WP3: Downstream Environmental Impact Assessment

Kadambari Lokesh[1]; Vincent Rossi[2]; Apostolis Koutinas[3]; Dimitris Ladakis[3]; Demetres Briassoulis[3]; Iana Camara Salim[4]; Irena Wojnowska[5]

[1]University of York, UK; [2]Quantis, Switzerland; [3]Agricultural University of Athens, Greece; [4] University of Santiago Compostela, Spain; [5] University of Warmia-and Mazury, Poland.

Goal and Scope

To develop an environmental assessment framework covering the stages between manufacturing and end-of-life management of bio-based products. This framework will feed into the overall sustainability assessment blueprint, the ultimate deliverable of STAR-ProBio.

Gap analysis and Methodology

Life Cycle Assessment (LCA) was chosen as the method of choice, acknowledging its robust nature and capability at encompassing product and process-level environmental impact.

A review of national and international standards, certification protocols and 85+ peer-reviewed publications, helped identify gaps in the existing methods of environmental sustainability evaluation. Resource efficiency and circularity characteristics of bio-based products and their production processes were seldom addressed in these schemes and studies (Figure 1). Moreover, such environmental evaluations provided limited coverage on the end-of-life characteristics and management of post-consumer products.

A set of environmental indicators, drawn from LCA and from the principles of green chemistry and circularity (hybridised indicators) were selected or developed (where lacking) to draw an environmental framework that will address resource consumption-level impacts, in addition to addressing resource efficiency and circularity characteristics of the production process.

Analysis and Validation

The selected environmental indicators were tested for effectiveness through application to a combination of bio-based and fossil-derived products as dedicated case studies (Table 1). A comparative environmental impact assessment employing LCA, incorporating resource efficiency analysis was undertaken (Table 2). An example of their application to one of the case studies and a reflection of the impacts as expected to be reported in the sustainability assessment tool has been presented in Figure 2.

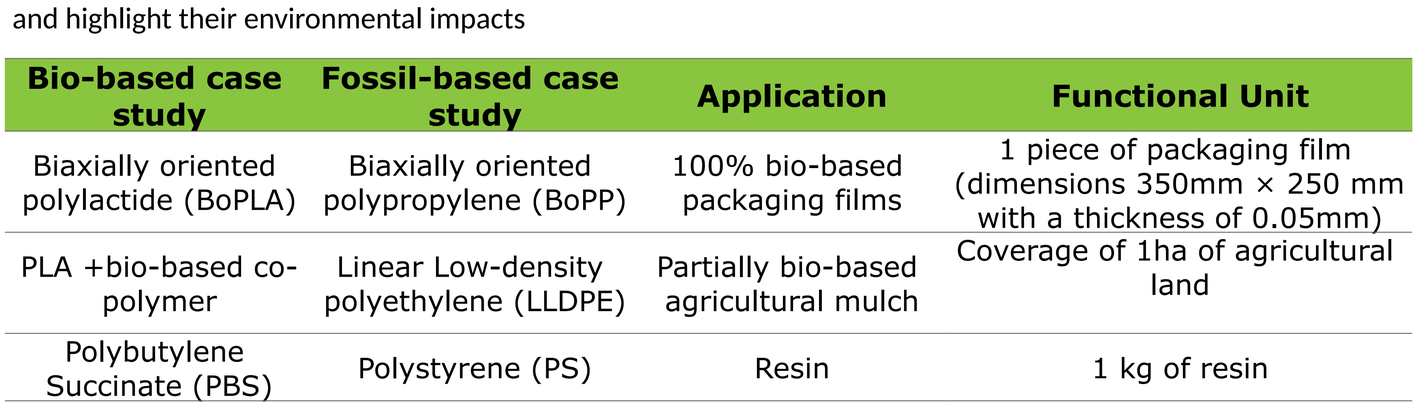


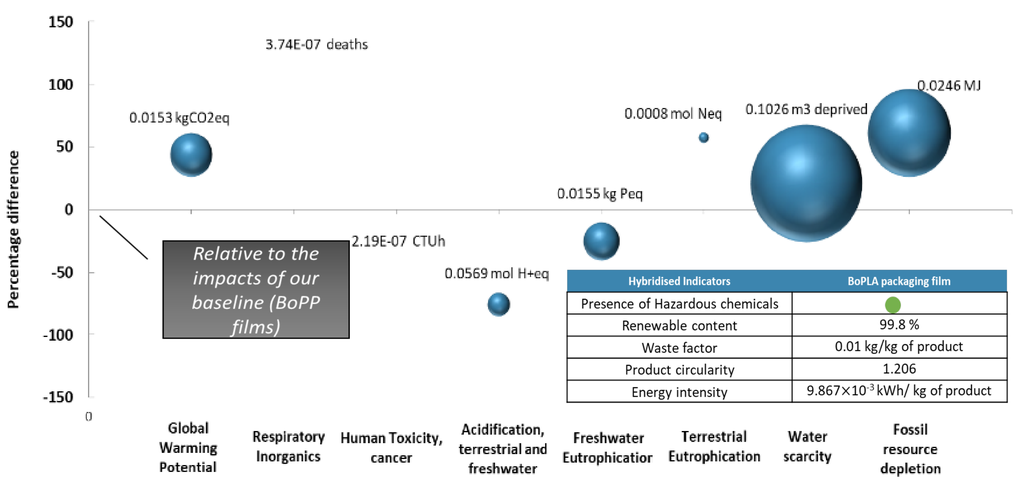
Figure 1. Resource flow across the life cycle stages of a product and the methodologies employed to quantify and highlight their environmental impacts

Bio-based case study	Fossil-based case study	Application	Functional Unit
Biaxially oriented polylactide (BoPLA)	Biaxially oriented polypropylene (BoPP)	100% bio-based packaging films	1 piece of packaging film (dimensions 350mm × 250 mm with a thickness of 0.05mm)
PLA +bio-based co-polymer	Linear Low-density polyethylene (LLDPE)	Partially bio-based agricultural mulch	Coverage of 1ha of agricultural land
Polybutylene Succinate (PBS)	Polystyrene (PS)	Resin	1 kg of resin

Table 1. List of bio-based and fossil-based case studies chosen for framework application and validation

LCA impact categories	Units	Applicability (life cycle stages)		
		Manuf. and dist.	Use	End-of-life management
Global warming potential (Bio)	*kg of CO_2 eq*	✓	✓	✓
Particulate matter	*Disease incidence*	✓	✓	✓
Acidification	*mol H^+_{eq}*	✓	✓	✓
Eutrophication	*kg P_{-eq}*	✓	✓	✓
Human toxicity, cancer	*CTUh*	✓	✓	✓
Fossil resource depletion	*MJ*	✓	✓	✓
Water scarcity	*m^3 water deprived*	✓	✓	✓
Hazardous Chemical use	*Qualitative*	✓		✓
Feedstock efficiency	*kg of feedstock*	✓		
Waste factor	*kg of waste*	✓	✓	✓
Product renewability	*%*	✓		
Process Material circularity	*%*	✓		✓
Energy intensity	*kWh of energy*	✓	✓	✓
Presence of Hazardous chemical	*Qualitative*			✓
Product circularity				✓
Secondary resource productivity	*kg of recycled material*			✓

Table 2. List of Environmental Indicators for Downstream impact



Hybridised Indicators	BoPLA packaging film
Presence of Hazardous chemicals	●
Renewable content	99.8 %
Waste factor	0.01 kg/kg of product
Product circularity	1.206
Energy intensity	9.867×10^{-3} kWh/ kg of product

Figure 2. Quantified environmental impacts acquired from the comparison of BoPP and BoPLA packaging films – an example

Conclusion

The proposed set of indicators were valuable in bridging some of the key gaps in existing environmental sustainability assessments, capturing the resource efficiency and circularity, in addition to expanding their boundaries for a wide range of products and product groups. Further refinements through engagement with industrial stakeholders and reaching a scientific consensus on developing science based targets for environmentally efficient product development, use and disposal marks the next necessary steps.

WP3 Partners

University of York; Green Chemistry Centre of Excellence; USC Universidade de Santiago de Compostela; University of Warmia and Mazury in Olsztyn; Γεωπονικό Πανεπιστήμιο Αθηνών Agricultural University of Athens; Quantis

Publications

1. K Lokesh, AS Matharu, IK Kookos, D Ladakis, A Koutinas, P Morone, and J Clark, "Hybridised Sustainability Metrics for Use in Life Cycle Assessment of Bio-Based Products: Resource Efficiency and Circularity", Green Chemistry, 2020, p. 10.1039.C9GC02992C.
2. K Lokesh, A Matharu, J Clark, V Rossi, X Bengoa, D Briassoulis, and et al., STAR-ProBio Deliverable 3.2: Assessing Sustainability of Managed End-of-Life Options for Bio-Based Products in a Circular Economy, Deliverable 3.2, October 30, 2019.

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