

LANDRY INDUSTRIES · HEMPOXIES DIVISION

HEMPOXIES

*Hemp-Carbon Reinforced Hempseed-Oil Epoxy Vitrimers
without Raw Fibers — Chemistry, Stoichiometry, Green & Organic
Practice, and the Road to Hemp Furan Nanothreads*



hemp carbon



Zn²⁺ exchange

vitrimer network

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*For the farmers of hemp, the chemists of tomorrow,
and everyone who believes a plant can replace a refinery.*

Status of this book

TRL 1–2 · FORWARD-LOOKING RESEARCH HYPOTHESIS

Hempoxies is a research programme at Technology Readiness Level 1–2. Every formulation, loading, property value and performance target in this book that is attributed to Hempoxies is a *projected design target*, not a validated laboratory result. No Hempoxy composite described here has yet been fabricated and tested to the specifications given. Values attributed to the published literature are cited to their sources; values attributed to Hempoxies are labelled as projections. Nothing in this book is engineering certification, structural approval, or a claim of organic certification for any product.

How this book was compiled

This edition consolidates the Hempoxies corpus that Marie-Soleil Seshat Landry has built since late 2025 — the public Zenodo record series, and the working dossiers in her Google Drive (the Hempoxies 74 proposal, the >99 % hemp monoculture report, Hempoxies 100, the failure-analysis logbook and the October 2026 furan-nano-thread manual). Every external scientific claim was re-checked against live web sources in October 2026 and is cited in the reference list at the back. Scribd was searched but its document listing could not be retrieved by automated means during compilation (the site served a JavaScript challenge), so Scribd-hosted versions of these documents are not cited separately; the Zenodo and Drive copies were used instead.

Where the earlier dossiers contained a statement that live verification did not support — an author name, a pressure, a feedstock origin — this book corrects it and says so in [Appendix B, Editorial corrections](#). That is the Seshat’s Axiom discipline the author applies to all her work: retrieve, store, cite.

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CHAPTER 1

Who is Marie-Soleil Seshat Landry, and how Hempoxies began

An Acadian investigator from Moncton taught herself materials chemistry in public, one versioned record at a time.

Marie-Soleil Seshat Landry is the CEO and founder of Landry Industries Inc., a pre-revenue incubator based in Moncton, New Brunswick, on the Acadian coast of Canada. Her primary profession for more than a decade has been open-source intelligence: she runs Marie Landry's Spy Shop, an OSINT practice, and describes herself as an investigator and spymaster. She is bilingual in English and French, self-taught, and a prolific self-publisher with more than a hundred and thirty records on Zenodo and a long trail of work on Scribd, GitHub and a family of Blogger sites. Her ORCID is 0009-0008-5027-3337.

That background explains the shape of Hempoxies better than any chemistry credential could. An intelligence analyst works by collecting open sources, cross-checking them, keeping a ledger of what is known and what is only claimed, and publishing assessments with explicit confidence levels. Landry brought exactly that discipline to a materials-science question: *could the whole of a high-performance composite – matrix, hardener, diluent, catalyst ligand and reinforcement – be traced back to one plant?* Her own frameworks formalise the habit. Seshat's Axiom (Retrieve = Store = Cite), the Landry Hallucination-Free Protocol and the Fact-Constant/Narrative-Variable architecture, all on Zenodo, are rules for keeping facts and stories apart. The Hempoxies series is those rules applied to polymers.

The invention, as a sequence of public records

Hempoxies was not invented in a single moment; it was invented the way open-source software is, by versioned iteration in public. The Zenodo ledger (Appendix A) shows the arc. In November 2025 a *Master Technical SOP Suite* described a seven-component, reproducible, hemp-derived vitrimeric epoxy system.^[40] In December 2025 the *9-Component Formulation* report framed Hempoxies as a green-chemistry bionanocomposite,^[41] and the *Hempoxies 13* dossier compiled three sub-variants into an industrial blueprint.^[42] The furan-nanowool thread entered the corpus the same month, with a photochemically assisted high-pressure synthesis proposal dated 19 December 2025.

Spring 2026 was the period of consolidation. The *Industrial Manual* v.15 (March 2026) set out the "Trideca-Hemp" thirteen-component architecture;^[43] v.20.1 tested a lignin-based hardener;^[44] v.40 and v.41 (April 2026) set epoxidised hempseed oil as the matrix and added hemp-derived carbon fibre as the macro tier of a three-tier reinforcement hierarchy;^[45,46] v.17.2 (April 2026) fixed the core quartet that still defines the platform — epoxidised hempseed oil, citric acid, zinc acetate and furfuryl glycidyl ether.^[47] Version 56 (May 2026) added anhydrous ethanol as a dispersion aid to fix catalyst-dispersion problems.^[48]

Summer 2026 produced the designs this book builds on: the *Hempoxies* 74 proposal (1 July 2026), which set the explicit goal of a composite at least 90 % hemp-derived by mass reinforced only by hemp carbons;^[50] the *BASE Framework* SOPs (July 2026);^[49] the >99 % hemp-monoculture technical report and *Hempoxies* 100 (August 2026);^[51,52] the failure-analysis logbook (September 2026) that documented stoichiometric drift and catalyst traps;^[53] and the furan-nanothread experimental manual (6 October 2026).^[54]

A note on the name

"Hempoxy" is also the name of a commercial resin. ZILA BioWorks, a Renton, Washington company founded in 2014, makes a patented bio-epoxy resin from hempseed oil for composites, coatings and adhesives, and has demonstrated it in snowboards and is developing it for wind-turbine blades.^[35,36,37] Landry's work has drawn on ZILA's example as proof that hempseed-oil epoxies can be industrial, and she has reached out to ZILA about collaboration. **Hempoxies** — plural, the Landry Industries research platform — is distinct from ZILA's product: its defining choices are the hemp-carbon reinforcement, the rejection of raw fibers, the furan bridge, zinc-catalysed vitrimer chemistry and the 90 %+ single-plant mass target. Anyone commercialising under either name should take trademark advice.

WHAT "INVENTED" MEANS HERE

Each building block of *Hempoxies* exists in the peer-reviewed literature on its own: hempseed-oil epoxies, vitrimers, hemp carbon nanosheets, biochar fillers, glycidyl-ether diluents, furan nanothreads. Landry's contribution is the *system*: a specific architecture that combines them under one sourcing rule (everything from hemp, nothing raw) and one chemistry (zinc-catalysed transesterification), published openly as defensive prior art with a public version history.

CHAPTER 2

What a Hempoxy is

A reprocessable epoxy made from hempseed oil, reinforced only by carbon that was once hemp.

A Hempoxy is a composite with two phases. The **matrix** is an epoxy vitrimer: epoxidised hempseed oil (EHO), thinned and functionalised with furfuryl glycidyl ether (FGE), cured with carboxylic acids, and kept dynamic by a zinc catalyst. The **reinforcement** is a family of hemp-derived carbons at five length scales — graphene oxide and reduced graphene oxide sheets, carbon nanosheets, biochar particles and chopped short carbon fiber — every one of which has passed through a furnace. No untreated plant fiber enters the material.

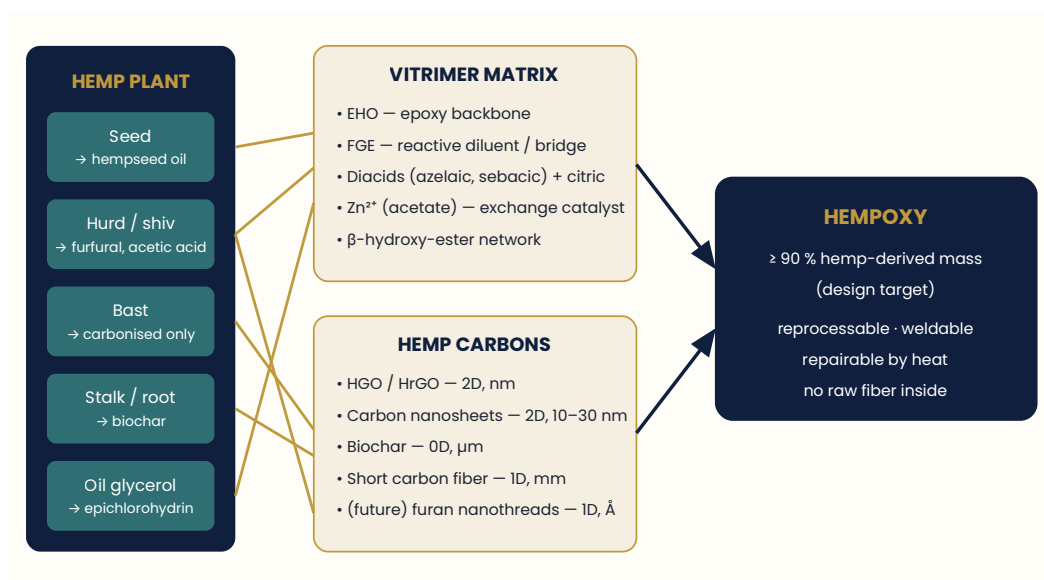


FIGURE 1 · The Hempoxies architecture. Each plant fraction feeds one or more components; bast fiber enters only after carbonisation. Composite-level properties are design targets.

The three design rules

1. **One plant.** Every carbon atom should be traceable to *Cannabis sativa* L. where a route exists, and the mass balance should say exactly which components are not yet hemp-derived (Chapter 9).
2. **No raw fiber.** Plant tissue enters only as carbon (pyrolysed, activated, oxidised or reduced). Chapter 3 explains why.

3. **Stay a vitrimer.** Every additive is judged by whether it preserves the catalysed bond-exchange that lets the material be reshaped, welded and recycled (Chapter 4).

Why a vitrimer and not an ordinary epoxy

Conventional epoxy thermosets are permanently crosslinked: once cured they cannot be melted, reshaped or meaningfully recycled. Vitrimers, introduced by Montarnal, Capelot, Tournilhac and Leibler in *Science* in 2011, are covalent networks that can rearrange their topology through thermally activated exchange reactions without changing the total number of bonds.^[4,5] They are insoluble like thermosets yet malleable when hot, and the first vitrimers were epoxy resins.^[5] For a plant-based composite this matters twice: a plant-oil epoxy that can be reground and remoulded keeps its embodied carbon in use instead of in landfill, and a cracked part can, in principle, be healed by heat.

CHAPTER 3

Why Hempoxies reject raw fibers

Hemp fiber is a superb textile and a troublesome reinforcement for a vitrimer. Carbonise it first.

Most hemp composites in the literature use the fiber as it comes off the decorticator: retted bast or hurd, perhaps alkali-washed, laid into a resin. Hempoxies deliberately does not. The rejection is not aesthetic; it follows from four chemical and physical facts about untreated plant fiber, three of which are documented in the composites literature and one of which is specific to vitrimers.

1 • Water

Natural fibers absorb moisture from humid air, from immersion and by capillary action, and that heterogeneity produces a weak fiber–matrix interface with poor stress transfer.^[32] The hydrophilic hydroxyl groups of cellulose are the main source of water uptake; swelling of the fibers then degrades the interface.^[34] In hemp-fiber/unsaturated-polyester composites, tensile and flexural properties fall as moisture uptake rises.^[33] A 2025 review in *SPE Polymers* catalogues the same problem across hemp composite systems and adds variability from growth conditions, stem position and fiber cross-section.^[31]

2 • Polarity mismatch

Poor adhesion between plant fibers and polymers arises from the polar, hydrophilic fiber surface meeting a comparatively non-polar, hydrophobic polymer.^[34] Coupling agents can help, but in hemp/polyethylene work they also lowered flexural strength after water exposure.^[33]

3 • Variability

Designing hemp-fiber components is complicated by the plant itself: fiber properties vary with origin, growth conditions, age, position on the stem, separation method and the irregular fiber cross-section.^[31] Carbonisation homogenises: whatever the stem position, a fiber held at 1000 °C under nitrogen ends as a carbon of roughly predictable composition.

4 · Raw fiber interferes with the vitrimer itself (Hempoxies hypothesis)

The fourth reason is the one that decides the matter for Hempoxies, and it is stated here as a hypothesis to test. A transesterification vitrimer works because ester groups exchange with free hydroxyls under a zinc catalyst. Raw cellulose, hemicellulose and lignin carry an enormous excess of free hydroxyls and some carboxyls, plus bound water. In a hempseed-oil vitrimer those groups would be expected to (a) consume epoxide groups during cure and skew the carefully set acid:epoxy ratio, (b) coordinate or hydrolyse the zinc catalyst, and (c) graft the network permanently to the fiber surface, so that the reprocessing step – grinding and hot-pressing at roughly 180–200 °C – subjects lignocellulose to repeated thermal stress near the temperatures where hemicellulose begins to decompose. Carbonised hemp, by contrast, is largely inert to transesterification; the >99 % report and the failure-analysis logbook both treat biochar and carbon fiber as non-interfering fillers. ^[51,53]

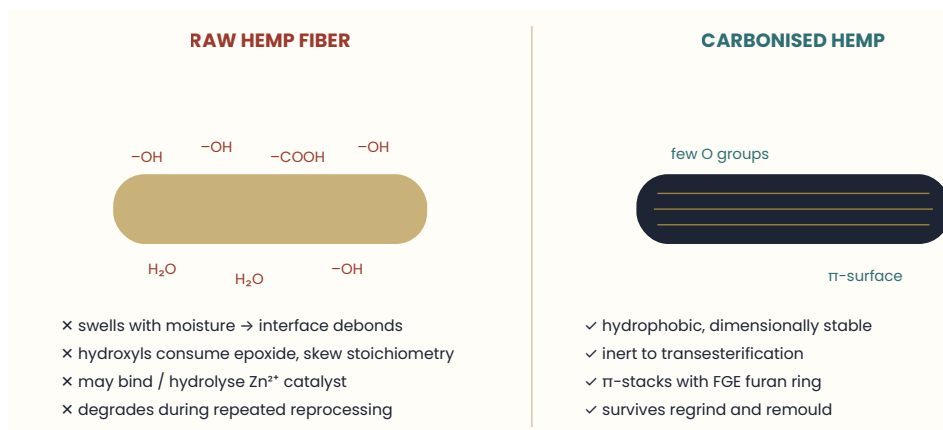


FIGURE 2 · Why carbonisation precedes incorporation. Left-column effects on moisture and interface are documented in the literature [31–34]; catalyst and stoichiometry effects are Hempoxies hypotheses to be tested.

THE COST OF THE RULE

Carbonisation is not free. A 2025 study carbonising hemp fiber slowly to 1000 °C under nitrogen recovered only 18 % of the mass as carbon, and in compression-moulded phenolic composites the raw hemp fiber actually gave higher flexural strength (69 MPa at 40 % loading) than the carbonised fiber – although the carbonised composites were more thermally stable, more hydrophobic and, when extruded, mechanically better than the raw-fiber ones. ^[13] Rejecting raw fiber is therefore a trade: lower mass yield and more energy, bought in exchange for moisture resistance, a clean vitrimer chemistry and recyclability. Hempoxies makes that trade knowingly.

CHAPTER 4

The hempseed-oil vitrimer matrix and its zinc catalyst

Oxirane rings on a triglyceride, opened by acids, rearranged by zinc.

Epoxidised hempseed oil

Hempseed oil is rich in polyunsaturated fatty acids, which makes it a good substrate for epoxidation with in-situ peracids. The Hempoxies dossiers use an in-situ peracetic route (acetic acid plus hydrogen peroxide with a mineral-acid catalyst at about 70 °C) targeting an oxirane oxygen content near 7.2 %, which corresponds to an epoxy equivalent weight (EEW) of about 222 g/eq ($16 \div 0.072$).^[51] Epoxidised hemp oil is an established bio-based resin: Manthey and colleagues showed in 2013 that EHO-based bioresins in jute-fiber composites performed marginally better than epoxidised soybean oil, though synthetic epoxy still had the best mechanical and water-resistance properties.^[3]

The most direct precedent for an all-hemp matrix is the 2023 *Polymers* paper by Lerma-Canto, Samper, Dominguez-Candela, Garcia-Garcia and Fombuena, which cured EHO with mixtures of petroleum-derived methyl nadic anhydride (MNA) and maleinised hemp oil (MHO).^[2] Raising the MHO fraction lowered strength and raised ductility; the balanced formulation was 25 % MHO / 75 % MNA, which absorbed 180 % more impact energy than pure MNA and cured in about 78 minutes rather than 170.^[2] The lesson for Hempoxies is two-sided: an all-hemp anhydride hardener is possible, but on its own it makes a soft network. That is why Hempoxies leans on short diacids, citric acid and a furanic diluent rather than MHO alone.

The acid cure and the β -hydroxy ester

When a carboxylic acid opens an epoxide ring, it forms an ester and leaves a hydroxyl on the adjacent carbon — a β -hydroxy ester. A network built this way is therefore studded with exactly the two partners a transesterification needs: esters and nearby free hydroxyls. Add a catalyst and, above a characteristic temperature, esters swap partners. Crosslink count stays constant; topology flows.

① CURE — epoxide ring-opening by acid

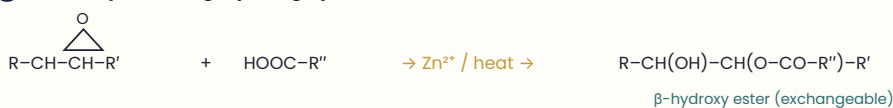
② EXCHANGE — associative transesterification above T_v 

FIGURE 3 · Cure and exchange chemistry. The acid-epoxy reaction creates β -hydroxy esters; Zn^{2+} catalyses their associative exchange, the mechanism Leibler's group introduced for epoxy vitrimers [4].

Forms of zinc

Zinc is the workhorse catalyst for epoxy-acid vitrimers. EXAFS work published in *Polymer Chemistry* in 2016 found the zinc cation in an epoxy-acid network coordinated by four oxygen atoms, two of them negatively charged carboxylates, and concluded that network-bound Zn^{2+} is a good option for catalysing transesterification and conferring vitrimer properties; the same paper notes that zinc was selected in the earlier composite-oriented vitrimer work for its superior thermal robustness.^[6] Three forms appear across the Hempoxies corpus and the literature:

Form	Where it appears	Hempoxies notes
Zinc acetate, $\text{Zn}(\text{OAc})_2 \cdot (2\text{H}_2\text{O})$	Bio-vitrimer of epoxidised canola oil and lactic acid at 1–2 wt% [8]; Hempoxies v.17.2, 56, 74 [47,48,50]	Preferred. The acetate ligand can come from hemp-shive acetic acid (Ch. 7), leaving zinc metal as the only mineral atom. Use anhydrous or account for hydrate water.
Zinc acetylacetonate, $\text{Zn}(\text{acac})_2$	DGEBA/sebacic-acid vitrimer [7]; Hempoxies >99 % report and Hempoxies 100 [51,52]	Excellent solubility in oils; the acetylacetone ligand is a petrochemical, so it counts against the hemp fraction.
Polymeric Zn^{2+} ionomers	Poly(acrylonitrile-co-zinc methacrylate) out-performed $\text{Zn}(\text{OAc})_2$ and TBD at equal loading [9]	Future option: a hemp-derived carboxylate polymer bearing Zn^{2+} could make the catalyst part of the network.

Catalyst loading is expressed in moles of Zn per mole of carboxyl. The Hempoxies dossiers converge on roughly 2–5 mol %; the failure-analysis logbook records that too little zinc stalls exchange while too much shortens pot-life dramatically and invites hydrolysis in humid service.^[53] Chapter 8 uses 5 mol % as the design value and treats it as a variable to be measured by stress relaxation.

REALITY CHECK ON GLASS TRANSITION

Plant-oil vitrimers made with flexible aliphatic acids can be rubbery. The epoxidised-canola-oil/lactic-acid vitrimers had glass transitions between –15 and –23 °C, with topology-freezing temperatures of 195–235 °C.^[8] A structural Hempoxy therefore depends on high crosslink density, the rigid furan ring of FGE, the trifunctional citric acid and heavy carbon loading to reach a useful service temperature. Hempoxies targets in this book are set accordingly modestly (Chapter 15).

CHAPTER 5

Furfuryl glycidyl ether: diluent and bridge

A five-membered furan ring on one end, an epoxide on the other, and a hemp-shive origin.

Furfuryl glycidyl ether (FGE, CAS 5380-87-0, $C_8H_{10}O_3$, 154.16 g/mol, density about 1.12 g/mL) is a monofunctional epoxy carrying a furan ring.^[21] It is widely used as a reactive diluent: it lowers the viscosity of epoxy formulations and, unlike a solvent, reacts into the network rather than evaporating.^[21] A 2023 RSC *Advances* study of bio-based reactive diluents reports earlier work by Ding and colleagues showing that FGE reduces viscosity more strongly than the commercial diluent Cardura E10P.^[19] Related furfural-derived epoxies have been shown in 2026 to reduce DGEBA viscosity and to raise tensile strength.^[20]

Role 1 • Rheology

EHO is viscous, and every carbon filler raises viscosity further. Without a diluent, the 30–60 wt% carbon loadings the Hempoxies variants need would not wet out. FGE is the processing enabler; the Hempoxies 100 specification uses a solvent-free EHSO/FGE blend specifically to avoid ethanol.^[52]

Role 2 • The bridge (Hempoxies hypothesis)

The furan ring is aromatic and electron-rich. Hempoxies proposes that it engages in π – π stacking with the graphitic domains of rGO, nanosheets and carbon fiber, so that one FGE molecule is simultaneously bonded covalently into the network through its glycidyl end and physically anchored to the carbon surface through its furan end. That would make FGE a molecular coupling agent made from the same plant as the carbon. The >99 % report adds a second possibility: at elevated temperature, furans can undergo Diels–Alder chemistry with suitable dienophiles, which could supply a secondary population of reversible bonds.^[51] Both claims are testable (Raman G-band shifts, interfacial shear testing) and neither is yet demonstrated for this system.

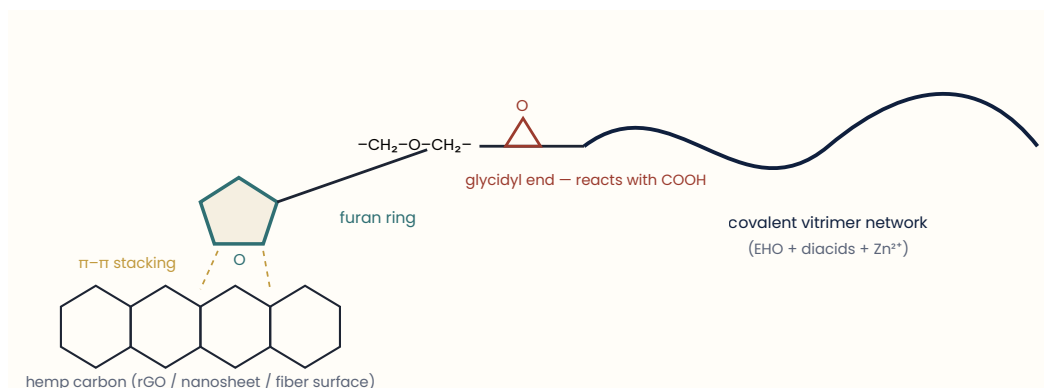


FIGURE 4 · FGE as a bridge. The glycidyl end enters the network covalently; the furan end is proposed to anchor to graphitic hemp carbon by π - π stacking (Hempoxies hypothesis).

Making FGE from hemp

FGE is made by glycidylating furfuryl alcohol with epichlorohydrin. Both halves have hemp routes:

- **Furfuryl alcohol** comes from hydrogenating furfural, and furfural comes from the pentose sugars in hemicellulose. Brazdausks and colleagues at Riga Technical University obtained furfural from industrial-hemp shives at 64.8–67.2 % of the theoretical yield (9.4–9.7 wt% of oven-dry shives) using aluminium-sulfate catalysis at 160–180 °C, while retaining the cellulose for other products.^[22,23]
- **Epichlorohydrin** is conventionally made from propylene and chlorine, but the commercial Epicerol process makes it from glycerol instead, via dichloropropanol and dehydrochlorination; the licensor reports about 60 % lower CO₂ emissions and 20–40 times less wastewater than the propylene route.^[24] Glycerol is a by-product of transesterifying hempseed oil — so a hemp biorefinery that makes biodiesel or fatty-acid esters also makes the glycerol for its own FGE.

In carbon terms, five of FGE's eight carbons come from furfuryl alcohol and three from epichlorohydrin; that 5/8 split is what Chapter 9 uses when FGE is bought rather than made from hemp glycerol.

CHAPTER 6

The hemp carbon family

Five morphologies, five length scales, one feedstock.

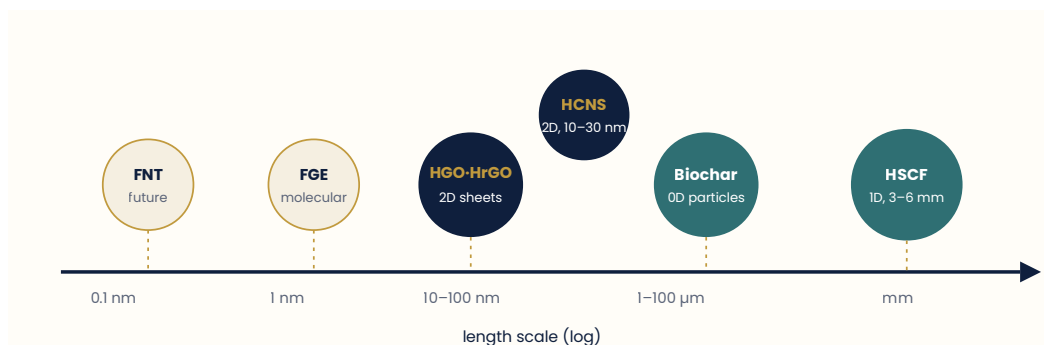


FIGURE 5 · The hierarchical reinforcement ladder. Each morphology targets a different failure mechanism: sheets deflect nano-cracks, biochar fills interstitial resin, short fiber carries load.

Hemp carbon nanosheets (HCNS)

The founding result is the 2013 ACS Nano paper from David Mitlin's group, then at the University of Alberta. Using hydrothermal carbonisation followed by activation of hemp bast fiber, they made interconnected, partially graphitic carbon nanosheets 10–30 nm thick with specific surface area up to 2287 m²/g, up to 58 % mesoporosity and electrical conductivity of 211–226 S/m.^[1] The authors credited the multilayered structure of the bast fiber itself for the sheet morphology.^[1] Note what this means for the "no raw fiber" rule: hemp bast is not discarded by Hempoxies — it is the *best* nanosheet precursor, used only after it has been turned into carbon. The Hempoxies hypothesis is that wrinkled, porous nanosheets will anchor in the matrix by mechanical interlocking better than flat graphene, at a fraction of the cost.^[50]

Hemp biochar (HB)

Biochar is the cheapest and highest-volume hemp carbon. Slow pyrolysis of hemp residues to 1000 °C has given about 29 % solid carbon yield, with the volatile stream rich in phenols, furans and acetic acid that a biorefinery can recover.^[14] As an epoxy filler, biochar is well studied though not always kind: Miscanthus biochar raised epoxy Young's modulus 27 % at 20 wt% and peaked tensile strength at 10 wt%, with strength and elongation falling at higher loading.^[16] Wheat-straw biochar has doubled the Young's modulus of neat epoxy.^[17] For hemp specifically, Zecchi and colleagues carbonised hemp fiber at 400 °C and hurd at 550 °C as epoxy reinforce-

ments and found that agglomeration at high filler content hurt properties in a 1:1 hurd:fiber ratio, while 3:1 hurd:fiber was optimal.^[15] The design takeaway: biochar is for stiffness, interstitial filling and cost, not for strength, and its loading must be capped.

Hemp short carbon fiber (HSCF)

Carbonising hemp fiber slowly to 1000 °C under N₂ gave an 18 % yield in the 2025 *Materials* study, and carbonisation made the resulting composites more thermally stable and hydrophobic.^[13] Chopped to 3–6 mm, HSCF is the macro tier — the component that actually carries load. Its single-filament strength is the largest unknown in the whole Hempoxies programme and the first number the validation roadmap must measure.

Hemp graphene oxide (HGO) and reduced graphene oxide (HrGO)

Graphene oxide is usually made by oxidising graphite with the modified Hummers method, but biomass-derived activated carbon can stand in for graphite.^[18] In 2025, Fazi and colleagues showed that slow-pyrolysis biochar (900 °C, varied residence times) can replace graphite as the starting material for Hummers GO, and that a graphite-like biochar with high carbon content and extended conjugated domains is required.^[25] For Hempoxies the two forms play complementary roles. HGO, decorated with epoxide, hydroxyl and carboxyl groups, can bond covalently into the matrix but is insulating; HrGO restores the sp² lattice for electrical percolation but bonds weakly. The >99 % report proposes an HGO:HrGO ratio of 2:1 to 3:1 to balance them, and warns that GO surfaces adsorb the zinc catalyst — the "catalyst tax" discussed in Chapter 8.^[51]

Carbon	Precursor & route	Literature anchor	Role in Hempoxies	Window (wt% composite)
HCNS	Bast; hydrothermal carbonisation + activation	10–30 nm sheets, ≤ 2287 m ² /g, 211–226 S/m [1]	Interlocking, crack deflection, conductivity	1–15
HB	Stalk/hurd/root; slow pyrolysis 450–700 °C	~29 % yield at 1000 °C [14]; modulus gains, strength drops at high load [16,17]	Stiffness, interstitial fill, cost, CTE	5–20
HSCF	Bast; carbonised 1000–1500 °C, chopped 3–6 mm	18 % yield at 1000 °C [13]	Primary load path	20–35
HGO	Biochar; modified Hummers	Biochar can replace graphite [18,25]	Covalent interface, dispersion	0.5–2
HrGO	HGO; thermal or ascorbic-acid reduction	—	Electrical/thermal percolation	0.5–8

Table 6.1 · Hemp carbon morphologies. Literature values are cited; "role" and loading windows are Hempoxies design choices.

CHAPTER 7

Acids and additives

Sebacic acid is excellent chemistry and the wrong plant. Azelaic acid is the hemp answer.

Sebacic acid

Sebacic acid (decanedioic acid, C₁₀) is a proven vitrimer hardener: a 2021 *Materials* paper built an epoxy vitrimer from DGEBA, sebacic acid and Zn(acac)₂ and used Zn²⁺-catalysed transesterification to rearrange the network.^[7] Its long aliphatic chain gives toughness. But it is not a hemp product. Sebacic acid is made industrially by alkaline fission of the ricinoleic acid in **castor oil**, typically at about 250 °C with caustic soda, co-producing 2-octanol.^[26] Optimised alkali fusion of castor oil reached 68.8 % yield with Pb₃O₄ as the best catalyst.^[27] Hempseed oil contains no ricinoleic acid. In Hempoxies, sebacic acid is therefore a bio-based but *non-hemp* input, allowed in "today-sourced" formulations and replaced in hemp-integrated ones. The lead catalyst in the classic route is a further green-chemistry reason to prefer the alternative.

Azelaic acid — the hemp-native diacid

Azelaic acid (nonanedioic acid, C₉) differs from sebacic acid by one methylene group and plays the same role. Industrially it is made by oxidative cleavage of the C₉ double bond of oleic acid, classically by ozonolysis.^[28] Two-step oxidative cleavage processes now use hydrogen peroxide and air instead of ozone, and Novamont's commercial process converts the unsaturated chains of vegetable oils — oleic, linoleic and linolenic — into azelaic acid and co-products.^[29] Tungstic-acid/H₂O₂ and dihydroxylation-then-hypochlorite routes have also been demonstrated as replacements for ozonolysis.^[30] Because every common unsaturated C₁₈ chain in hempseed oil has a double bond at C₉, a hemp biorefinery can split part of its oil stream into azelaic acid and use it as the Hempoxies diacid. This substitution is what moves the composite past 90 % hemp-derived mass (Chapter 9).

Citric acid

Citric acid is a tricarboxylic acid with a hydroxyl, used since Hempoxies v.17.2 as a branching crosslinker.^[47] Its three carboxyls raise crosslink density and help offset the softness of the oil backbone; its own hydroxyl adds exchange partners. Citric acid is produced commercially by fermentation; in a hemp-integrated plant the sug-

ar feedstock would be hemp cellulose hydrolysate. Its drawbacks are limited solubility in oil and a tendency to dehydrate on heating, which is one reason v.56 introduced anhydrous ethanol as a dispersion aid and Hempoxies 100 later moved to a solvent-free FGE-diluted route.^[48,52]

Acetic acid

Acetic acid has three jobs in the Hempoxies flowsheet and must be kept out of a fourth. It is (1) the peracid precursor for epoxidising hempseed oil, (2) the ligand of the zinc acetate catalyst and (3) a by-product that comes free with hemp-shive furfural: Brazdauskas quantified 51.4 kg of acetic acid per tonne of dry shives alongside the furfural.^[22] It must not be used as a *curing* acid: being monofunctional, every acetic acid that reacts with an epoxide caps a chain instead of bridging two, lowering crosslink density. Residual acetic acid in the resin therefore counts against the carboxyl budget in Chapter 8 and should be stripped after epoxidation.

Other acids and additives

Additive	Function	f (COOH)	AEW g/eq	Hemp route
Azelaic acid	Primary diacid crosslinker	2	94.1	Yes — oxidative cleavage of hempseed-oil C18 chains [29]
Sebacic acid	Diacid crosslinker, toughness	2	101.1	No — castor oil [26]
Citric acid	Branching crosslinker	3	64.0	Via fermentation of hemp sugars
Lactic acid	Hydroxy-acid; soft networks [8]	1	90.1	Via fermentation of hemp sugars
Maleinised hemp oil	Anhydride hardener, flexibility [2]	anhydride	by titration	Oil yes; maleic anhydride conventionally petrochemical
Vanillic acid	Aromatic rigidity (proposed in v.74) [50]	1 (+OH)	168.1	From lignin oxidation (research stage)
Acetic acid	Epoxidation, Zn ligand — not a curative	1	—	Yes — co-product of shive furfural [22]
Anhydrous ethanol	Nanofiller dispersion, fully removed	—	—	Fermentation of hemp sugars [51]

Table 7.1 · Candidate acids and additives. "Hemp route" indicates whether a published route from hemp-available feedstocks exists.

AEW = acid equivalent weight = molar mass $\div$ number of carboxyl groups. Vanillic and lactic acid are monocarboxylic; their hydroxyls add exchange sites but they cap rather than bridge, so they belong in small amounts only.

CHAPTER 8

Stoichiometry, worked from first principles

Count equivalents, not grams. Then measure them, because the oil will not match the textbook.

The equivalents balance

Every curing calculation for an epoxy–acid vitrimer reduces to one ratio:

$$r = \Sigma (m_{\text{acid},i} \div \text{AEW}_i) \div \Sigma (m_{\text{epoxy},j} \div \text{EEW}_j)$$

where EEW is grams of resin per mole of epoxide and AEW is grams of acid per mole of carboxyl. For the Hempoxies components:

EHO

EEW = 16 ÷ OOC. At 7.2 % oxirane oxygen, EEW ≈ 222 g/eq. Measure by titration (AOCS Cd 9-57).

FGE

Monofunctional; EEW = 154.2 g/eq at 100 % purity. Correct by GC purity.

Acids

Azelaic 94.1 · Sebacic 101.1 · Citric 64.0 g/eq.

Choosing r

At $r = 1$ every epoxide finds a carboxyl and every ester is born with its β -hydroxyl. The Hempoxies failure-analysis logbook nevertheless recommends running slightly acid-lean, at an epoxy:carboxyl ratio of 1:0.8, and lists the exact 1:1 ratio as a documented error mode because theoretical equivalents computed from datasheets drift from the real oil.^[53] Running acid-lean leaves a small epoxide excess that can etherify, consuming no exchangeable ester but adding permanent crosslinks; running acid-rich leaves free acid that lowers Tg and can hydrolyse esters in humid service. This book uses $r = 0.90$ as a central design value and brackets it at 0.80 and 1.00 in the first design-of-experiments.

Worked example: the HX resin (per 80 g EHO)

1. Epoxide from EHO: $80 \div 222.2 = 0.360$ eq.
2. Epoxide from FGE at 14 g: $14 \div 154.16 = 0.091$ eq. Total epoxide = 0.451 eq.
3. Carboxyl required at $r = 0.90$: $0.90 \times 0.451 = 0.406$ eq.

4. Split 60 % diacid / 40 % citric on an equivalents basis: diacid 0.244 eq; citric 0.162 eq.
5. Masses — azelaic: $0.244 \times 94.11 = 22.9$ g (or sebacic: $0.244 \times 101.12 = 24.6$ g); citric: $0.162 \times 64.04 = 10.4$ g.
6. Catalyst at 5 mol % Zn per carboxyl: $0.406 \times 0.05 = 0.0203$ mol Zn $\rightarrow$ anhydrous $\text{Zn}(\text{OAc})_2$: $0.0203 \times 183.48 = 3.72$ g.

Component	Mass, g (azelaic)	wt% resin	Mass, g (sebacic)	wt% resin	eq
EHO (EEW 222.2)	80.0	61.1	80.0	60.3	0.360 ep
FGE (EEW 154.2)	14.0	10.7	14.0	10.5	0.091 ep
Diacid	22.9	17.5	24.6	18.5	0.244 COOH
Citric acid	10.4	7.9	10.4	7.8	0.162 COOH
$\text{Zn}(\text{OAc})_2$, 5 mol %	3.7	2.8	3.7	2.8	0.020 mol Zn
Total	131.0	100	132.7	100	r = 0.90

Table 8.1 · HX base resin, computed in the book's calculation script. Percentages of the resin phase; projected design values.

Corrections that real batches need

- **Titrate, don't assume.** Measure EHO EEW and the acid value of every acid lot; the logbook records a 12 % shift between theoretical and titrated EEW as a common cause of stoichiometric drift.^[53]
- **Residual acetic acid** from epoxidation adds carboxyl equivalents that cap chains. Subtract them from the acid budget or strip them.
- **Hydrate water.** If $\text{Zn}(\text{OAc})_2 \cdot 2\text{H}_2\text{O}$ (219.5 g/mol) is used, scale the mass by $219.5/183.5$ and remove the water before cure.
- **The catalyst tax.** GO and high-surface carbons adsorb zinc. The >99 % report recommends adding 0.5–1.0 phr catalyst once total nano-filler exceeds about 2 phr, or pre-loading zinc onto the GO.^[51] Verify by stress-relaxation rather than by adding catalyst blindly.
- **Surface acids on carbons.** HGO carries carboxyl and epoxide groups that react with the matrix. Titrate the GO (Boehm titration) and include its groups in the balance when HGO exceeds ~1 wt%.

CHAPTER 9

Reaching 90 %+ hemp content honestly

The carbons are easy. The resin decides. And sourcing decides the resin.

"Hemp content" can mean two different things, and Hempoxies uses both explicitly:

- **Hemp-derived mass fraction** — a mass balance over the formulation: what share of the finished composite's mass came from hemp through a documented route. This is the Hempoxies 90 % target.
- **Bio-based carbon content** — what ASTM D6866 measures. The method uses the ratio of carbon-14 to total carbon to distinguish contemporary biomass carbon from fossil carbon.^[38] It cannot tell hemp from castor or corn; it only says "recently alive." The current edition is D6866-24a.^[39]

Three sourcing scenarios

The calculation script applies the HX base resin of Chapter 8 to each variant and attributes mass as follows. Hemp carbons count 100 % hemp in every scenario. Zinc metal never counts.

Scenario	Diacid	Citric	FGE epichlorohydrin part	Zn acetate ligand
A · Today-sourced	Sebacic (castor)	Commercial	Fossil (FGE 5/8 hemp)	Purchased
M · Partial integration	Azelaic from hempseed oil	Commercial	Bio, non-hemp (5/8 hemp)	Purchased
B · Hemp-integrated	Azelaic from hempseed oil	From hemp sugars	From hempseed-oil glycerol	Hemp acetic acid

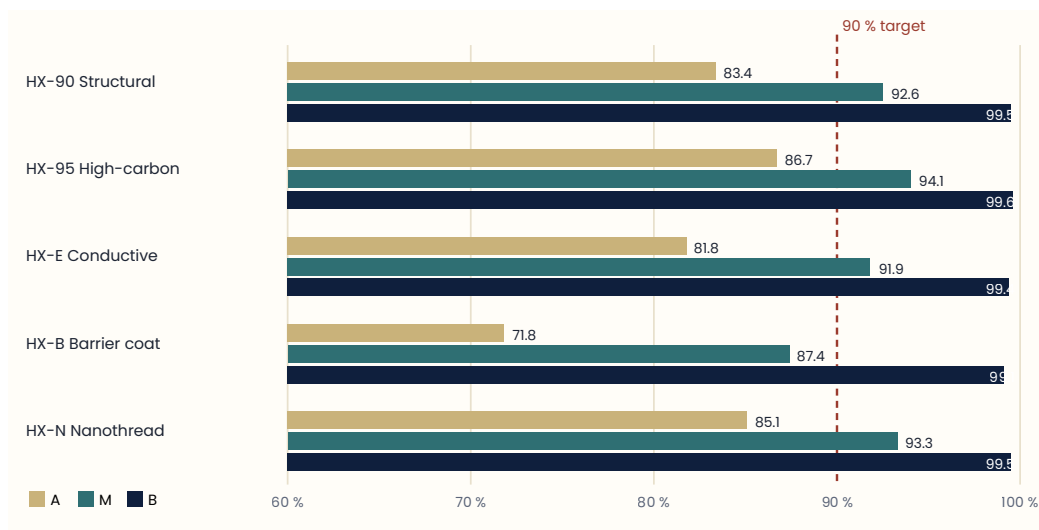


FIGURE 6 · Hemp-derived mass fraction by variant and sourcing scenario (projected, mass-balance basis). With today's commercial acids no variant reaches 90 %; replacing sebacic with hemp-derived azelaic acid crosses the line for every structural variant.

What the numbers say

Three conclusions follow, and they reshape the earlier Hempoxies claims.

1. **With commercial acids, 90 % is out of reach.** In scenario A the resin itself is only about 67 % hemp-derived, because sebacic acid, citric acid and the epichlorohydrin part of FGE are not hemp. Even the high-carbon variant stops at 86.7 %. The bio-based carbon content in scenario A is still high — about 96–97 % for the structural variants — but bio-based is not the same as hemp.
2. **The single most important substitution is the diacid.** Moving from castor-derived sebacic acid to hemp-derived azelaic acid (scenario M) lifts every structural variant above 90 %. That one choice is the 90 % rule.
3. **The ">99 %" figure is only reachable in a fully integrated biorefinery.** Scenario B reaches 99.1–99.6 %, limited only by zinc metal (0.4–0.9 wt%). That is consistent with the >99 % report's claim — but only when every acid, ligand and epichlorohydrin molecule is made from hemp, which no supplier currently offers.

Carbon loading helps but cannot rescue a non-hemp resin. The barrier-coat variant, which is 85 % resin, shows it: 71.8 % in scenario A, 87.4 % in M. Coatings will reach 90 % only in scenario B.

CHAPTER 10

Example variants

Five starting points for the first laboratory matrix. Every property here is a target to be measured.

Variant	Resin	HSCF	HB	HCNS	HGO	HrGO	FNT	Hemp % A / M / B
HX-90 Structural	50	30	12	5	1.5	1.5	—	83.4 / 92.6 / 99.5
HX-95 High-carbon	40	35	17	5	1.5	1.5	—	86.7 / 94.1 / 99.6
HX-E Conductive	55	—	20	15	2	8	—	81.8 / 91.9 / 99.4
HX-B Barrier coat	85	—	10	3	2	—	—	71.8 / 87.4 / 99.1
HX-N Nanothread	45	30	12	5	1.5	1.5	5	85.1 / 93.3 / 99.5

Table 10.1 · Variant compositions (wt% of composite). Resin = HX base resin, Table 8.1. Hemp % from Figure 6.

HX-90 · Structural

The reference formulation. Half resin by mass keeps fiber wet-out realistic with compression moulding; 30 % chopped HSCF is the load path; 12 % biochar fills interstitial resin pockets; the nano tier is held at 8 % total. Intended use: panels, brackets, sporting-goods cores. First measurements: flexural modulus and strength (ASTM D7264), Tg by DMA, stress relaxation at 160–200 °C, and three regrind/re-mould cycles.

HX-95 · High-carbon

Pushes the carbon phase to 60 %. This is the variant most likely to beat the hemp target and least likely to stay a vitrimer: at 40 % resin, chain mobility and catalyst access fall. It exists to find the ceiling. Expect to need the higher catalyst bracket and vacuum-assisted compression.

HX-E · Conductive / EMI

No fiber; 25 % nano-tier with HrGO-rich ratio for electrical percolation. Hemp nanosheets already conduct at 211–226 S/m as powders;^[1] whether the composite percolates is the test. Use: antistatic housings, EMI shielding, heated surfaces.

HX-B · Barrier coating

A low-viscosity coat for wood, concrete and metal, with platelets for tortuosity. Coatings are where ZILA's commercial hempseed epoxy already competes, which makes it the fastest route to a market comparison.^[37]

HX-N · Nanothread (future)

HX-90 with 5 % furan nanothreads replacing part of the resin. Placeholder for Chapter 14; not makeable today in any quantity.

CHAPTER 11

Processing protocol and failure modes

The logbook of how not to make Hempoxies is as valuable as the recipe.

Reference protocol (laboratory scale)

1. **Precondition carbons.** Dry biochar, HSCF and nanosheets at 120 °C under vacuum; record moisture by Karl Fischer. The failure logbook flags moisture above ~500 ppm as a cause of ring-opening by water and catalyst poisoning.^[53]
2. **Pre-load the catalyst.** Dissolve Zn(OAc)₂ in the warm diacid/citric melt (or, for GO-rich variants, stir it onto the GO in hemp ethanol and dry), so zinc is coordinated to carboxylates before epoxide is present.
3. **Disperse the nano tier in FGE** (not in ethanol, where avoidable) by bath then probe sonication; FGE is the carrier that will later anchor to the carbons.
4. **Combine with EHO** and mill (three-roll mill or high shear). Add the biochar.
5. **Add the acid/zinc melt at ≤ 80 °C**, degas under vacuum.
6. **Fold in HSCF** at low shear to avoid fiber breakage.
7. **Cure in steps** — the dossiers use 120 °C / 2 h, 150 °C / 2 h, 180 °C / 2 h — under compression.^[51]
8. **Reprocess** by grinding and hot pressing at 180–200 °C, 1–5 MPa, 10–30 min.^[51]

Documented failure modes

Failure	Cause	Prevention
Stoichiometric drift	Datasheet EEW/AEW instead of titrated values	Titrate every lot; run $r = 0.8\text{--}1.0$ bracket
Oxirane loss in epoxidation	Temperature above $\sim 60\text{--}70\text{ }^{\circ}\text{C}$; residual acid opens rings	Controlled exotherm; neutral wash; dry over Na_2SO_4
Stalled exchange	Too little Zn or Zn adsorbed on GO	Stress-relaxation QC; pre-load Zn; catalyst tax
Short pot-life / premature gel	Excess Zn, hot mixing	Upper bound on Zn; add acid melt $\leq 80\text{ }^{\circ}\text{C}$
Hydrolytic weakness	Moisture, ionic residues (Na^+ , Cl^-), excess free acid	Dry fillers; wash GO to neutral; keep $r \leq 1$
Voids, poor wet-out	Carbon loading beyond viscosity window	FGE window; vacuum degassing; compression
TRL overreach	Publishing projected values as results	Label every number; placeholders for data

Table 11.1 · Condensed from the Hempoxies failure-analysis logbook [53] and Hempoxies 100 [52].

CHAPTER 12

Green chemistry principles for Hempoxies

The twelve principles are a checklist, not a slogan. Hempoxies passes some, works toward others, and fails one on purpose.

Paul Anastas and John Warner set out twelve principles of green chemistry in *Green Chemistry: Theory and Practice* (Oxford University Press, 1998), the book that founded the field.^[10,11] Warner himself has said he has never addressed all twelve simultaneously in any single piece of work.^[12] Table 12.1 maps Hempoxies against them honestly.

#	Principle (paraphrased)	Hempoxies practice	
1	Prevent waste	Vitrimer regrind/remould keeps parts in use; biorefinery cascades shives → furfural + acetic acid → residue → biochar	●
2	Atom economy	Epoxy-acid addition cure has no by-product; epoxidation and Hummers oxidation are atom-poor	●
3	Less hazardous syntheses	Epichlorohydrin and $\text{KMnO}_4/\text{H}_2\text{SO}_4$ (Hummers) remain hazardous	○
4	Safer products	BPA-free; no amine hardeners; zinc instead of tin	●
5	Safer solvents and auxiliaries	Solvent-free FGE route (Hempoxies 100); ethanol only where needed, fully removed	●
6	Energy efficiency	Pyrolysis at 1000 °C+ and 180 °C cures are energy-heavy	○
7	Renewable feedstocks	The defining principle: one plant, 90 %+ by mass	●
8	Avoid derivatives	Few protecting steps; FGE glycidylation is a derivatisation	●
9	Catalysis	Zn^{2+} catalyses both cure and exchange at a few mol %	●
10	Design for degradation	Designed for <i>reprocessing</i> , not degradation; durable by intent	●
11	Real-time analysis	In-line FTIR of oxirane band and rheometry proposed	●
12	Accident prevention	Peracid exotherms and pyrolysis gases need engineered control	●

Table 12.1 · The twelve principles [10] applied to Hempoxies. ● strong · ● partial · ○ open problem.

The three open problems, and their routes

- **Hummers oxidation** is the least green step in the platform. Mitigations: keep HGO below ~2 wt%; prefer direct activation (HCNS) where conductivity is not required; evaluate electrochemical exfoliation of graphitised hemp carbon as a research option.
- **Epichlorohydrin** is toxic but makes the glycidyl group. The glycerol route cuts its footprint,^[24] the longer-term alternative is epoxidising furfuryl-derived allyl ethers with peroxide, avoiding chlorine — a research topic, not a protocol.
- **Energy** for carbonisation should come from the pyrolysis gases themselves; the volatile stream from hemp slow pyrolysis is energy- and chemical-rich.^[14]

CHAPTER 13

Organic chemistry, certified organic hemp, and "organic Hempoxies"

"Organic" means two things. Hempoxies is entirely the first and can partially be the second.

Organic chemistry

In the chemist's sense every Hempoxies reaction is organic chemistry: electrophilic epoxidation of alkenes by peracids; nucleophilic ring-opening of oxiranes by carboxylates; Lewis-acid-catalysed transesterification; acid-catalysed dehydration of pentoses to furfural and its hydrogenation to furfuryl alcohol; Williamson-type glycidylation; oxidative cleavage of alkenes to azelaic acid; and, for nanothreads, pressure-driven [4+2] cycloadditions of furan.^[54,55] The corpus already contains standard operating procedures for each step.^[51]

Certified organic

In the agricultural sense, "organic" is a regulated claim. In Canada it is governed by CAN/CGSB-32.310 (general principles and management standards) and CAN/CGSB-32.311 (permitted substances lists); the latter lists substances by table and forbids using a listed substance outside the scope of its table except as annotated.^[57,58] As far as could be verified for this book, those tables are written for crop production, livestock and the preparation of agricultural products. A thermoset composite made with epichlorohydrin, Hummers oxidants and a zinc catalyst falls outside them, so **a finished Hempoxy cannot currently carry a Canada Organic claim**, and this book makes none.

What can be certified, and how to say it truthfully

1. **Certified organic hemp feedstock.** Seed, stalk and shives can be grown and handled under CAN/CGSB-32.310 by an accredited certifier. That is achievable today.
2. **Organic-integrity chain of custody.** Segregation of certified organic hemp through oil pressing, shive processing and pyrolysis, with documented lot traceability – the same discipline the organic standard imposes, applied to industrial processing.

3. **Bio-based content verification** by ASTM D6866 on the finished part.^[38]
4. **A truthful label**, for example: "*Made with ≥ 90 % hemp-derived materials from certified organic hemp; bio-based carbon content X % (ASTM D6866).*" Not: "certified organic composite."

A Hempoxies-specific "organic hempoxy" protocol would go further: no Hummers step (use HCNS and HrGO by thermal routes only), azelaic acid made by peroxide/air cleavage rather than ozone, citric acid fermented from certified organic hemp sugars, and zinc acetate made from mineral zinc oxide and hemp acetic acid. Even then, its organic claim would rest on a certifier agreeing to a new scope — a conversation worth opening with Canadian certifiers and the Universal Declaration of Organic Rights community the author leads.

CHAPTER 14

The future: Hemp Furan Nanotreads

A diamond-cored thread whose every carbon was once a hemp shive – and the pressure gap that stands in the way.

What nanotreads are

Carbon nanotreads are one-dimensional sp^3 -rich polymers with sub-nanometre widths and diamond-like cores, predicted to combine high tensile strength with flexibility. They form by pressure-induced polymerisation of stacked sp^2 molecules such as benzene, which requires onset pressures of 17 GPa or more.^[55] In 2021, Huss, Badding, Elacqua and co-workers reported that furan polymerises into crystalline nanotreads at ambient temperature with an onset of only 10 GPa – because furan is less aromatic – and that slow compression to 15 GPa and decompression to 1.5 GPa produced a sharp six-fold diffraction pattern with d-spacings of 4.75–4.9 Å.^[55] The Advanced Photon Source's HPCAT summary describes this as the lowest recorded nanotread onset pressure.^[56] Theory has since rationalised why furan and thiophene threads form at about 15 and 35 GPa respectively.^[59]

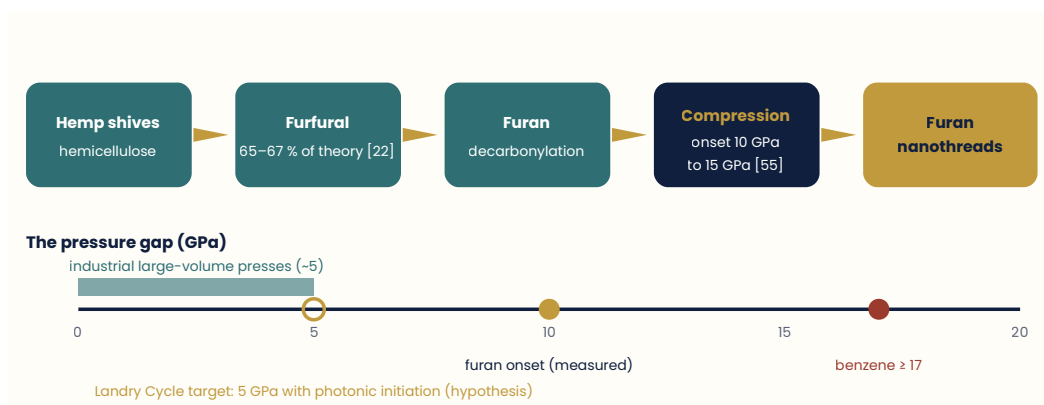


FIGURE 7 · From hemp shive to furan nanotread. Each link is documented separately; no published work has yet run the whole chain from hemp biomass. The 5 GPa photo-assisted route is the Hempoxies hypothesis.

The hemp route

Every link from plant to precursor exists: hemp shives give furfural (Chapter 5); furfural is decarbonylated industrially to furan; and furan is the lowest-pressure nanothread precursor known. Landry's October 2026 experimental manual sets out this route explicitly and is careful to label it TRL 1-2: every link is documented in the literature on its own, but no published work yet runs hemp biomass all the way to crystalline nanothreads.^[54] Furan from hemp is chemically identical to furan from corncobs — the claim of novelty is the integrated, single-plant supply chain and its use in Hempoxies, not the threads themselves.

The "Landry Cycle" hypothesis: 5 GPa

The industrial obstacle is pressure. Diamond-anvil cells reach 10–15 GPa only on microscopic samples; large-volume presses work in the single-digit-GPa range. Since December 2025, Landry has proposed closing the gap by photonic initiation — first ultraviolet excitation through moissanite anvils at about 8 GPa, then resonant two-photon absorption with a femtosecond 450 nm laser at about 5 GPa — to seed cycloaddition below the thermal onset.^[43,54] This is a hypothesis without experimental support yet. It should be tested first in a diamond-anvil cell with in-situ Raman (loss of the $\sim 1500\text{ cm}^{-1}$ C=C band, growth of sp^3 C-H) and X-ray diffraction looking for the 4.75–4.9 Å six-fold pattern reported by Huss and colleagues.^[55]

Why nanothreads belong in Hempoxies

- **Chemical kinship.** Furan-derived threads carry an oxygen in their repeat structure. The FGE in the matrix carries the same furan heritage, so thread-matrix compatibility is a natural hypothesis.
- **The missing scale.** The carbon ladder (Figure 5) has sheets, particles and fibers; nanothreads add a stiff 1D element at the ångström scale, between molecule and sheet.
- **Related chemistry is moving.** Double-core nanothreads have been formed from α -fural, a molecule with two furan rings, via a pressure-induced planarisation pathway.^[60] Furan-family precursors are an active research front.

DO NOT OVER-PROMISE

Nanothread mechanical properties quoted in the wider literature are predictions for ideal threads. Real furan nanothread samples are milligram-scale crystals made in diamond-anvil cells. HX-N (Chapter 10) is a placeholder for a material that does not yet exist in usable quantity.

CHAPTER 15

Validation roadmap

From TRL 1–2 to TRL 4: six gates, each with a number that can fail.

Gate	Test	Pass criterion (target)
G1 · Resin	EHO titration; neat HX resin cure (DSC), Tg (DMA)	EEW within ±5 % of design; Tg ≥ 40 °C neat
G2 · Vitrimer	Stress relaxation 160–200 °C; Arrhenius fit	Relaxation to 1/e in ≤ 10 min at 180 °C; ≥ 90 % property retention after 3 regrinds
G3 · Carbons	HSCF single-filament strength; HCNS BET; HGO C/O	Measured values recorded; HSCF ≥ 0.5 GPa to justify the structural tier
G4 · Composite	HX-90 flexural (ASTM D7264), void content	Flexural modulus ≥ 5 GPa; voids ≤ 2 %; Tg ≥ 60 °C
G5 · Durability	Water uptake; wet/dry property retention	Lower uptake than an equivalent raw-hemp-fiber control (tests the Chapter 3 thesis directly)
G6 · Content	ASTM D6866 + mass-balance audit	Bio-based carbon ≥ 95 %; hemp-derived mass ≥ 90 % (scenario M sourcing)

Table 15.1 · Stage gates. All targets are proposed acceptance criteria, not predictions of success.

The raw-fiber control experiment

The most important single experiment in this book is G5. Make HX-90 twice — once with carbonised HSCF, once with the same mass of untreated hemp fiber — and compare cure conversion, stress relaxation, water uptake and property retention after reprocessing. If carbonised hemp wins on vitrimer behaviour and durability, the founding rule of Hempoxies is vindicated with data. If it does not, the rule must change. Either result is publishable, and either is progress.

The Hempoxies programme began as a question asked in public by an investigator who refused to separate what she knew from where she learned it. It ends this edition the same way: with every claim tied to a source, every projection labelled, and an open invitation — to farmers, chemists and companies like ZILA BioWorks — to help turn targets into measurements.

APPENDIX A

The Hempoxies record ledger

Public Zenodo records and the working dossiers this book draws on.

Date	Record	Identifier
2025-11-13	Master Technical SOP Suite (8 Protocols) + Expert-Level Technical Report	10.5281/zenodo.17597562
2025-12-05	Hempoxies: A Paradigm Shift in Green Chemistry (9-Component Formulation)	10.5281/zenodo.17834113
2025-12-19	Photochemically Assisted High-Pressure Synthesis of Furan-Derived Nanothreads	Drive manuscript
2025-12-26	Hempoxies 13 Master Dossier (13A/13B/13C)	10.5281/zenodo.18057879
2026-03-14	Industrial Manual: Hempoxies v.15 (Trideca-Hemp)	10.5281/zenodo.19016041
2026-03-14	Hempoxies 20.1 (Su-lignin hardener)	10.5281/zenodo.19016082
2026-04-02	Hempoxies v.40 – fully bio-based hemp vitrimer nanocomposite	10.5281/zenodo.19378380
2026-04-03	Hempoxies v.41 – three-tier reinforcement with HDCF	10.5281/zenodo.19393945
2026-04-29	Hempoxies Platform v.17.2 – EHSO / citric / Zn acetate / FGE	10.5281/zenodo.19877276
2026-05-30	Hempoxies 56 – ethanol processing aid	10.5281/zenodo.20457469
2026-07-01	Hempoxies 74 Platform proposal – 90 % hemp target	Drive: Hempoxies_74.pdf
2026-07-19	Hempoxies BASE Framework SOPs	10.5281/zenodo.21443127
2026-08	>99 % Hemp-Monoculture Multiscale Vitrimer report	Drive
2026-08	Hempoxies 100 Technical Specification	Drive
2026-09	Comprehensive Failure Analysis and Lessons Learned	Drive
2026-10-06	Hemp-Derived Furan Nanothreads: An Experimental Manual	Drive

APPENDIX B

Editorial corrections

What live verification changed, relative to earlier Hempoxies dossiers.

1. **Author of the EHO/MHO paper.** Several dossiers cite the 2023 Polymers paper as "Domínguez-Candela et al." The first author is Alejandro Lerma-Canto; Dominguez-Candela is third author.^[2]
2. **Sebacic acid is not hemp-derived.** It comes from castor oil.^[26] Formulations using it cannot be counted as >90 % hemp by mass; azelaic acid is the hemp-native replacement (Chapters 7, 9).
3. **>99 % hemp" requires full integration.** The mass balance in Chapter 9 reproduces >99 % only when every acid, the epichlorohydrin and the zinc ligand are hemp-made. With commercial inputs the figure is 72–87 %.
4. **Furan nanothread pressure.** The measured onset is 10 GPa with compression to 15 GPa;^[55] the 5 GPa and 8 GPa figures in the corpus are hypotheses for photo-assisted routes, not results.
5. **Projected stiffness.** Hempoxies 100's 45–65 GPa tensile modulus for a short-fiber composite is not supported by any data in hand and is withdrawn here in favour of the G4 gate (≥ 5 GPa flexural, to be measured).
6. **Placeholder citation.** Hempoxies 74 reference [14] carries an incomplete DOI ("107XXX"); it should be completed or removed before reposting.
7. **The name "Hempoxy".** ZILA BioWorks markets a hempseed-oil "Hempoxy" resin;^[37] Hempoxies (Landry Industries) is a separate research platform (Chapter 1).

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