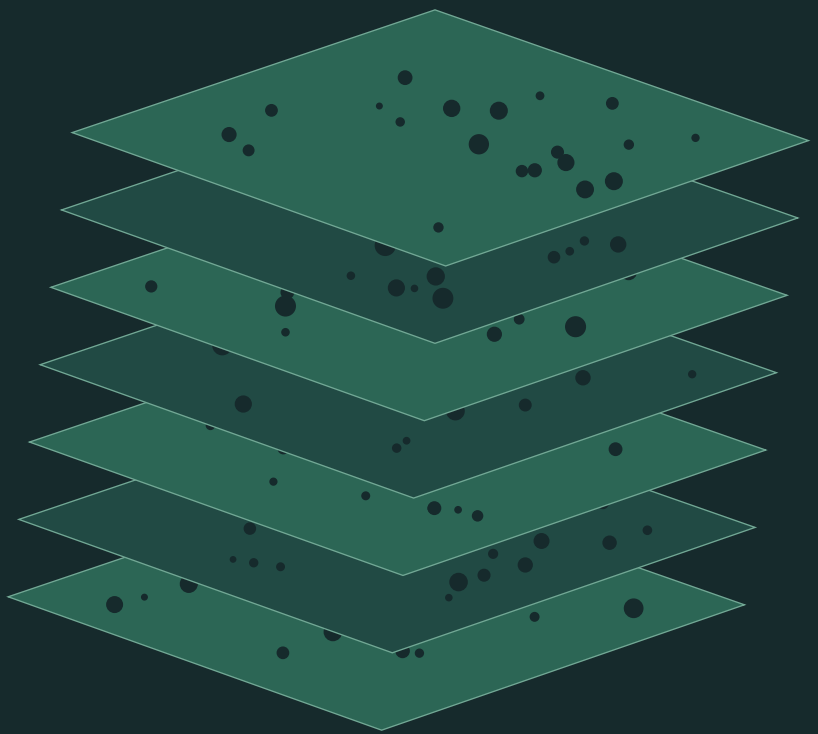
LANDRY INDUSTRIES / HEMPOXIES RESEARCH PLATFORM

HEMP-NANO 2030

Universal Hemp Carbon Materials Enhancement Programme

A cross-industry research charter for renewable porous carbon nanosheets, functional additives and next-generation composite materials.



PROPOSED PROGRAMME / VERSION 1.0 / 15 NOVEMBER 2026

Initiative proposed by Marie-Soleil Seshat Landry | AI-assisted research draft

Conceptual illustration: stacked porous carbon sheets; not a micrograph.

RESEARCH PROGRAMME / 01

Executive charter

A universal screening programme, not a universal performance claim.

HEMP-NANO 2030 proposes a coordinated research division within the Hempoxies research platform to investigate hemp-derived porous carbon nanosheets (HNS) in compatible material systems. The programme seeks measurable advantages over commercially available carbons, conventional fillers and unmodified matrices, while excluding unsafe or technically unjustified applications.

Mission and boundaries

Develop reproducible HNS feedstocks; classify their functions in different matrices; compare performance at controlled loading, composition and processing conditions; validate promising applications independently; and publish positive, null and negative results. The programme covers bulk additives, surface layers, electrode architectures and reactive carbon precursors. These are distinct technologies.

Evidence at inception

Evidence level	Current position
Direct hemp-specific precedent	2013 work demonstrated porous, partially graphitic nanosheets derived from hemp bast fiber and their use in supercapacitors [1].
Adjacent material evidence	Graphene-family fillers have been studied in polymer, cement, metal and ceramic composites [5–14]. Their results do not establish equivalent HNS performance.
Adjacent metallurgical evidence	Biochar can substitute for some fossil carbon in steelmaking [2–4]. Carbon substitution does not establish survival of nanosheets.
Proposed research	All specific HNS composite formulations, comparative advantages and scale-up economics in this charter require validation.

Programme outcomes by 2030

Deliver a characterized reference HNS grade, harmonized measurement protocols, documented multi-matrix screening, a public negative-results registry, independent replication of selected systems and market-specific feasibility dossiers. A calendar target is not an assurance of completion.

Status: AI-assisted research proposal; not a validated material specification, an operating laboratory SOP, a certification, a patentability opinion or a claim of completed experiments. No partner participation, funding or laboratory access is confirmed.

RESEARCH PROGRAMME / 02

The material under investigation

Define the material before naming its advantages.

HNS is used here as a working designation for hemp-derived, sheet-like carbon particles exhibiting nanoscale thickness and measurable carbon structure. The term covers a family of grades, not a fixed chemical formula. Graphene, graphite nanoplatelets, graphene oxide (GO), reduced graphene oxide (rGO), activated carbon and bulk biochar are comparator classes; they must not be treated as synonyms [15,16].

Landmark benchmark: hemp bast fiber carbon [1]

Reported measurement	Published experimental value	Interpretation
Thickness	10–30 nm	Partially graphitic interconnected sheets, not evidence of monolayer graphene.
BET specific area	Up to 2,287 m^2/g	Large accessible surface in the studied grade; not a universal specification.
Mesoporosity	Up to 58% volume fraction	Useful for some transport and electrode functions; may compromise load transfer.
Electrical conductivity	211–226 S/m	Reported for the studied carbon; test method and density must accompany comparison.
Electrode capacitance	106 F/g at 0 °C, 10 A/g	Specific published ionic-liquid test; not a device-level or universal value.

Three functional pathways

Pathway	What must be established
R / Retained reinforcement	Sheet morphology, distribution and interface survive processing; a controlled performance gain is demonstrated.
F / Functional additive	A useful electrical, thermal, adsorption, barrier or rheological function is measured in the final material.
P / Reactive precursor	HNS carbon transforms into dissolved carbon, carbides or other phases; benefit is attributable to chemistry or processing, not necessarily to an intact sheet.

Do not assume that surface area, electrical conductivity, intrinsic tensile modulus, or graphitic ordering of commercial graphene is transferable to a porous biomass-derived grade.

RESEARCH PROGRAMME / 03

Feedstock & grade development

Produce a traceable carbon material with measurable batch-to-batch consistency.

Proposed grade families

Grade	Proposed design space	Intended first tests
HNS-A	High-area, activated porous nanosheets	Supercapacitors, adsorption, catalyst supports
HNS-G	More graphitically ordered sheet-like carbon	Conductive polymers, coatings, selected metals
HNS-O	Controlled oxygen-rich surface chemistry	Polar resins, waterborne dispersion, cement compatibility
HNS-L	Purified, low-ash, low-volatile grade	High-temperature matrices and metallurgy
HNS-R	Reprocessed recovered carbon fraction	Circularity and property retention experiments

Feedstock-to-grade workflow

1. Traceability. Record hemp cultivar where available, geography, plant fraction, preprocessing, moisture, contaminant screening and lot identification. Start with bast fiber given direct literature precedent [1]; evaluate hurd and processing residues separately.

2. Carbon conversion. Compare a literature-based hydrothermal carbonization/activation route with suitable alternative carbonization routes at qualified laboratories. Treat precursor selection, temperature history, atmosphere, activation, washing and particle separation as recorded experimental factors. Obtain the original method, risk assessment and equipment approvals before any work.

3. Purification and conditioning. Evaluate ash removal, residual activating chemicals, washing efficiency, drying, fractionation and surface modification. Document changes in yield, properties and wastewater burden.

4. Release and distribution. Quarantine nonconforming material; retain characterized samples; supply sealed dispersions or masterbatches where practical. Each grade receives a distinct lot and certificate-of-analysis record.

Mass balance and traceability

Dry mass yield (%) = 100 × dry recovered HNS mass / dry input hemp mass. Carbon yield (%) = 100 × recovered product carbon mass / feedstock carbon mass. Record process additions, liquid and gas outputs and unaccounted mass; do not equate total biochar yield with verified nanosheet yield.

No synthesis recipe here is represented as proven for a new HNS grade. High-temperature equipment and chemical activation require institution-approved procedures.

RESEARCH PROGRAMME / 04

Characterization & release gates

One shared characterization package enables fair comparison across the research network.

Measurement	Preferred tools	Reason for measurement
Morphology and size	SEM; TEM; AFM where appropriate	Thickness and lateral-size distributions, porosity, agglomeration; distinguish sheets from particulate char.
Carbon ordering	Raman; XRD; TEM	Disorder, stacking and graphitic domains. Interpret Raman ratios within the relevant carbon regime.
Area and pores	Gas adsorption; BET; pore analysis	Use justified adsorption model and degassing protocol; characterize accessible porosity.
Composition	CHNS/O; XPS; ICP-OES/MS; ash	Bulk C, H, N, S, O; surface chemistry; inorganic residues and metals.
Thermal behavior	TGA/DSC in relevant atmosphere	Moisture, volatiles, oxidation, decomposition and processing compatibility.
Electrical properties	Four-probe or validated pellet method	Record compaction pressure, density and contact method; avoid comparing incompatible test geometries.
Dispersion	Microscopy; rheology; sedimentation	Assess stability and cluster distribution in the actual matrix or representative solvent.
Safety & handling	Particle release evaluation; SDS review	Exposure scenarios, combustibility, contaminants and waste compatibility.

Initial reference-material release

At least three independently manufactured lots should be characterized. Establish acceptance bands from observed distributions, measurement uncertainty and downstream sensitivity, then freeze the specification before confirmatory trials. ISO/TS 80004-13:2024 and ISO/TS 21356-1:2021 provide useful graphene terminology and structural-characterization context [15,16], but their exact applicability to porous HNS must be evaluated.

Proposed gate: reject a lot if its composition or morphology is inconsistent with the defined grade, residual process chemicals exceed application-specific limits, or variability prevents reliable comparison. No universal numerical release limit is assumed.

RESEARCH PROGRAMME / 05

Multi-matrix research portfolio

The starting universe includes twelve workstreams, with scope expanded only after evidence warrants it.

WP / Matrix family	Representative candidates	Primary endpoints
01 / Thermosets	Petroleum epoxy, hemp-oil bioepoxy, lignin epoxy, vinyl ester	Fracture toughness, flexural strength, viscosity
02 / Vitrimers	Epoxy-acid dynamic networks, other compatible covalent adaptable networks	Healing/reprocessing, relaxation, Tg, creep
03 / Thermoplastics	PLA, PP, PE, PA, PET, PEEK	Mechanical response, melt flow, conductivity
04 / Elastomers	Natural rubber, silicone, EPDM, TPU	Tear, fatigue, hysteresis, conductivity
05 / Ferrous metals	Low-carbon steel, iron powder, cast iron	Carbon recovery, phases, toughness, wear
06 / Nonferrous metals	Al, Cu, Mg, Ti, Ni alloys	Density, interface, conductivity, strength
07 / Cementitious	Portland cement, mortar, concrete, geopolymers	Strength, flow, shrinkage, durability
08 / Road materials	Asphalt and recycled binders	Rutting, fatigue, low-temperature cracking
09 / Ceramics and glass	Alumina, zirconia, Si3N4, SiC, glass ceramics	Fracture toughness, densification, wear
10 / Energy materials	Supercapacitors, batteries, fuel-cell supports	Capacitance, cycling, impedance, stability
11 / Coatings and textiles	Paint, barrier films, fibers, conductive textiles	Adhesion, corrosion, wash durability
12 / Membranes / sorbents	Filtration media, sorbents, polymer membranes	Flux, selectivity, leaching, regeneration

Scope restriction: no medical, food-contact, agricultural-release, potable-water or consumer-contact application is cleared by this charter. Such uses need dedicated exposure, toxicology, regulatory and migration studies.

RESEARCH PROGRAMME / 06

Polymer and vitrimer research

Start with readily processable materials where controlled laboratory comparisons are feasible.

WP01 — Thermosets

Use a conventional epoxy benchmark and a documented bioepoxy candidate. Incorporate HNS as a dispersion or compatible masterbatch, maintain resin-to-curing-agent stoichiometry, record mixing energy, temperature, cure schedule and degassing, and characterize viscosity, cure conversion, glass transition, density, voids and fracture behavior. Surface chemistry may alter cure kinetics and the matrix interface [5,6].

WP02 — Hempoxies dynamic networks

Use a separately qualified neat matrix before adding HNS. Candidate chemistries may include hempseed-oil-derived epoxide, lignin-derived functional ingredients and epoxy-acid bond exchange. Establish reactive equivalent weights experimentally. HNS may act as a filler, polymer adsorption surface, catalyst interaction site or photothermal/conductive additive; none is assumed beneficial.

Measure Tg, stress relaxation versus temperature, creep, tensile/flexural properties, thermal stability, healing recovery and reprocessing retention. Define healing efficiency for a specified property: $\eta = 100 \times$ recovered property / corresponding undamaged property, with identical specimen geometry and conditioning. Control for thermal annealing of the unfilled matrix. Distinguish reversible exchange from degradation.

WP03 — Thermoplastics and WP04 — elastomers

Compare melt-compatible HNS grades and masterbatches in selected polymers; track melt flow, residence-time effects, molecular-weight degradation, morphology, dispersion and contact-network formation. For rubber, record cure torque and kinetics, crosslinking proxies, hysteresis, cyclic fatigue and abrasion. Compare against carbon black and commercial graphite-family additives.

Decision rule

A promising mechanical result is insufficient if processing becomes impractical or the material becomes brittle, loses repairability, creeps excessively, or cannot be recycled. Use an application-specific minimum benefit and noninferiority constraints, set before testing.

RESEARCH PROGRAMME / 07

Metals & metallurgy

Two hypotheses require two different experimental designs: renewable carbon substitution and retained reinforcement.

WP05-A — Ferrous carbon substitution (P)

Test characterized low-ash hemp carbon against a conventional recarburizer on an equal fixed-carbon basis. Conduct pilot trials only with a qualified metallurgical partner. Record slag chemistry, off-gas, carbon recovery, final alloy chemistry and process energy; account for sulfur, phosphorus and other contaminants. Biochar metallurgy is supported by adjacent literature [2–4].

Carbon recovery (%) = 100 × (final steel carbon inventory − baseline carbon inventory, corrected for other inputs and losses) / introduced additive carbon. A matched final-carbon experiment is necessary to separate carbon-source effects from ordinary changes in alloy grade.

WP05-B — Retained sheet composite (R)

Compare powder metallurgy, controlled solid-state consolidation and selected surface routes. Evaluate how mixing, temperature, residence time, atmosphere and metal chemistry influence carbon dissolution, interfacial reaction, carbides and carbon retention. Confirm retained sheet-like morphology and phase identity with suitable microscopy and spectroscopy; a higher hardness alone is not proof of nanosheet reinforcement.

WP06 — Nonferrous systems

Candidate	Main question	Critical countermeasure
Al / Mg	Can dispersion and interface improve specific mechanical properties?	Evaluate oxide films, reactive phases, moisture sensitivity and powder hazards.
Cu / Ni	Can functional networks modify electrical or thermal response?	Compare equal density, porosity and contact resistance.
Ti / other alloys	Does reactive carbon produce useful strengthening or unwanted brittle phases?	Quantify carbide formation, retained carbon and ductility.

Graphene-metal composite literature provides candidate routes, not proof of hemp-specific performance [10–12]. Industrial molten metal and combustible metal powders are outside general-purpose bench experimentation.

RESEARCH PROGRAMME / 08

Construction & ceramic materials

Prioritize measurable improvements without compromising durability or structural qualification.

WP07 — Cementitious matrices

Begin with paste screening and progress to mortar and concrete only after dispersion and hydration effects are understood. Record water-to-binder ratio, superplasticizer use, added dispersion water, composition and curing. Report dose relative to dry binder, not total wet concrete. Distinguish fixed water-to-binder comparison from controlled-flow comparison. Test workability, compressive/flexural strength, shrinkage, permeability and relevant durability conditions. GO-cement studies demonstrate that chemistry and dispersion strongly influence outcomes [7–9].

WP08 — Asphalt and road binders

Evaluate HNS addition to virgin and recycled binders, with conventional carbon additives as controls. Monitor mixing stability, viscosity, rut resistance, low-temperature behavior, aging, moisture damage and fatigue. A stiffer binder is not necessarily a better pavement material; compare in relevant climate and traffic conditions.

WP09 — Ceramics and glass

Screen chemically compatible ceramic feedstocks and atmosphere-controlled densification. Measure relative density, porosity, fracture toughness, flexural strength, wear, phase evolution and persistence of carbon sheets. Carbon oxidation, reactions, poor densification and altered sintering kinetics are primary risks. Published graphene-silicon-nitride experiments and reviews support the research analogy, not transfer of numerical gains [12–14].

Qualification constraints

Any structural use needs independent testing against applicable building codes and material standards, environmental durability and engineering design requirements. No house, bridge, road, vehicle or load-bearing component is authorized solely by coupon-scale screening results.

Suggested initial demonstration: non-load-bearing laboratory mortar specimens and small ceramic coupons. Structural applications follow only after validated material data and appropriate engineering review.

RESEARCH PROGRAMME / 09

Functional materials & energy

Use the strongest existing hemp-specific evidence as the first anchor for the programme.

WP10 — Electrochemical systems

Replicate a documented hemp-nanosheet supercapacitor benchmark as closely as practical [1]. Compare HNS with commercial activated carbon at documented active-material mass, electrode density, loading, binder, electrolyte, voltage window and cell configuration. Report gravimetric and volumetric metrics plus device-level results; do not present active-material-only energy densities as packaged-device performance.

For battery electrodes and catalyst supports, screen electrochemical stability, reversible capacity, coulombic efficiency, impedance, rate capability, cycle life, gas evolution and relevant safety constraints. Use matched electrode recipes and suitable reference materials. Supercapacitor results do not validate lithium-ion batteries or fuel cells.

WP11 — Coatings and textiles

Compare dispersed HNS in waterborne or otherwise suitable polymer coatings and textile finishes. Measure adhesion, electrical resistance, barrier response, abrasion, weathering and wash durability. Test exposed and damaged coatings, not only pristine films. Evaluate galvanic corrosion risk when conductive particles contact metal, and evaluate release of particles during use.

WP12 — Membranes and adsorption

Investigate immobilized HNS as a membrane modifier, support layer or adsorbent. Quantify adsorption capacity, breakthrough, flux, selectivity, fouling, regeneration and material release. Include blanks, conventional activated carbon and a relevant commercial membrane. GO membrane research establishes analogous engineering considerations [17,18].

Potable-water claims require application-specific validation of contaminants, leaching, microbial safety and regulatory compliance. No uncontrolled nanosheet dispersal or direct biological application is proposed.

RESEARCH PROGRAMME / 10

Controlled screening design

A common experimental backbone, customized by the matrix-specific lead investigator.

Nominal concentration ladder

Code	HNS wt%	HNS per 100 g final dry composite *
HNS-00	0%	0.00 g
HNS-01	0.01%	0.01 g
HNS-02	0.05%	0.05 g
HNS-03	0.1%	0.10 g
HNS-04	0.25%	0.25 g
HNS-05	0.5%	0.50 g
HNS-06	1%	1.00 g
HNS-07	2%	2.00 g
HNS-08	5%	5.00 g

* Applies only to composite-total dry-mass dosing. Cement uses dry binder mass; electrodes use documented active-solid basis; metallurgical substitution uses fixed-carbon mass. Recalculate each basis explicitly. The ladder is a proposed screening envelope, not an optimized dose. For incompatible or high-risk matrices, narrow or replace the ladder before fabrication.

Batch calculations

For total dry mass M and mass fraction w: m(HNS) = wM; m(other solids) = (1 − w)M. For additive dosing relative to a fixed matrix mass m: m(HNS) = w × m / (1 − w) when w represents final-composite fraction. Retain stoichiometric ratios among matrix reactants. Correct wet dispersions for their measured solids content and record carriers separately.

Comparators and independent replication

Use a matrix-only blank, a carrier/dispersion blank if needed, one relevant commercial graphene-family grade, graphite, carbon black and conventional hemp biochar where justified. Match loading, purity, size or surface chemistry according to the hypothesis. Measure actual composition and processing history; equivalence cannot be assumed.

Initial three-level pilot per system: 0, 0.1 and 1 wt% (or justified matrix-specific doses). Prepare three independent batches per cell, then expand the ladder only after processability is established. Specimens from one batch are not independent manufacturing replicates.

RESEARCH PROGRAMME / 11

First campaign: 2026–2027

A finite pilot programme precedes the universal expansion.

Proposed Phase A uses four accessible candidate systems: conventional epoxy (E), qualified bioepoxy or vitrimer (V), cement mortar (C), and supercapacitor electrode (S). Each system has its own approved dose basis; for electrodes the dosage represents the HNS replacement fraction in the active-carbon mixture, not the same physical basis as epoxy or cement.

Pilot treatment	E / V / C / S application	Independent batches
T0	Matrix or reference electrode blank	3 per system
T1	Carrier or process blank if required; otherwise reserved	3 per system if required
T2	HNS at low dose	3 per system
T3	HNS at middle dose	3 per system
T4	Best relevant commercial graphene-family comparator at middle dose	3 per system
T5	Conventional hemp biochar at middle dose	3 per system
T6	Conventional carbon black or activated-carbon reference at middle dose	3 per system, if distinct

Maximum planned design: 4 systems × 7 treatments × 3 independently prepared batches = 84 batches. If T1 and/or T6 is redundant, remove the cell, document the reason and report the revised total. Determine specimen counts from the selected test methods and a prospective power analysis; not from the coupon count alone.

Dose selections to pre-register

E/V: proposed 0.1 and 1.0 wt% of dry composite. C: proposed 0.05 and 0.1% of dry binder. S: proposed 10 and 30% replacement of reference active carbon by HNS; retain electrode loading and binder fraction. These choices are planning assumptions subject to safety, dispersion and processability gates.

Identifiers and randomization

Use HN26-[system]-[treatment]-[batch]-[specimen], e.g. HN26-E-T2-B01-S01. Randomize manufacturing order in balanced blocks; randomize measurement order separately. Record material lot, operator, date, equipment and deviations. Reserve samples for independent verification.

RESEARCH PROGRAMME / 12

Laboratory procedure framework

These are design-level SOP templates requiring local approval, not executable operating instructions.

SOP	Required activities and records
01 / Receiving	Verify supplier/lot, labels, safety documentation, mass and storage conditions. Assign sample ID, quarantine and retain aliquot.
02 / Characterization	Define calibrated methods; collect morphology, chemical, thermal and dispersion measurements; document uncertainties and release decision.
03 / Dispersion	Select compatible carrier and process with risk assessment; record input mass, mixing energy, time, temperature, viscosity, losses and aggregation.
04 / Polymer processing	Maintain formulation stoichiometry, document time-temperature history, cure state, dimensions and conditioning. Independently prepare batches.
05 / Cement processing	Control ingredient lot, water/binder, admixture solids, mixing and curing. Record workability, sample geometry and testing age.
06 / Electrode assembly	Freeze active mass, current collector, binder, electrolyte and geometry; document test window, conditioning, cycling and instrument calibration.
07 / High-temperature routes	Use a qualified metallurgy/ceramics partner; obtain approved gas, furnace and powder procedures; monitor phases, emissions and material balance.
08 / Testing & retention	Blind/encode specimens where feasible, calibrate instruments, preserve raw files and archive remaining material; log failed or excluded tests.
09 / Waste and incident	Segregate nanomaterial-bearing waste; record containment failures, spills, disposal and corrective action. No drain disposal by default.

Pre-experiment checklist

No experiment starts without an approved matrix recipe, risk assessment, compatible equipment, verified material lot, dose basis, control groups, outcome definitions, sample plan, exclusion criteria, waste plan and authorizing laboratory personnel.

RESEARCH PROGRAMME / 13

Statistics & decision gates

Every claimed improvement must survive a comparison with controls and uncertainty.

Analysis plan

Pre-register one primary endpoint per system and minimum meaningful effect, together with safety and processability constraints. Estimate batch-level variation using pilot data, then size confirmatory experiments for the chosen effect and power. Use appropriate regression or factorial models for dose, grade and processing factors; include batch/block effects when justified. Report absolute and relative differences, uncertainty intervals and raw distributions; adjust or explicitly label multiple exploratory comparisons.

Relative improvement (%) = 100 × (mean HNS response − mean control response) / mean control response. Reverse the sign for outcomes where smaller is beneficial, and avoid percentage change when the denominator is near zero. Use appropriate physical units and report uncertainties.

Stage-gate framework

Gate	Evidence needed	Decision
G0 / Identity	Characterization and safe-handling documentation; repeatable input grade	Release or quarantine
G1 / Compatibility	Dispersion, processing, safety, quality and baseline measurements	Continue or reformulate
G2 / Signal	Pilot response versus relevant controls; no critical degradation	Select for confirmation or close
G3 / Confirmation	Independent batches and pre-specified effect/constraints met	External replication or stop
G4 / Translation	Application prototype, durability, cost, lifecycle and release assessments	Partner pilot or defer
G5 / Qualification	Independent evidence, applicable standards and regulatory review	Commercial evaluation only if qualified

Negative-results policy

Publish null responses, adverse results and failed processing attempts with sufficient methodological detail for interpretation. Do not change endpoints after observing results without marking the analysis exploratory. Avoid selection bias by disclosing all enrolled formulations and exclusions. The research objective is a defensible applicability map, not universal adoption.

RESEARCH PROGRAMME / 14

Safety, environment & circularity

Renewable feedstock does not eliminate occupational, ecological or climate risks.

Nanomaterial risk management

Treat dry HNS as an engineered particulate with uncertain material-specific toxicology. Follow institution-approved chemical hygiene and occupational exposure procedures, with engineered containment, enclosed transfer, local exhaust and filtration as appropriate. Prefer contained dispersions, train workers, prevent dust accumulation, and assess fire/explosion hazards and suitable respiratory protection with a qualified safety professional. Follow NIOSH laboratory guidance [19].

Investigate particle release during mixing, cutting, sanding, machining, weathering, abrasion, washing and recycling. Include handling of spent activators, washing liquids, residual chemicals, off-gases and solids. Biomass recovered from contaminated soils is not presumed safe for material production; assay relevant metals and contaminants before any release.

Lifecycle assessment and circular design

Define a functional unit (for example, a square metre of coating achieving specified service life or a structural coupon meeting an equivalent load-bearing requirement). Compare HNS against a conventional additive and the no-additive baseline. Include hemp cultivation, land use where material, transport, feedstock allocation, carbon conversion yield, process heat/electricity, activators, water, waste, formulation, service life and end-of-life. Apply ISO 14040 principles [20].

Distinguish fossil-carbon displacement, biogenic carbon temporarily retained in a product, and verified durable net removal. Carbon introduced into molten metal or combusted during processing may return to the atmosphere. Do not label steel, cement or any composite carbon-negative unless an appropriately scoped lifecycle assessment demonstrates net removal, including emissions and permanence assumptions.

Environmental and cost gate

At minimum report energy use per kilogram of qualified HNS, reagent/water consumption, yield, production cost, release testing and waste treatment. Assess environmental impact per unit of delivered function rather than relying solely on material mass or renewable-content percentage.

RESEARCH PROGRAMME / 15

Deployment roadmap & governance

Scale after reproducibility, not before.

Period	Proposed milestones	Exit condition
2026–2027	Literature mapping; partner outreach; reference grades; 84-batch maximum pilot; open data structure	At least one characterized grade and credible pilot dataset
2027–2028	Expand successful polymer, binder and energy experiments; launch controlled metal/ceramic feasibility via partners	Replicated application-specific benefits or documented exclusion
2028–2029	Selected prototype components, durability and lifecycle/cost assessments, external round robin	Independent reproduction and credible value proposition
2029–2030	Scale-up grades, qualification plans, industrial trials and decision dossiers	Demonstrated process readiness or explicit no-go conclusion

Operating model

Proposed programme sponsor: Hempoxies research platform, under Landry Industries. Appoint an accountable principal investigator, carbon characterization lead, matrix-specific workstream leads, independent safety reviewer, statistician and data steward. Roles are recommended; no appointments or institutional affiliations are asserted.

The first budget should prioritize feedstock characterization, independent replication and small-batch screening rather than immediate development of twelve laboratories. Prepare quotations for equipment access, analytical testing, labor, containment, consumables, waste and external validation before seeking capital. No cost estimate is represented as a vendor quote.

Open-science package

Publish versioned protocols, formulation records, machine-readable raw data, analysis code, specimen provenance, instrument settings, images and uncertainty estimates to a persistent repository. Obtain permission for third-party data and address patent/disclosure strategy before public release. A digital object identifier does not constitute peer review or regulatory approval.

Success criterion

By 2030, establish where hemp carbon nanosheets provide reproducible, economically and environmentally defensible advantages; where reactive hemp carbon is more suitable; and where existing fillers or unmodified matrices remain superior.

RESEARCH PROGRAMME / 16

Evidence register & references

Core evidence, analogues and methodological standards. Links are provided for independent verification.

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RESEARCH PROGRAMME / 17

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Continued evidence register.

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Verification scope: References were checked against available publisher, bibliographic and official standards records on 15 November 2026. This is a focused evidence review, not a systematic literature review; some records were accessible only as abstracts. No full-text protocol validation, experimental work, cost quotation, novelty search or legal compliance assessment has been conducted.