Center for the Transformation of Chemistry (CTC)

The Price of Green: Life Cycle Costing for Emerging Bioplastics

2045

What role do BIOPLASTICS play in reaching the target? (2026-2045)

~400 Mt → ~1%

From biomass to biopolymers: feedstocks and polymer families

Renewable Feedstocks

- ▶ Starch & sugars
- ▶ Plant oils
- ▶ Lignocellulose
- ▶ Hemicellulose
- ▶ Waste oils
- ▶ CO_2 (emerging)

Biobased Polymers

PLA	PHA	PEF
PBS(x)	PBAT	Bio-PP
Bio-PE	Bio-PA	PTT
Polyurethanes	Epoxy resins	
Cellulose polymers		

Market Reality

- Global bioplastics capacity projected at <1% of total by 2030
- Biodegradable ≠ drop-in: different EoL pathways required
- Most polymers still at pilot/demo scale
- Strong EU policy pull but cost signals unclear

Why Future of bioplastics are harder than it looks

Cost Competitiveness

Biopolymers carry a 2–5× price premium over fossil-based counterparts. High feedstock costs, smaller production volumes, and immature process infrastructure keep gate prices uncompetitive without policy support.

Feedstock Volatility & Land Use

First-generation feedstocks (corn, sugarcane) compete with food systems and face seasonal price swings. Lignocellulosic and waste-based routes are still scaling. Sustainable sourcing is a bottleneck at every TRL stage.

End-of-Life Complexity

Biodegradable ≠ industrially compostable. Mixed plastic waste streams, absent sorting infrastructure, and consumer confusion undermine circularity claims. EPR frameworks are inconsistent across EU member states.

Innovation & Assessment Gaps

Environmental impact methodologies have been built for fossil chemistry. Applying LCA, SSbD, or TEA to early-TRL biopolymers introduces high uncertainty, biogenic carbon accounting debates, and missing data — distorting investment signals.

Bioplastics Landscape: TRL & Market Readiness

Selected bio-based polymers by technology readiness and production scale (2024)

Polymer	TRL (1–9)	Production (kt/yr)	Market Status (2024)
PLA	**9**	390	Commercial
PHA	**7**	60	Scale-up
PBS	**7**	45	Scale-up
PEF	**6**	5	Pilot (Avantium ~2026)
Bio-PP	**5**	10	Demo
PHBV	**5**	8	Demo
Bio-PA	**8**	30	Commercial (niche)
PBAT	**8**	70	Commercial

The financial structure of a bioplastics facility scales **non-linearly** due to the high capital intensity of fermentation, polymerization, and purification equipment..

Why current cost methodologies cannot capture bioplastic competitiveness

❌ Current Approach

Production-Gate TEA

- ▸ Stops at factory gate — ignores use-phase and EoL costs
- ▸ Uses static feedstock & energy prices (snapshot in time)
- ▸ No carbon pricing or EPR cost integration
- ▸ Cannot model scale effects or learning curves
- ▸ Misses circular revenue (recyclate credits, biorefinery co-products)
- ▸ Linear economy assumption: produce → sell → discard

✅ What LCC Adds

Life Cycle Costing

- ▸ Full value chain: feedstock → conversion → use → EoL
- ▸ Dynamic cost modelling with price trajectories
- ▸ Carbon tax & EPR fee integration as cost drivers
- ▸ Scale and learning rate effects built in
- ▸ Circular revenue streams credited to system boundary
- ▸ Comparable to fossil alternatives on a system-wide basis

The competitiveness of bioplastics cannot be evaluated at the factory gate. The full cost story only emerges over the entire life cycle.

Why conventional cost analysis is insufficient for bioplastics

2–5×

Cost premium: bio-based vs. fossil-derived polymers

< 2%

Global plastics production currently bio-based (2024)

→ 2030

EU Green Deal mandates measurable circularity metrics

Why Life Cycle Costing?

1. LCC captures costs across the full value chain — feedstock, conversion, use, and end-of-life — not just gate price.

2. Conventional TEA snapshots miss externalities, policy costs, and circular revenue streams critical for biopolymers.

3. Dynamic LCC models future carbon pricing, feedstock volatility, and scale effects — essential for investment decisions.

4. LCC provides the common currency to compare bio-based and fossil alternatives on a **system-wide basis**.

How LCC captures value recovery, EoL burden, and EPR cost allocation

Feedstock	Processing & Conversion	Product Use Phase	Collection & Sorting	Mechanical / Chemical Recycling
Feedstock cost (€/kg biomass) Subsidy eligibility	CAPEX/OPEX Energy intensity Process yield losses	Durability costs Product lifespan → functional unit	EPR levy allocation Logistics cost Contamination losses	Recyclate revenue Quality degradation Credit vs. virgin cost

← Circular value return (credited back to LCC system boundary)

Key LCC Metrics for Bioplastics

Quantitative indicators across the techno-economic and sustainability domains

MSP — **Minimum Selling Price**

Break-even price at zero NPV; primary commercialisation threshold (€/kg)

CAPEX — **Capital Expenditure**

Upfront plant, equipment, and commissioning costs; often decisive for biopolymer scale-up

GHG/€ — **Eco-efficiency Ratio**

kg CO_2e per € of value created; integrates eLCC with LCA carbon results

NPV — **Net Present Value**

Discounted sum of all cash flows at chosen WACC; investment viability signal

OPEX — **Operating Expenditure**

Feedstock, energy, labour, maintenance, and waste treatment per annum

PMI — **Process Mass Intensity**

Total mass input per unit product output; proxy for resource efficiency

IRR — **Internal Rate of Return**

Discount rate at which NPV = 0; benchmark against capital cost of equity

MAC — **Marginal Abatement Cost**

Cost per tonne CO_2 avoided vs. fossil reference; €/tCO_2e signal for policy

EROI — **Energy Return on Investment**

Energy output divided by energy input across full lifecycle

Metrics Focused on Emerging Bioplastics

01 🏭 CAPEX & OPEX Decomposition

Separates capital expenditure (plant, infrastructure) from operational costs (feedstock, energy, labour). Identifies the dominant cost driver — critical for scale-up strategy.

02 💰 Minimum Selling Price (MSP)

The lowest price at which a plant breaks even over its lifetime at a given discount rate. The primary benchmark for comparing biopolymer competitiveness against fossil counterparts.

03 📈 Net Present Value (NPV)

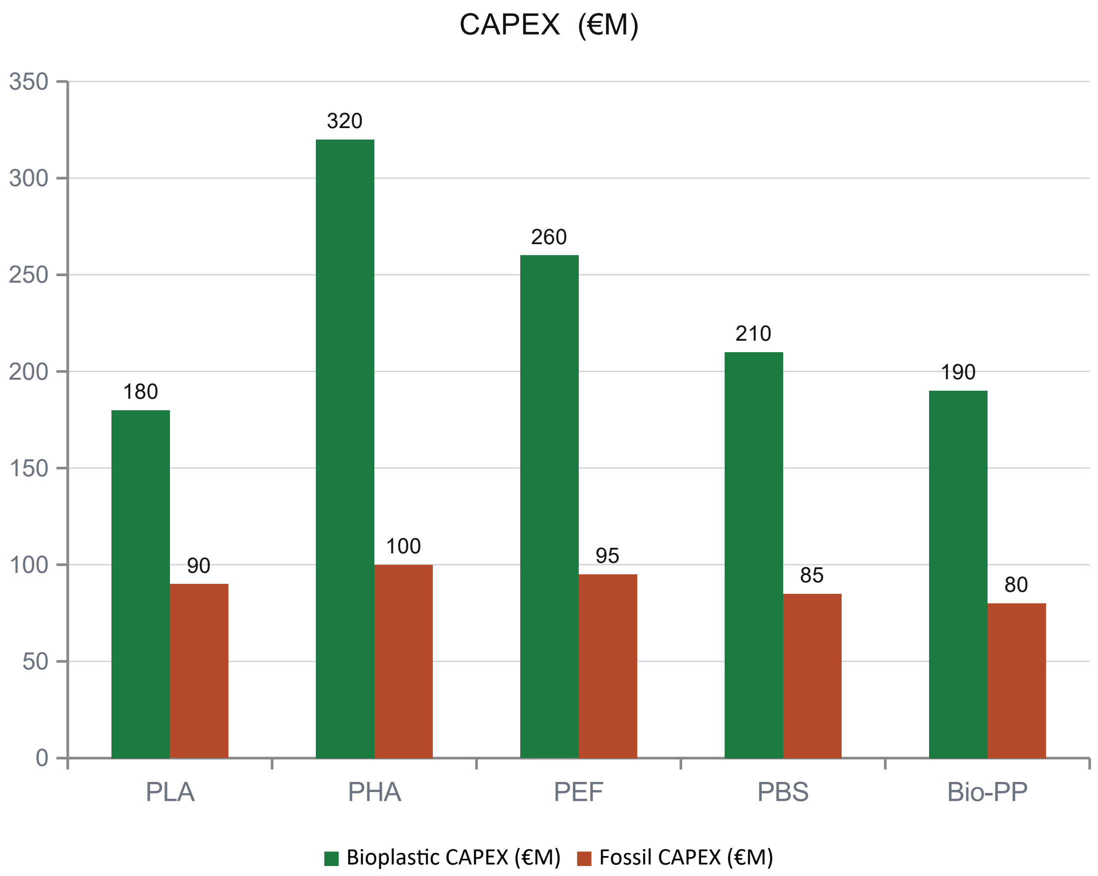
Discounted cash flow over the investment horizon. Captures time-value of money, policy risk, and scale trajectory. Positive NPV = economically viable project at given conditions.

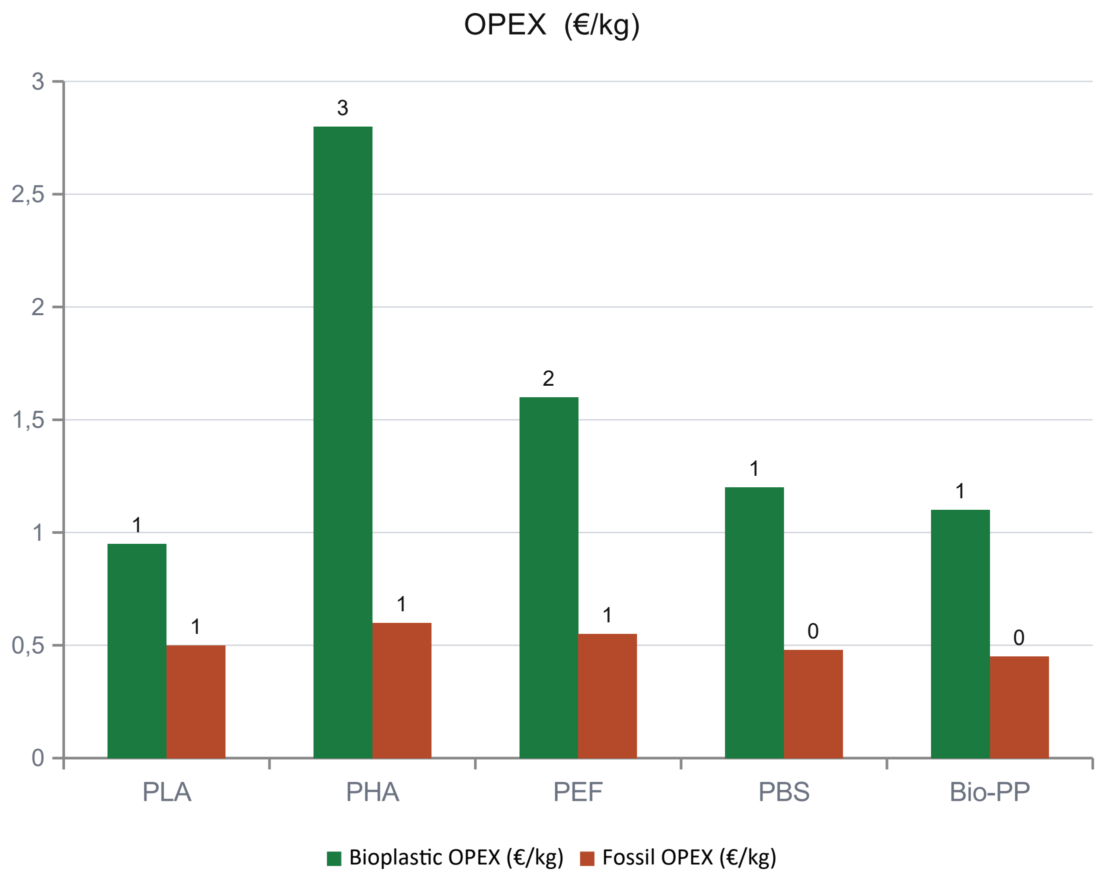
04 ⚖️ Marginal Abatement Cost (MAC)

Cost per tonne of CO_2 avoided relative to the fossil reference product. Directly comparable to EU ETS carbon price — the bridge between cost competitiveness and climate policy.

CAPEX & OPEX Comparison

Capital and operating expenditure per 50,000 tonne/year plant — bioplastic vs. fossil equivalent



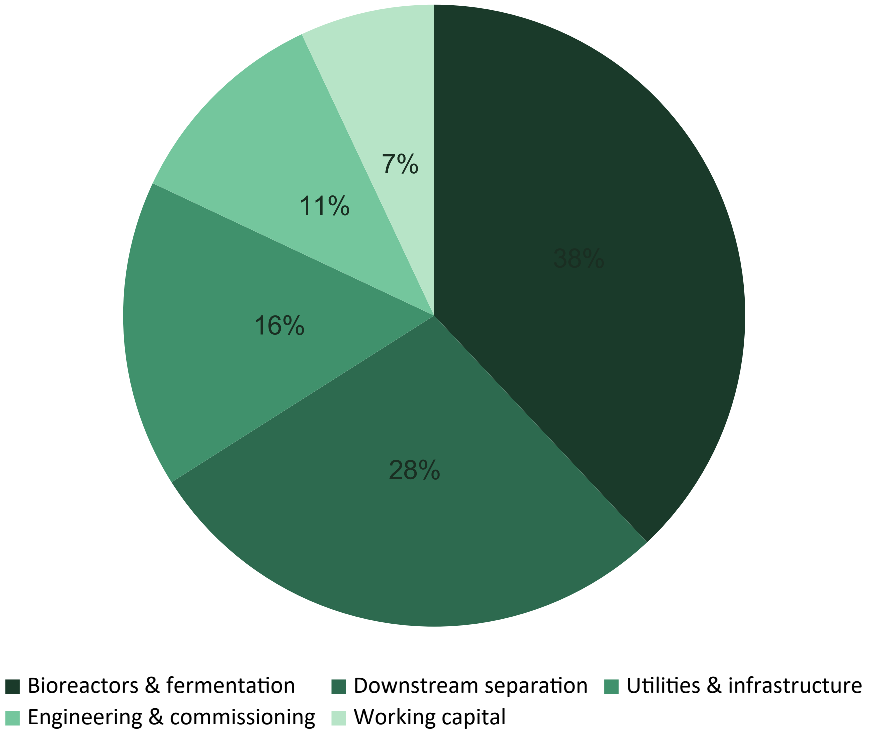


Bioplastics carry 2–3× higher CAPEX owing to unproven scale. Feedstock accounts for 40–60% of PHA's OPEX — the dominant cost driver across the sector.

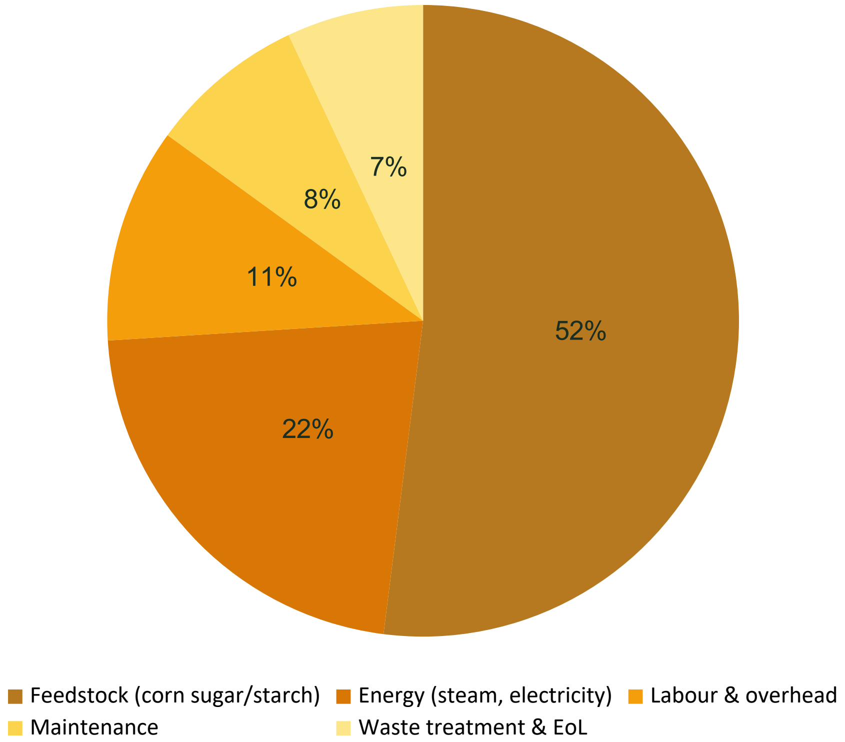
Cost Structure Decomposition

CAPEX and OPEX allocation for representative biopolymer production routes

CAPEX Breakdown — PHA (10 kt/yr)



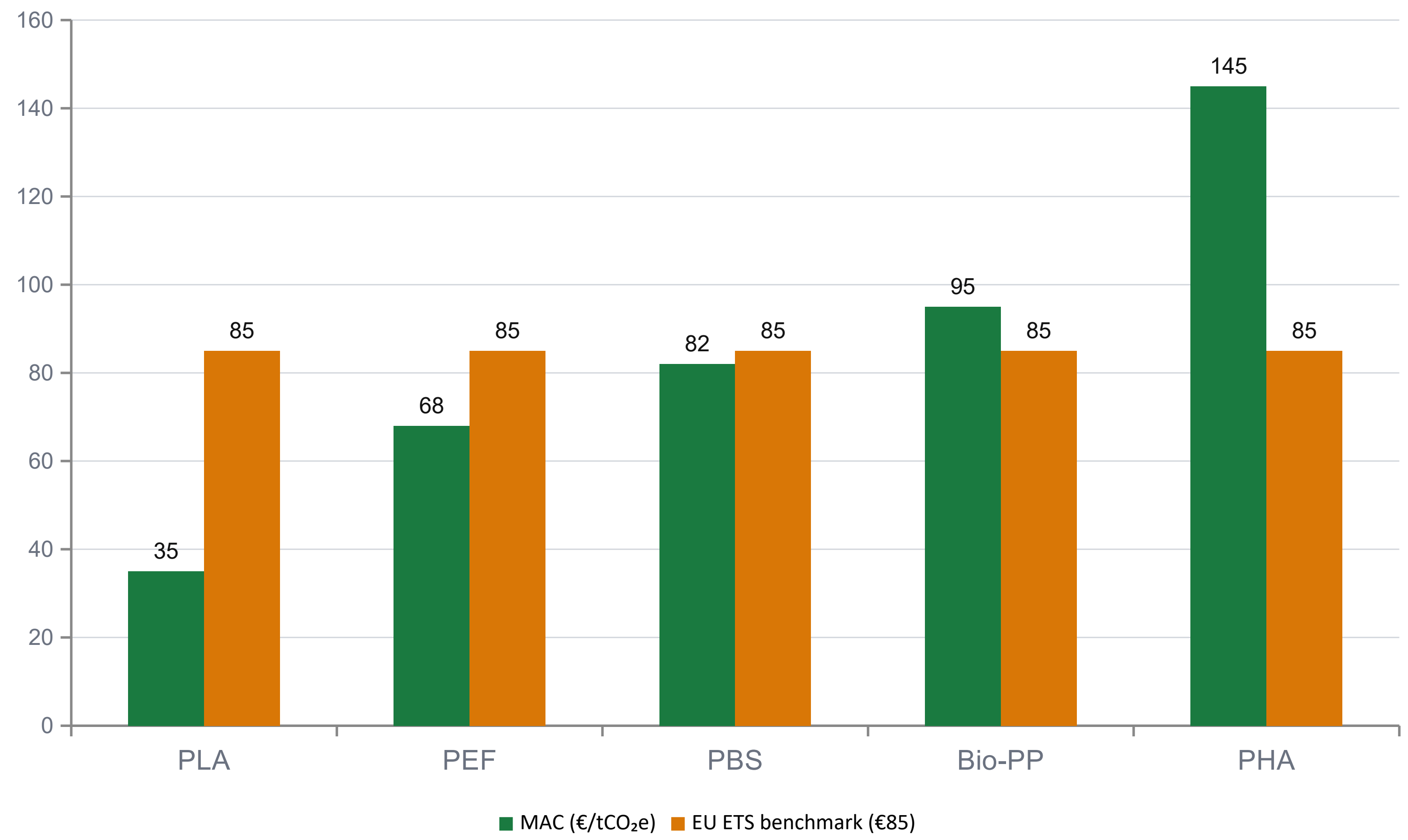
OPEX Breakdown — PLA (75 kt/yr)



Feedstock dominates OPEX for sugar-platform biopolymers; fermentation infrastructure dominates CAPEX. Both are targets for LCC optimisation via scale, feedstock diversification, and process integration.

Marginal Abatement Cost

€/tCO_2e required for investment viability vs. current EU ETS benchmark (€85/tCO_2e)



Material	MAC
PLA	€35
PEF	€68
PBS	€82
Bio-PP	€95
PHA	€145

Thank you