

Carbon-Dioxide-Derived Feedstock Claims in Photocurable Materials: Provenance Evidence, Carbonate and Carbamate Functionalisation, Carbon Accounting and Performance Limits

A qualification framework that separates carbon-source evidence from photocurability and environmental claims

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Abstract

Claims that a photocurable feedstock is carbon-dioxide-derived require a continuous provenance chain rather than recognition of a carbonate group or the use of CO₂ somewhere in processing. Controlled evidence for this review separates three distinct literatures: chemical fixation of CO₂ into cyclic carbonates, photocurable cyclic-carbonate-derived urethane or polyhydroxy-urethane chemistry, and carbon accounting. The held sources do not yet join those literatures into one verified chain from CO₂ to a polymerisable precursor and then to a photopolymerised network. ER-411 therefore treats CO₂ derivation as a claim to be qualified, not as an established property of a material class. It defines the minimum provenance, functionalisation, mass-balance and performance evidence needed before such a claim can be transferred to a photocurable formulation, while reserving lifecycle comparison and environmental superiority to ER-17.

Keywords: carbon dioxide · CO₂-derived feedstock · cyclic carbonate · carbamate · polyhydroxy urethane · photocurable materials · provenance · carbon accounting · mass balance · qualification

1. Scope: qualify the claim, not the name

A carbonate, carbamate or polycarbonate label does not establish that any carbon atom in the material originated from carbon dioxide. ER-411 owns the evidentiary chain needed to qualify a CO₂-derived-feedstock claim in a photocurable material. It does not assert that a general class of photocurable carbonates or carbamates is CO₂-derived. The article also separates CO₂ used as a process medium, CO₂ captured after manufacture, bio-based carbon, recycled carbon and CO₂-derived carbon. Those are different claims and require different evidence.

2. Provenance chain

A defensible claim requires an identified route from CO₂ to a precursor, preservation or documented transformation of the CO₂-derived moiety during functionalisation, and an identified photocurable formulation or network. Błażek et al. demonstrate chemical fixation of CO₂ into bis(cyclic carbonate)s from bio-based bis-epoxides and report thermal polyaddition with a bio-based amine; the work does not address photocure [1]. This is a concrete case in which one molecule can contain bio-based carbon in its precursor backbone and CO₂-derived carbon in its carbonate functionality, so the two provenance claims must be reported separately. Usman et al. review CO₂ cycloaddition to epoxides and glycerol, but do not discuss glycidyl methacrylate or a photocurable cyclic carbonate [2]. Buchheit et al. establish the photocurable cyclic-carbonate-methacrylate to multifunctional urethane-methacrylate route, while CO₂ provenance of that precursor remains unverified in the evidence available to this review [3]. No held source therefore closes the complete chain.

3. Nomenclature is not provenance

The strongest failure mode is to infer feedstock origin from a functional-group name. Usman et al. report that the direct glycerol-plus-CO₂ route to glycerol carbonate is thermodynamically disfavoured for industrial production [2]. A downstream monomer named for glycerol carbonate therefore cannot be called CO₂-derived merely because it contains a carbonate ring. The same rule applies to cyclic carbonates, polycarbonates and carbamate-containing photopolymers unless the carbon-source route is explicitly documented.

4. Functionalisation and preservation of identity

Functionalisation can preserve, transform or remove the carbon-containing motif that motivated the provenance claim. Buchheit et al. report cyclic-carbonate methacrylates reacting with diamines to form multifunctional urethane methacrylates that can be photopolymerised [3]. That supports a carbonate-to-carbamate functionalisation route and direct photocure, but it does not by itself prove that the starting carbonate carbon came from CO₂. A provenance ledger should therefore record precursor identity, carbon source, functionalisation step and the fate of the claimed carbon separately.

5. Carbon accounting boundary

ER-411 may report carbon-source evidence or a feedstock mass balance, but it does not own lifecycle comparison. ER-17 owns life-cycle assessment, inventory flows, allocation and environmental-superiority claims. A statement that a fraction of feedstock carbon is traceable to CO₂ is not equivalent to lower greenhouse-gas emissions, sequestration, circularity or net climate benefit. Those comparisons require a declared system boundary and the accounting framework controlled by ER-17.

6. Evidence matrix

Table 1. Minimum evidence for a CO₂-derived-feedstock claim

Claim element	Minimum evidence	Insufficient substitute
CO ₂ provenance	documented CO ₂ -to-precursor route	carbonate or carbamate name alone
Photocurable identity	identified polymerisable group and direct photocure	thermal polymerisation only
Carbon continuity	documented fate of claimed carbon through functionalisation	assumed retention from structure name
Accounting	auditable carbon-source or feedstock mass balance	nominal formulation fraction without provenance

7. Performance remains formulation-specific

Feedstock provenance does not determine resin viscosity, cure rate, conversion, glass transition, modulus, toughness, shrinkage, extractables or print resolution. Buchheit et al. report formulation-specific rheology and rigid-thermoset properties for their own polyhydroxy-urethane systems [3]. Those values cannot be transferred to a different carbonate, carbamate, oligomer, reactive diluent, photoinitiator, exposure history or post-cure. Performance qualification therefore remains a second axis, independent from carbon-source qualification.

8. Photocurability is a separate gate

A CO₂-derived cyclic carbonate that polymerises thermally is not yet evidence for a photocurable resin. Conversely, a photocurable carbonate-derived urethane is not evidence for CO₂ provenance. The minimum chain requires both: a verified CO₂-derived precursor and a verified photopolymerisable route that retains or transforms the identified carbon in a documented way. Where the chain is split across sources, the manuscript must state the split rather than bridge it by inference.

9. Adjacent corpus boundaries

Table 2. ER-411 boundaries within the Engineering Review corpus

Boundary	Owns	ER-411 disposition
ER-17	LCA, inventory flows, allocation, environmental superiority	source/mass-balance only; no climate comparison
ER-57	CO ₂ capture by printed or derived structures after manufacture	capture is not feedstock provenance
ER-103	urethane/urea and non-isocyanate PHU identity	use only where provenance changes interpretation
ER-116 / ER-118	PTMC identity; scCO ₂ process-medium example	neither proves CO ₂ incorporation into feedstock

10. Qualification decision boundary

A CO₂-derived-feedstock claim is supported only when provenance is explicit and the claimed carbon survives a documented chemical route into the stated photocurable precursor or network. A carbonate name, CO₂ used as solvent or processing medium, post-manufacture CO₂ capture, bio-based content or recycled content cannot substitute for that evidence. If provenance is unresolved, the correct statement is that the material is carbonate- or carbamate-containing and that CO₂ derivation is unverified.

11. Minimum reporting record

The minimum record should identify the CO₂ source where known, precursor identity, reaction that fixes or transfers carbon, carbon-containing functional group, polymerisable functionality, formulation composition at the level needed to interpret cure, photocure conditions, conversion or state metric, post-processing, and the method used for carbon-source or mass-balance attribution. If any link is inferred rather than measured or documented, it should be labelled as a gap rather than treated as evidence.

12. Carbon-source evidence and measurement gaps

The current evidence set contains no verified method that quantifies CO₂-derived carbon in the final photocurable formulation. Carbon-source measurement therefore remains an open evidence requirement. Molecular class names and nominal stoichiometry may support bookkeeping only when the full synthesis route is controlled; they do not replace direct or auditable provenance records. Environmental comparison remains outside this article even after the mass balance is closed.

13. Research priorities

The highest-value evidence is a primary study that joins the presently separated halves of the chain: CO₂ carbonation of a polymerisable epoxide or equivalent precursor, followed by direct photocure of the resulting material with composition, conversion and properties reported. A second priority is a reproducible carbon-source or mass-balance method that follows the claimed CO₂-derived carbon through functionalisation and formulation. Without those two links, the field can discuss chemical possibility but not a general class of verified CO₂-derived photocurable feedstocks.

14. Evidence gaps and limitations

This review is deliberately narrower than the original roadmap title. The available evidence establishes CO₂ fixation into cyclic carbonates in one literature and photocurable carbonate-derived urethane chemistry in another, but it does not yet establish a single primary-source chain joining CO₂ origin to a photocured network. The review therefore supplies a qualification framework, not a catalogue of proven CO₂-derived photoresins. No lifecycle advantage, climate benefit, sequestration claim, product equivalence or commercial-material performance claim is made.

References

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Competing interests

The author is Founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L. ER-411 contains no comparative recommendation between commercial materials and uses no manufacturer claim as independent scientific proof.

Data availability

ER-411 is a literature-based engineering review; no new experimental dataset was generated. Source depth and unresolved provenance links are recorded in the accompanying source-and-boundary ledger.