WHITE PAPER

GoldLeaf

From Ambient Air to Soil Nutrition: MOF Photocatalytic Carbon Capture on Building Surfaces

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Executive Summary

GoldLeaf produces GL-1, a metal-organic framework (MOF) photocatalyst that captures CO2 from ambient air on building surfaces and converts it to soil-enriching nitrogen compounds. This white paper describes the technology platform, production process, product properties, intellectual property position, manufacturing roadmap, and competitive advantages. The compound's passive operation — requiring only visible light and moisture — creates a fundamentally different approach to carbon capture that integrates into existing building materials supply chains rather than requiring purpose-built industrial infrastructure.

1. The Carbon Capture Challenge

Global CO2 emissions exceed 36 billion tonnes annually. The built environment accounts for approximately 40% of energy-related emissions. Current approaches to carbon capture fall into two categories: industrial direct air capture (DAC) — energy-intensive plants that concentrate CO2 for sequestration — and nature-based solutions like reforestation. DAC costs $400–600 per tonne of CO2 captured and requires significant energy and infrastructure investment. Nature-based solutions are effective but compete for land use.

A third approach has remained unexplored until now: distributed passive carbon capture integrated into existing surfaces. Buildings, roads, and infrastructure already expose hundreds of billions of square metres of surface area to the atmosphere. If these surfaces could capture even a fraction of ambient CO2, the cumulative effect would be significant — without dedicated land, without energy input, and without new infrastructure.

GL-1 enables exactly this. Applied as an additive to paints, coatings, concrete, or brick glazes, GL-1 turns every coated surface into a passive carbon sink that simultaneously enriches surrounding soil with nitrogen compounds.

Approach	Cost per tonne CO2	Energy required	Infrastructure
Industrial DAC (Climeworks)	$400–600	High (2–3 MWh/tCO2)	Purpose-built plant
Reforestation	$5–50	None (solar)	Dedicated land
GL-1 surface capture	$80–150 (est.)	None (photocatalytic)	Existing surfaces

Figure 1: Carbon capture approaches compared — cost, energy, and infrastructure requirements

2. Technology Platform

GL-1 is a titanium-nitrogen coordination complex embedded in a polymer carrier matrix. It operates as a photocatalyst: in the presence of visible light (400–700nm) and atmospheric moisture, GL-1 catalyses the reduction of ambient CO2 to glycine and urea — simple organic nitrogen compounds that dissolve in rainwater and enrich soil. The catalyst regenerates and is not consumed in the reaction.

The technology was invented during the CTO's PhD research at Wageningen University under Prof. de Groot, building on published research into MOF-based photocatalysis. GoldLeaf's proprietary contribution is the specific synthesis route that achieves the required catalytic activity at commercially viable production cost — this process is protected by a PCT patent application.

Core Mechanism

The titanium centre in the MOF structure cycles between oxidation states during the photocatalytic cycle. CO2 molecules adsorb to the MOF surface, where they are activated by light-driven electron transfer. Atmospheric nitrogen and water participate in the subsequent reduction step, producing glycine (H2N-CH2-COOH) and urea (CO(NH2)2). Both products are water-soluble and transported by rainfall to surrounding soil, where they serve as bioavailable nitrogen — a micro-fertilisation effect.

Why MOF Photocatalysis

Metal-organic frameworks are porous crystalline materials with extremely high surface area per unit mass. This porosity allows MOFs to adsorb gas molecules efficiently. By incorporating photocatalytically active metal centres (titanium in GL-1's case) into the MOF lattice, the material combines gas adsorption with light-driven chemistry in a single compound. The key engineering challenge — solved by GoldLeaf's synthesis process — is producing a MOF that remains catalytically active when embedded in a polymer carrier and exposed to real-world conditions rather than controlled laboratory settings.

Performance Characteristics

One square metre of GL-1-coated surface absorbs approximately 200g CO2 per year under standard Northern European light conditions. Performance varies with light intensity (linear below saturation), moisture availability (minimum 40% relative humidity), temperature (reduced below 5°C), and GL-1 loading density. The 200g/m^2 figure represents the average across tested conditions, not peak performance.

For context: a mature tree absorbs approximately 10kg CO2 per year. A 50m^2 painted wall with GL-1 would capture approximately 10kg CO2 per year — the equivalent of one tree. A single commercial building with 2,000m^2 of coated surface would capture 400kg CO2 per year.

Surface	Area	CO2/year	Tree equivalent
Residential facade	200 m^2	40 kg	4 trees
Commercial building	2,000 m^2	400 kg	40 trees
1 km road surface	7,000 m^2	1,400 kg	140 trees
Municipality (10,000 buildings)	5M m^2	1,000 t	100,000 trees

Figure 2: Illustrative CO2 capture at scale — from single building to municipality

3. Product Properties — GL-1

GL-1 is sold as a compound additive, integrated into the host material (paint, concrete, brick glaze) during standard manufacturing. The loading is 2–5% by weight in the carrier matrix, which minimises impact on the base material's colour, viscosity, and adhesion properties.

Property	Specification	Significance
CO2 absorption	~200g/m^2/year	Passive, no energy input
Active wavelength	Visible light, 400–700nm	No UV required; works on shaded surfaces
Moisture threshold	Min 40% relative humidity	Met in NW European climates year-round
Temperature range	5–45°C operational	Reduced activity in winter months
By-products	Glycine, urea	Soil-enriching; regulatory implications for waterways
Catalyst lifetime	>18 months accel. aging	≈5yr equivalent; field data pending
GL-1 loading	2–5% by weight	Low impact on host material properties

Property	Specification	Significance
Target price	€120/kg GL-1	Adds €2–5/m² to coating cost
COGS at scale	€35/kg (est.)	71% gross margin; unvalidated

Figure 3: GL-1 product specifications

4. Unit Economics

GL-1's unit economics are driven by the raw material cost of titanium precursors and nitrogen reagents (commodity chemicals), the proprietary MOF synthesis process, and polymer compounding. At target commercial scale (1–5 tonnes/month), estimated COGS is €35/kg with a target selling price of €120/kg, delivering a 71% gross margin.

For the end customer (a paint manufacturer), GL-1 adds approximately €2–5 per square metre to the coating cost. Against carbon credit pricing of €50–100/tonne CO2, the payback calculation for a building owner is: 200g CO2/m²/year × €0.05–0.10/kg CO2 = €0.01–0.02/m²/year in carbon credit equivalent value. At current carbon prices, the payback period on GL-1 cost exceeds the catalyst lifetime. The value proposition therefore rests on regulatory compliance (CSRD reporting), corporate ESG commitments, and the emerging carbon credit monetisation opportunity — not on direct economic return from carbon capture alone.

Unit Economics Reality Check

At current carbon prices, GL-1 does not pay for itself through carbon capture economics alone. The value proposition is regulatory compliance and ESG positioning. If voluntary carbon credit markets mature and pricing reaches €150–200/tonne, the economics improve significantly. The Province of Gelderland's independent suggestion to monetise GL-1 surfaces as carbon credit generators may prove more valuable than the direct product revenue.

5. Manufacturing Strategy

GoldLeaf's manufacturing strategy follows a staged approach: prototype (kg-scale, Emmen, Q4 2026), pilot production (100–500 kg/month, 2027), and commercial (1–5 tonnes/month, 2028+). The business model decision — direct supply vs technology licensing — has not been made and determines whether GoldLeaf builds its own commercial facility or transfers the process to licensees.

Phase	Capacity	Timeline
Prototype (Emmen)	10–50 kg/month	Q4 2026
Pilot production	100–500 kg/month	2027
Commercial (direct supply)	1–5 tonnes/month	2028+
Licensed production	Per licensee site	2029+ (if licensing model)

Figure 4: Scale-up progression from prototype to commercial

6. Intellectual Property

GoldLeaf's IP strategy centres on process protection. The titanium-nitrogen coordination chemistry underlying GL-1 builds on published academic research (CTO's three PhD papers, 2019–2022), limiting the scope of compound claims. The patent portfolio consists of a PCT application covering the specific MOF synthesis process and a provisional Dutch application covering the polymer carrier composition.

The real IP moat is the combination of the patented synthesis route with accumulated process know-how: specific catalyst formulation (coordination geometry, ligand selection, synthesis conditions), polymer carrier compounding, and quality control methods. A competitor reading the academic publications and patents could identify the general approach but would need years of process development to match GL-1's performance characteristics at viable cost.

IP Risk

The academic publication trail provides a roadmap for competitors. Major chemicals companies (BASF, Johnson Matthey, Umicore) hold broad MOF-related patents. Freedom-to-operate analysis has not been reviewed in available materials. This is a significant gap.

7. Competitive Position

No direct competitor exists in passive surface carbon capture. GL-1 competes for the same corporate sustainability budget as industrial DAC, carbon offsets, and sustainability-enhanced building materials — but through a fundamentally different mechanism.

Company	Approach	GL-1 advantage
Climeworks (CH)	Industrial DAC — sorbent, heat	Zero energy, zero infrastructure, distributed
Carbon Engineering (US/CA)	Industrial DAC — liquid solvent	Integrates into supply chain, no purpose-built plants
BASF (DE)	Sustainability additives	Purpose-built for carbon capture; risk: could develop competitor
TiO2 photocatalysis (various)	Self-cleaning coatings	GL-1 captures carbon; TiO2 only degrades pollutants
Biochar / enhanced weathering	Soil-based carbon sequestration	GL-1 uses existing surfaces; no land competition

Figure 5: Competitive positioning — GL-1 vs existing carbon capture approaches

8. Environmental Impact

GL-1's environmental proposition is passive carbon capture integrated into existing infrastructure. Unlike DAC, which requires energy to operate, GL-1 uses only sunlight and atmospheric moisture. The net carbon balance — CO2 captured by GL-1 surfaces minus CO2 emitted during GL-1 production — has not been calculated. This is a critical gap for a product positioned as a carbon capture solution.

The nitrogen by-products (glycine, urea) represent both an opportunity and a risk. In agricultural contexts, the micro-fertilisation effect is a positive externality. In urban contexts, nitrogen compound runoff into waterways is regulated under the EU Nutrient Directive and Dutch national water quality standards. Given the political sensitivity of nitrogen in the Netherlands (the stikstofcrisis), this regulatory dimension requires careful assessment before large-scale deployment.

9. Key Technical Risks

Risk	Severity	Status
Lab-to-kg-scale production failure	Critical	Open — existential technical gate. No production data.
Real-world durability < accelerated aging	High	Partially mitigated — field testing requires kg-scale product
Climate-dependent performance variation	High	Partially characterised — seasonal variation unknown
Nitrogen by-product regulatory barrier	Medium-High	Open — not assessed. Dutch stikstofcrisis context.
GL-1 destroyed by repainting/resurfacing	Medium	Unknown — critical for customer value proposition
Competitive response from major chemicals cos	Medium	3–5 year window estimated
Net carbon balance negative	Medium	Open — production carbon footprint not calculated

Figure 6: Key technical risks and current mitigation status

10. Conclusion

GoldLeaf's GL-1 compound represents a genuinely novel approach to carbon capture: passive, distributed, and integrated into existing building materials supply chains. If the chemistry scales from lab to commercial production, GL-1 creates a new product category — surface-applied photocatalytic carbon capture — with no direct competitor.

The critical path runs through three gates: kg-scale production matching lab performance (technical), business model decision between direct supply and licensing (strategic), and environmental impact assessment including nitrogen by-product implications (regulatory). All three must be resolved before a Series B raise can proceed with confidence. The regulatory tailwind from CSRD and CBAM creates a defined window: corporate sustainability reporting requirements that will drive demand for measurable, verifiable carbon reduction solutions from 2025–2028.

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