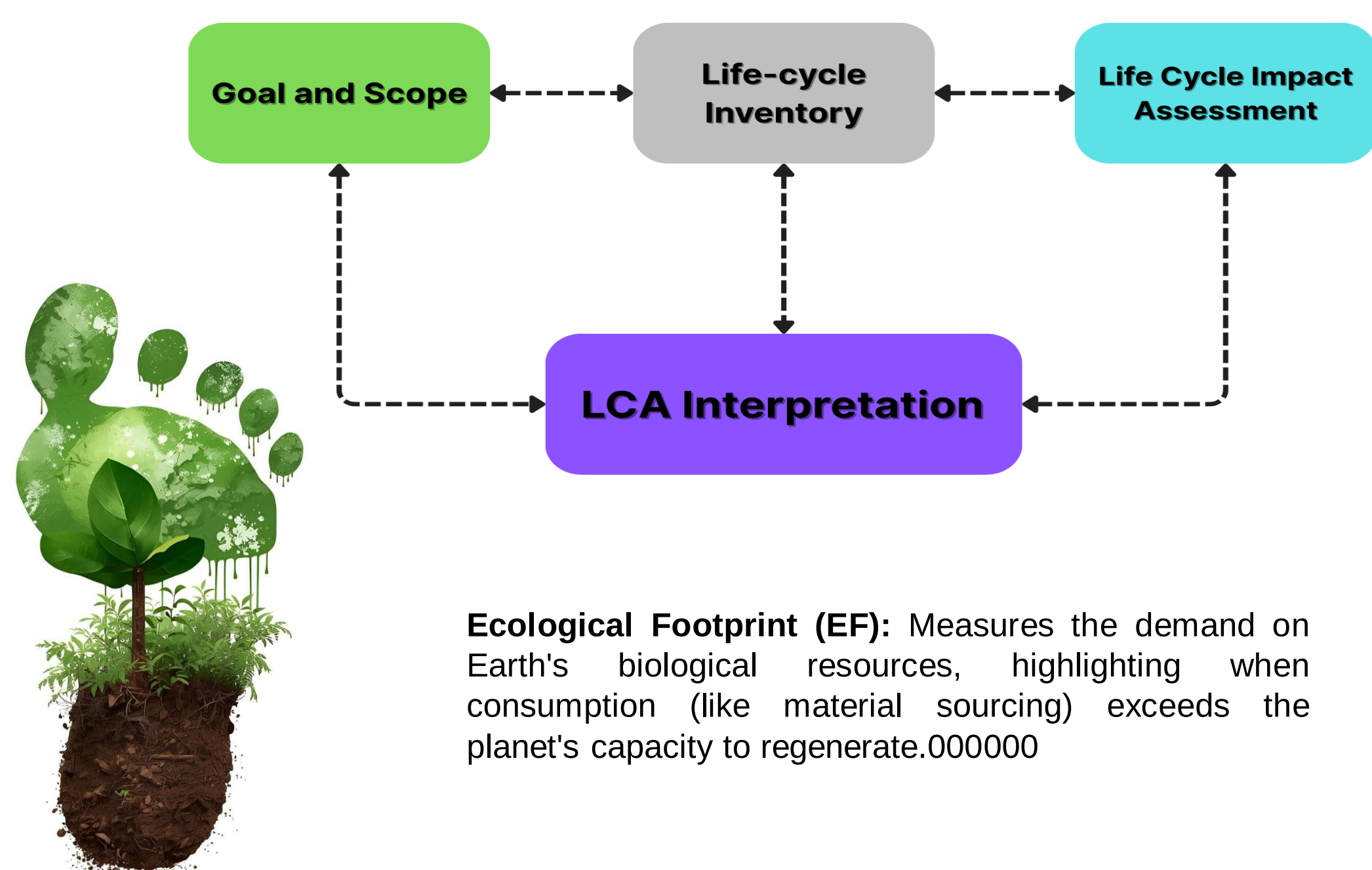
Corresponding author email: sksup7@gmail.com

INTRODUCTION & AIM

Industrial packaging is essential to global supply chains, but its manufacture and disposal have a substantial negative impact on the environment, contributing to resource scarcity, greenhouse gas emissions, and an increase in post-consumer waste. There is a critical need for sustainable packaging solutions as a result of tighter regulations and rising consumer demand. To critically compare the environmental performance of important conventional and alternative materials, this review synthesizes the most recent research and highlights the techniques used to determine their true impact from cradle to grave.

SUSTAINABILITY ASSESSMENT TOOLKIT

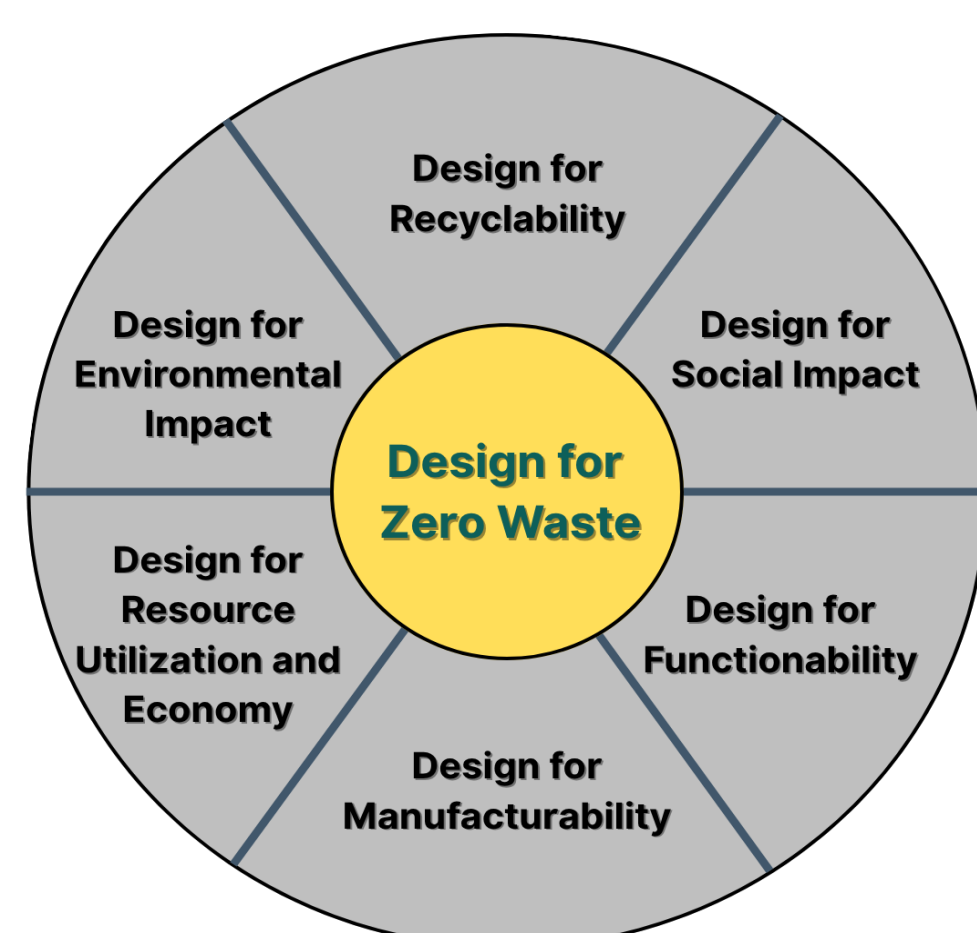
Life Cycle Assessment (LCA): A comprehensive "cradle-to-grave" analysis that quantifies environmental impacts at every stage of a product's life, from raw material extraction to disposal. The process involves four key phases as shown in the diagram.



Circular Economy Principles: A model that aims to eliminate waste by designing products and systems that enable reuse, remanufacturing, and recycling.

FUTURE OUTLOOK

A. Holistic Design Philosophy



B. Assess the Effectiveness of Policy

The effectiveness of these frameworks is demonstrated by measurable outcomes:

1. Extended Producer Responsibility (EPR): Schemes have shown a 15–25% improvement in recycling rates.
2. Plastic Taxes: Can lead to a 10–30% reduction in demand for virgin plastics.
3. Material Standards (ISO 14855): Provide clear benchmarks for claims like biodegradability.
4. Directives (EU Single-Use Plastics Directive): Effectively eliminate the most problematic items at the source.

Figure. "Design for Zero Waste" approach.

CHALLENGES

A. Source the Material & Treat the Waste

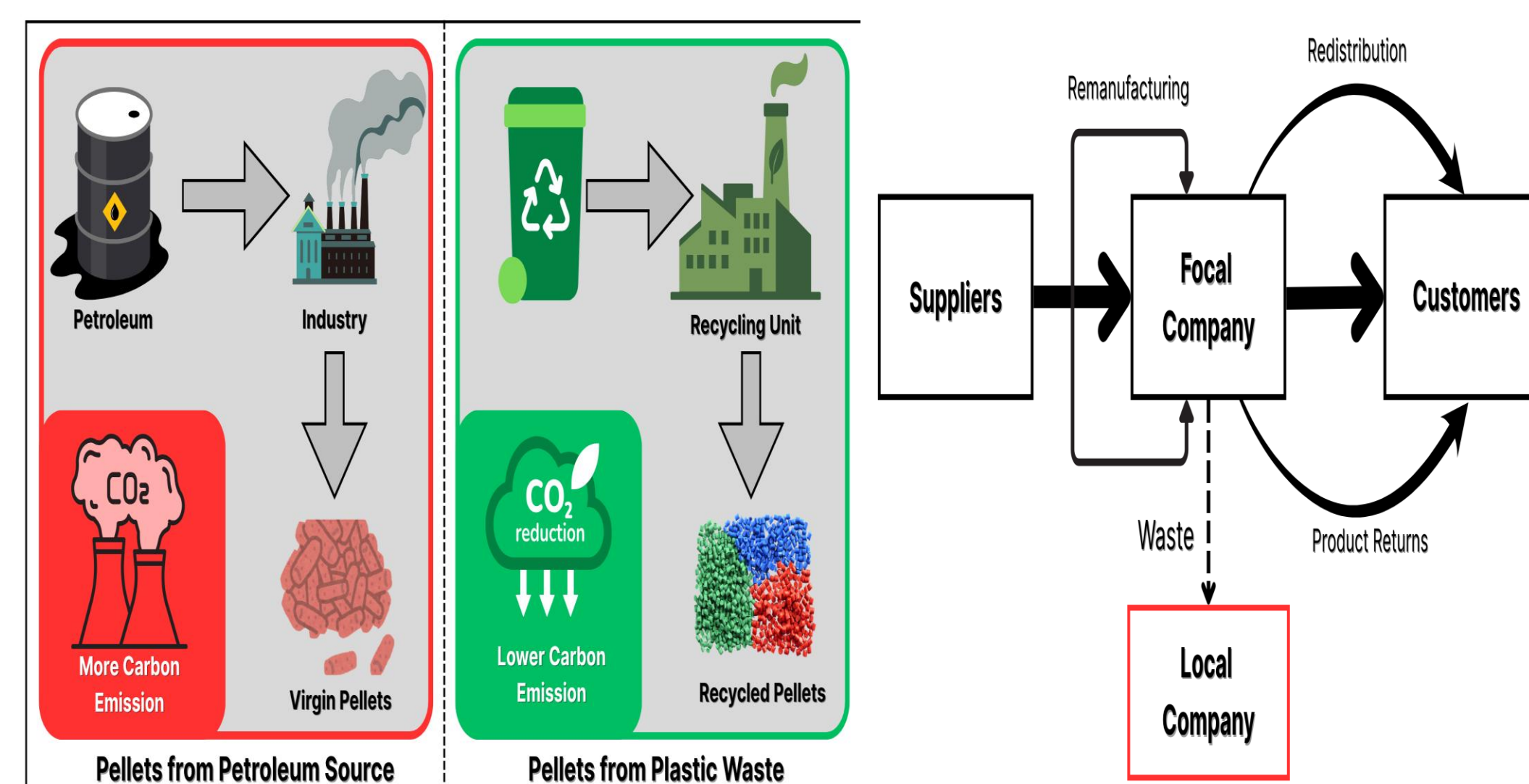
The fundamental challenge lies in shifting from a linear, extractive model to a circular one. Virgin material production, especially from petroleum, is carbon-intensive, while creating materials from plastic waste significantly lowers emissions and treats "waste" as a valuable resource.

B. Transportation

Modern supply chains are complex and global, contributing significantly to the overall environmental footprint. Implementing a circular economy requires not only efficient forward logistics but also robust reverse logistics systems for product returns, redistribution, and remanufacturing, which adds another layer of complexity.

C. Cost

Transitioning to sustainable materials and redesigning supply chains involves significant upfront investment. The economic trade-offs between lower-cost conventional packaging and more expensive, sustainable alternatives remain a major barrier to widespread adoption.



CONCLUSION

This review shows there is no single "silver bullet" for sustainable packaging. Every material, from bio-based plastics to renewable cardboard, has complex environmental trade-offs that require careful management. True progress hinges on moving beyond simple material substitution. The research strongly indicates that the path forward requires a combination of three core actions:

1. Integrate Environmental Standards: Proactively use tools like Life Cycle Assessment (LCA) and Ecological Footprint (EF) in the initial design phase.
2. Foster Cross-Sector Collaboration: Build partnerships between material suppliers, manufacturers, policymakers, and waste management sectors.
3. Put the Standardized Policy into Practice: Implement explicit laws such as Extended Producer Responsibility (EPR), bans on single-use plastics, and recycled content mandates.

REFERENCES

1. Pacana, A.; Siwec, D.; Bednárová, L.; Petrovský, J. Improving the Process of Product Design in a Phase of Life Cycle Assessment (LCA). *Processes* **2023**, *11*, 2579, doi:10.3390/pr11092579.
2. Ledakowicz, S.; Ziemińska-Stolarska, A. The role of life cycle assessment in the implementation of 1 circular economy in sustainable future. *Chemical and Process Engineering: New Frontiers* **2023**, 37–37, doi:10.24425/cpe.2023.147396.
3. Bimpizas-Pinis, M.; Santagata, R.; Kaiser, S.; Liu, Y.; Lyu, Y. Additives in the Food Supply Chain: Environmental Assessment and Circular Economy Implications. *Environmental and Sustainability Indicators* **2022**, *14*, 100172, doi:10.1016/j.indic.2022.100172.
4. Saleem, J.; Tahir, F.; Baig, M.Z.K.; Al-Ansari, T.; McKay, G. Assessing the Environmental Footprint of Recycled Plastic Pellets: A Life-Cycle Assessment Perspective. *Environmental Technology & Innovation* **2023**, *32*, 103289, doi:10.1016/j.eti.2023.103289.
5. Gupta, R.; Kushwaha, A.; Dave, D.; Mahanta, N.R. Waste Management in Fashion and Textile Industry: Recent Advances and Trends, Life-Cycle Assessment, and Circular Economy. In *Emerging Trends to Approaching Zero Waste*; Elsevier, 2022; pp. 215–242 ISBN 978-0-323-85403-0.