

# Biogenic-Carbon Accounting in Bio-Based Photopolymer Materials: Feedstock, Land Use, Allocation and End of Life

*Separating renewable carbon content from lifecycle climate performance in bio-based photocurable materials*

**Juan Seguro**

3Dresyns by Resyner Technologies S.L.

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Correspondence: info@3Dresyns.com · www.3Dresyns.com

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## Abstract

A bio-based fraction in a photocurable material does not by itself establish a climate benefit. Biogenic carbon uptake, feedstock production, land-use change, co-product allocation, additives, manufacturing energy, service life and end-of-life treatment all influence lifecycle results. This review defines a qualification framework for biogenic-carbon accounting in bio-based photopolymer materials. It focuses on transparent system boundaries, temporal carbon treatment, land-use assumptions, allocation rules, recycled content and realistic end-of-life scenarios rather than percentage bio-content as a proxy for sustainability.

Keywords: bio-based photopolymer; biogenic carbon; life cycle assessment; land use; allocation; end of life; carbon accounting; circularity

## 1. Significance and scope

Bio-based materials can reduce reliance on fossil feedstocks, but lifecycle assessment of renewable polymers is method-sensitive. Reviews repeatedly identify biogenic carbon, land-use change, allocation and end-of-life as critical choices [1].

This review owns carbon-accounting architecture for bio-based photocurable materials. It does not assign a sustainability score to any product; it defines what evidence is required before bio-content is converted into an environmental claim.

## 2. Bio-based content is not a carbon result

Bio-based mass fraction should be reported separately from biogenic carbon content because not all bio-derived feedstocks have the same carbon fraction and a formulation also contains photoinitiators, additives, pigments and fillers.

The carbon balance should identify when atmospheric carbon is taken up, how long it remains in the product and when it is released. Treating biogenic carbon as automatically neutral can hide the timing of uptake and emission.

The reference flow should describe the same useful function for bio-based and fossil comparators. Equal resin mass is not a valid comparison if cure yield, service life or required wall thickness differs between material systems.

Biogenic-carbon accounting should keep physical carbon flow separate from avoided-burden credits. Carbon stored temporarily in a product, fossil feedstock displaced by a co-product and energy recovered at end of life are different mechanisms and should not be combined into one opaque credit.

## 3. Biogenic carbon requires an explicit time model

Dynamic-LCA reviews show that timing and storage duration can materially affect interpretation of bio-based systems and that methods remain heterogeneous [2]. The selected temporal model should therefore be stated rather than implied.

Feedstock cultivation can affect soil carbon, biodiversity, water and land occupation. A photopolymer with high renewable content can shift impacts outside the factory boundary if agricultural burdens are omitted.

## 4. Land use and allocation can dominate interpretation

Allocation becomes important when biomass processing produces several products. Economic, mass-based or substitution approaches can assign very different shares of upstream burdens; the rule must be declared and sensitivity tested.

Comparative reviews of bioplastics show substantial variation in treatment of additives, land-use change, carbon sequestration and end-of-life assumptions [3]. Photocurable materials add further complexity because reactive diluents and crosslinkers can come from mixed fossil and biogenic sources.

Manufacturing energy and cure efficiency should remain in the inventory. A bio-based formulation does not erase exposure energy, post-cure, wash solvent, failed prints or support waste.

Recycled bio-based feedstock needs an explicit attribute rule. Once biogenic and fossil-derived molecules are mixed, physical carbon origin, recycled-content claim and accounting certificate can become three different quantities.

Geographic specificity matters when biomass yield, electricity, fertiliser production or land-use change differ by region. A generic global dataset can be useful for screening, but a comparative claim should state when location-specific assumptions are load-bearing.

## 5. End of life changes the carbon balance

Product lifetime matters because temporary carbon storage has different meaning in a disposable fixture and a long-lived component. Functional unit and service duration should match the use case rather than the kilogram of resin alone.

End-of-life scenarios should reflect realistic collection and treatment. Incineration, landfill, chemical recycling and reuse return biogenic carbon on different timescales and can create credits or burdens through displaced products.

Recycling requires careful chain-of-custody accounting if recovered bio-based and fossil-derived molecules become indistinguishable. Avoid double counting recycled content and biogenic carbon attributes.

| Axis            | Measurement                         | Failure mode                           |
|-----------------|-------------------------------------|----------------------------------------|
| Feedstock       | origin and biogenic-carbon fraction | bio-content treated as climate benefit |
| Time            | uptake, storage, release            | instant neutrality assumed             |
| Land/allocation | LUC and co-product rule             | upstream burden omitted                |
| Manufacturing   | energy, yield, consumables          | resin-only inventory used              |
| End of life     | collection, recycling, release      | single optimistic scenario used        |

**Table 1.** Domain-specific qualification matrix for biogenic-carbon accounting in bio-based photopolymer materials.

## 6. Device-level verification of environmental claims

Device-level verification of an environmental claim should link the formulation inventory to a functional unit based on useful printed output, including yield, reject rate and post-processing consumables.

Sensitivity analysis should vary allocation, land-use assumptions, service life, electricity and end of life. A claim that changes sign under plausible assumptions should be reported as conditional.

Failure modes include counting uptake without release, omitting land-use effects, crediting long-term storage to short-lived products, ignoring additives or comparing products on unequal functions.

Device-level verification should connect the lifecycle model to the manufactured function. If the bio-based formulation changes print yield, post-cure demand, component lifetime or replacement rate, those changes belong in the functional-unit comparison rather than in a separate technical appendix.

## 7. Minimum qualification framework

Report feedstock origin, bio-based and biogenic-carbon fractions, co-products, allocation method, geographic/temporal scope, energy inventory and functional unit.

Report land-use assumptions, carbon-storage treatment, recycling or disposal scenario, credits, uncertainty and the sensitivity cases that materially change the result.

## 8. Engineering conclusions

Biogenic carbon should be accounted rather than celebrated. A defensible bio-based photopolymer claim connects feedstock, land, allocation, manufacturing, service and end of life under a transparent lifecycle model.

## References

- [1] P. Pawelzik, M. Carus, J. Hotchkiss, R. Narayan, S. Selke, M. Wellisch, M. Weiss, B. Wicke, M. K. Patel, "Critical aspects in the life cycle assessment (LCA) of bio-based materials – Reviewing methodologies and deriving recommendations," *Resources, Conservation and Recycling* 73 (2013) 211-228. <https://doi.org/10.1016/j.resconrec.2013.02.006>
- [2] M. de Jong, B. Corona, M. Junginger, L. Shen, "From static to dynamic: Reviewing the application and potential of dynamic LCA to bio-based systems," *The International Journal of Life Cycle Assessment* 31 (2026) 56. <https://doi.org/10.1007/s11367-026-02624-1>
- [3] G. Bishop, D. Styles, P. N. L. Lens, "Environmental performance comparison of bioplastics and petrochemical plastics: A review of life cycle assessment (LCA) methodological decisions," *Resources, Conservation and Recycling* 168 (2021) 105451. <https://doi.org/10.1016/j.resconrec.2021.105451>

## Competing interest

Juan Segurola is founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L., which develops and commercialises photopolymer materials and related additive-manufacturing technologies. This review is an engineering analysis and does not constitute a product-performance claim or a device qualification.