Distillery Graphene Capture Systems (DGCS)

The Modular Evolution of Point-Source Carbon Removal

Slashing the energy cost of industrial carbon capture by up to 70% using atom-thin molecular sieves.

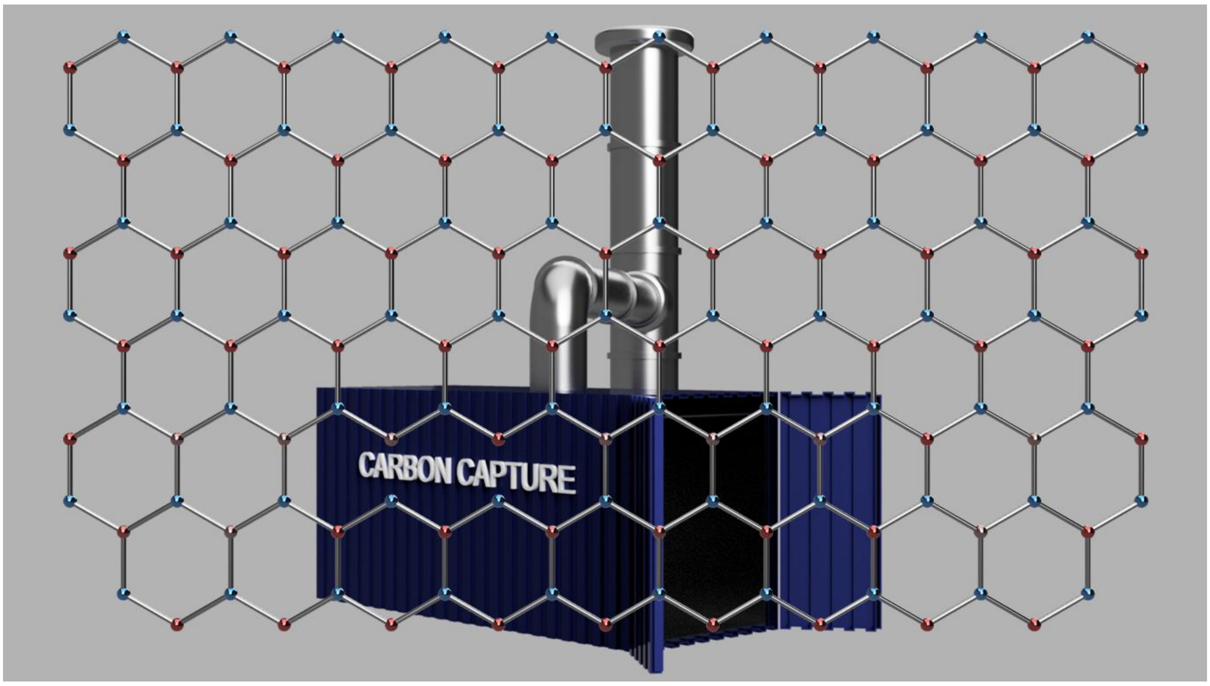

Figure 1 Carbon Capture

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Mission Statement

The Mission: To intercept biogenic and industrial emissions at the source before they reach the atmosphere, utilizing low-energy nanomaterials.

The Target Threshold: Architected from day one to scale across 1,400 global manufacturing chimneys, flues and exhausts meeting the minimum baseline reduction of 10 million tonnes of CO_2 annually by 2035.

The Founders' Ask: Seeking pre-seed partnership to transition laboratory-proven graphene oxide filtration into the first containerized pilot rig solving for removing CO_2 pollution from distilleries and breweries repurposing CO_2 as premium product.

The Core Problem

The Energy and Cost Trap of First-Generation Capture

The market demands carbon capture, but the current "solutions" are inefficient. First-generation carbon capture companies are trapped in an expensive high-energy loop.

[Traditional Capture] ➔ Requires High Thermal Heat (120°C - 900°C) ➔ High Electricity/Fuel Bills ➔ Costs £150+ per Tonne ➔ Commercially Unviable

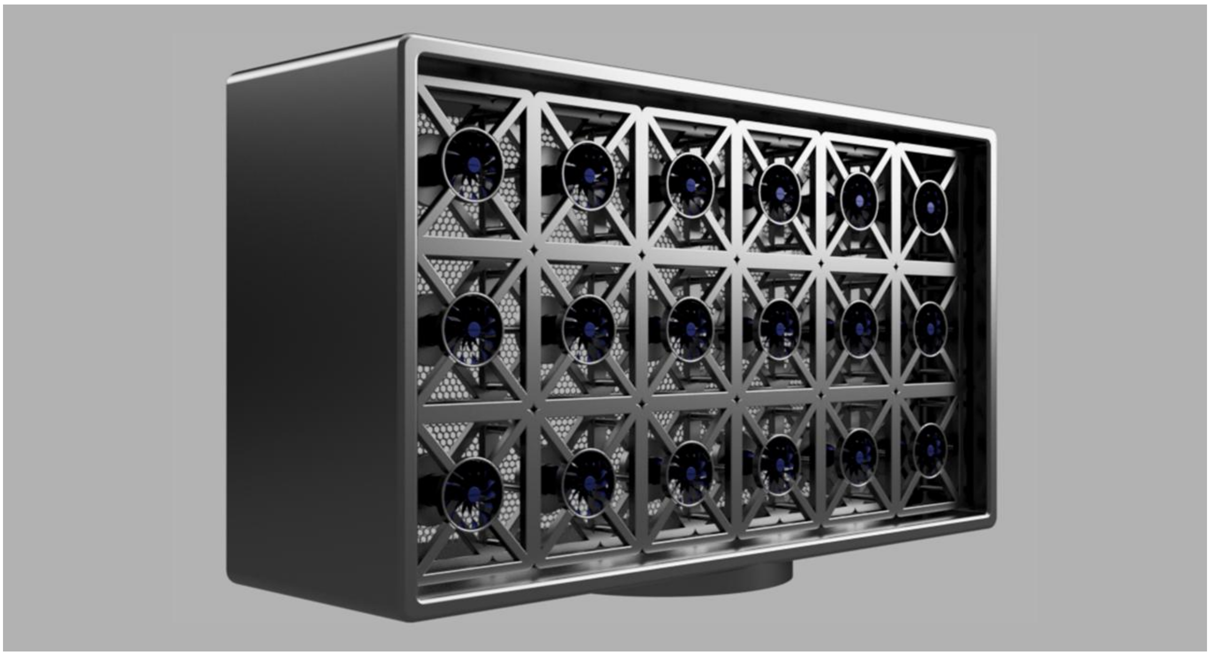

Figure 2 Unfeasible DAC

The Direct Air Capture (DAC) Illusion: Filtering open, ambient air is a losing battle against physics. At 0.04% concentration, moving trillions of cubic meters of air requires massive, expensive industrial fan arrays.

The Liquid Solvent Flaw: Existing factory chimney filters rely on boiling chemical liquids or melting limestone pellets. Up to 70% of a facility's operational cost is wasted just on the fuel needed to "un-stick" the carbon from the chemicals.

The Logistics Bottleneck: Heavy, stationary chemical towers take up acres of land, require years of grid-connection planning, and cost millions of pounds in upfront construction capital before a single gram of carbon is captured.

The Graphene Filter Container Concept

Graphene Sieve

We eliminate the thermal heat and chemical bill by taking advanced Graphene Oxide Mixed-Matrix Membranes and house them inside a converted shipping container, this creates a low-cost, high-velocity molecular filter.

[Concentrated Exhaust (99%)] ➔ [Pre-Treatment Dryer] ➔ [Graphene Hollow-Fiber Cylinder] ➔ [High-Value Pure Liquid CO_2]

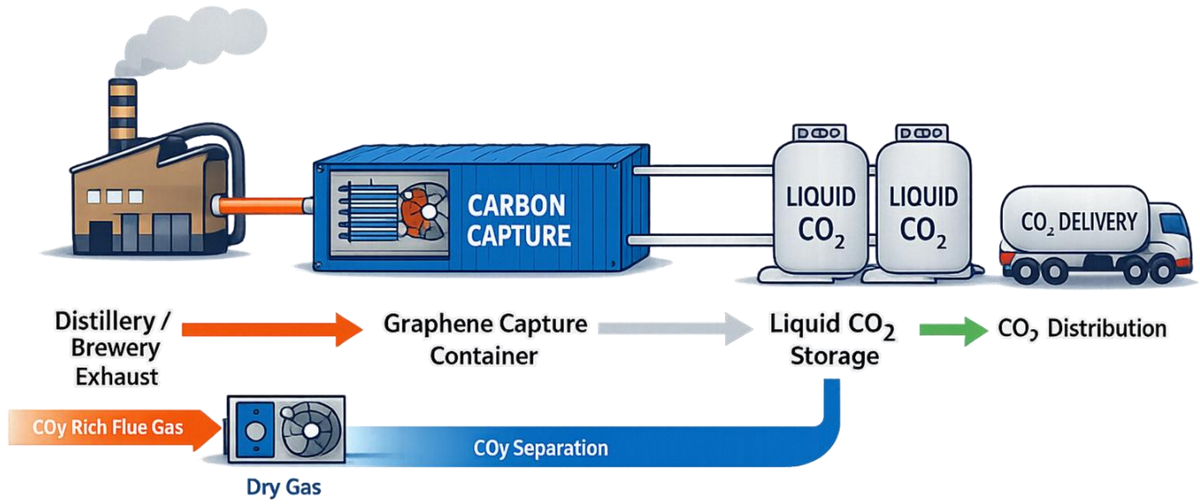

Figure 3 Shipping Container Concept

Technical Advantages

Zero Heat Requirement: Graphene acts as a physical, atomic-scale sieve. It separates smaller CO_2 molecules from larger nitrogen molecules at room temperature. The system runs entirely on low-energy utilising steady vacuum pressure pumps which dramatically reduces the capture cost to a market-leading £20–£40 per tonne.

Hollow-Fiber Architecture: Graphene is spun into millions of microscopic, rugged, hollow composite straws packed inside steel cylinders. This design packs thousands of square meters of filtering surface area inside a single container, eliminating the risk of membrane tearing, thus it is cost efficient and reduces maintenance.

Mobility & Scale: The system requires zero permanent construction but not limited to. To deploy we load the container onto a truck, drive to site and offload as close to the exhaust chimney as possible. We connect directly into the concentrated fermentation stream (which is nearly 100% pure CO_2). The container houses a dehumidifier, an integrated desiccant air-drying bay, multi-stage filters a compressor and temperature regulator. This method converts gas to a liquid which is then stored inside pressurised temperature-controlled payload tanks. We now have a premium product ready to be sold on or looped back into the system of origin.

Handling the Moisture Challenge

Primary Vulnerability of Graphene Oxide (GO)

Because GO is naturally hydrophilic (water-attracting), the high-humidity, steam-heavy vapor venting out of a whisky distillery or brewery fermentation tank will cause raw graphene layers to swell, altering the pore sizes and ruining the filter's purity. To overcome this, the design must include a two-step mitigation strategy:

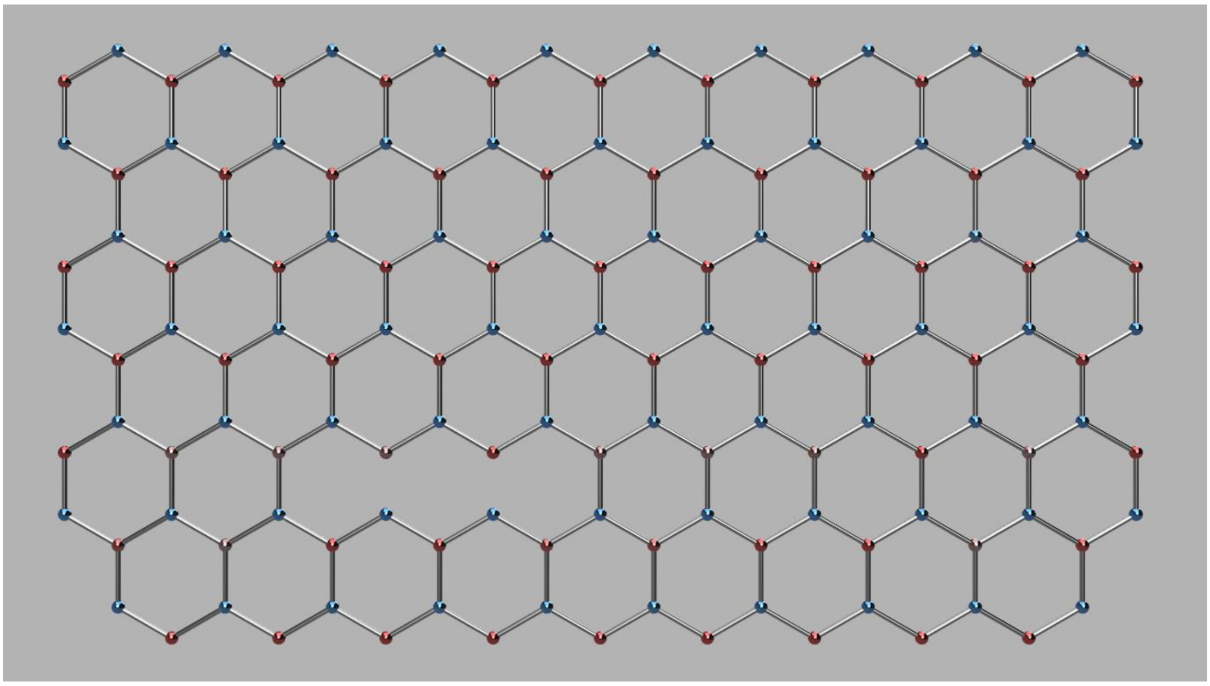

Figure 4 GO

Chemical Cross-Linking: The membrane must use Reduced Graphene Oxide (RGO) cross-linked with specific polymers (like Pebax) to strip away the water-attracting oxygen groups, making the filter structurally immune to humidity.

The Active Dehumidification Bay: The front chamber of the shipping container must feature a low-energy, automated cooling loop and desiccant wheel to drop the dew point of the incoming exhaust gas, ensuring only bone-dry, pure gas stream flows through the graphene core.

Graphene Filter Life Span

The Lifecycle of Graphene Oxide

In a commercial Point-Source industrial environment, a rugged, chemically cross-linked graphene oxide mixed-matrix membrane is engineered to last between 2 and 5 years before needing a complete structural replacement.

However, raw, un-modified graphene sheets are notoriously fragile. To achieve this multi-year operational lifespan inside the container variant, the filter must overcome three separate operational degradation timelines:

1. The Pure Chemical Lifespan (The 2–5 Year Ideal)

When shielded from harsh moisture and mechanical tearing, the carbon-to-carbon bonds in graphene are incredibly durable.

- In clean laboratory gas-separation loops, standardized composite membranes show rock-solid mechanical and chemical stability for hundreds of days of continuous pressure testing with negligible performance decay.
- In a commercial business model, a 3-year scheduled depreciation and maintenance replacement cycle is standard for the accounting sheet.

2. The Humidity Exposure Trap

If you do not pre-treat the gas and allow raw, un-modified Graphene Oxide (GO) to come into direct contact with wet industrial steam (such as the damp exhaust from a whisky fermentation tank):

- The Lifespan Drops to around 24 - 48 hours.
- The Reason: Raw GO is highly hydrophilic (water-attracting). Liquid water vapor slips between the atomic layers, causing the membrane matrix to swell, delaminate, and physically disintegrate within a couple of days under pressure.

3. The Particle Clogging Lifecycle (The 3–6 Month Backwash)

Industrial smokestacks do not just emit pure gas; they carry microscopic ash, soot, unburned particulates, and heavy volatile compounds. Over time, these microscopic particles physically cake onto the front surface of the hollow-fiber graphene cylinders, blinding the nanopores and choking off the air volume.

The Maintenance Solution: Every 3 to 6 months, the DGCS must execute an automated ultrasonic chemical backwash. The system pumps a specialized mild solvent backward through the fibres while hitting the cartridge with high-frequency sound waves to shake loose the industrial soot, instantly restoring the graphene's high-speed permeance without ripping the material. We are using Mixed-Matrix Membranes (MMMs), which blend graphene flakes with tough polymer plastics, research suggests this method ensures longevity thus the Filters should last 3 years before replacement.

The Business Model

We do not bury the carbon underground at a loss because fermentation gas from distilleries and breweries is biogenic (food-grade), it is a highly valuable and pure commercial commodity. We capture a waste product and sell it directly into existing, supply-starved commercial markets and we save businesses £50 per tonne of CO_2 tax leaked to atmosphere beyond their allowance as a further incentive.

[Distillery Waste] ➔ [GCS Container Filter] ➔ [Logistics Fleet] ➔ [Premium Commercial Sale]

Revenue Stream Examples

Filter-as-a-Service (FaaS) Subscriptions: Distilleries pay zero upfront capital. We drop The DGCS container onto their site for free. They pay a predictable monthly service fee based on the volume of gas we clean, allowing them to instantly meet corporate net-zero mandates.

Premium Merchant Gas Sales: We own the captured liquid payload. We truck the full 20-tonne containers directly to local beverage carbonation plants, vertical greenhouse farms, and e-fuel developers, who actively pay top-tier market prices for green, non-fossil CO_2.

High-Value Voluntary Carbon Credits (VCCs): Because the capture process avoids fossil-fuel heating cycles, The lifecycle data is incredibly clean. Every tonne we capture generates a premium, verifiable biogenic carbon credit that tech corporations purchase at a premium to hit their climate goals.

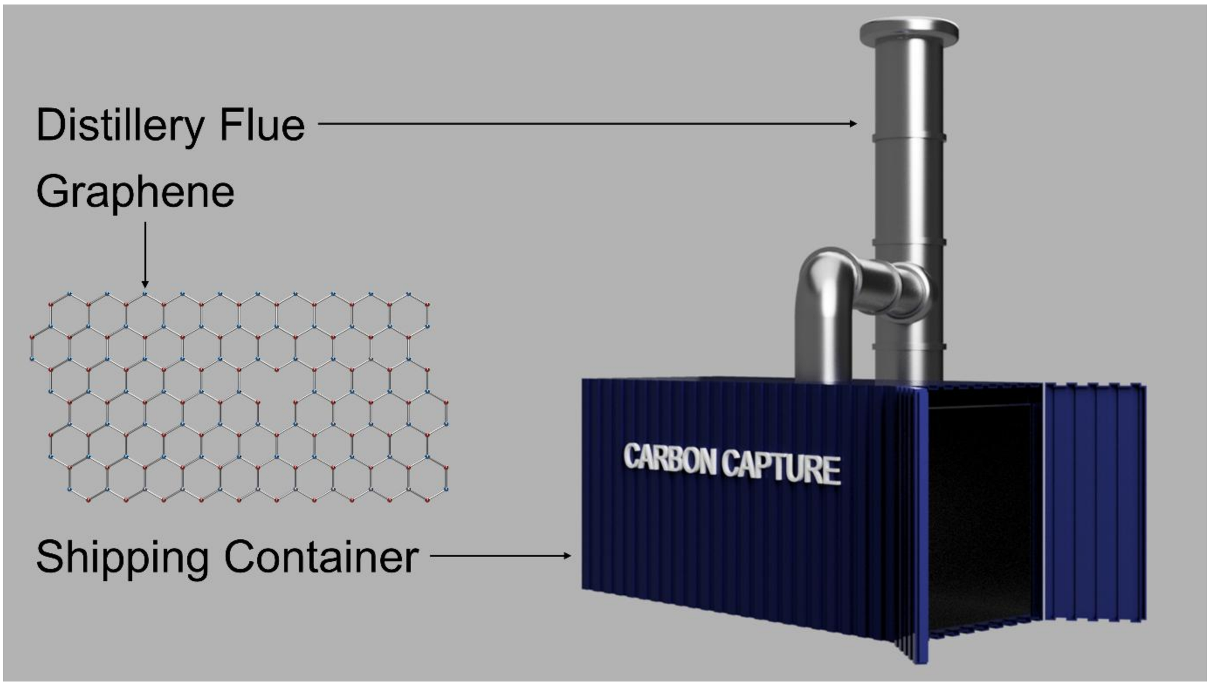

Figure 5 Basic Principle

The Unit Economics

DGCS Revenue Per Unit

The low-energy graphene membrane architecture shifts carbon capture from an expensive infrastructure debt into a high-margin manufacturing product. The following is based upon the average output of distilleries and breweries CO_2 output.

The Financial Breakdown (Per 20-Tonne Liquid CO_2 Container Payload)

The Build Cost (CapEx): £120,000 to manufacture one complete container variant (including frame, dehumidifier, dryer bay, graphene cylinders, and external 20 tonne liquid compression tanks).

The Turnaround Time: Attached to a mid-to-large industrial distillery, the container fills a 20-tonne liquid tank in approximately 24 hours.

Table 1 Daily Revenue

Daily Revenue	Sales Point	Value
Merchant Gas Sale	Beverage/Vertical farming/E-Fuel (£150/tonne)	£3000
Biogenic Carbon Credits	Sold to corporate buyers at (£80/tonne)	£1600
Gross Per Day		£4600

Daily Operating Costs (OpEx): ~£1,000 This covers grid/solar hybrid electricity for drying and liquefaction, truck haulage logistics, and a membrane maintenance reserve.

Daily Net Revenue (Ideal Case): ~£4,600 After OpEx, this yields an idealised net profit of ~£3,600/day, equivalent to ~£1.31M/year under continuous operation.

Realistic Annual Net Profit: Accounting for shutdowns, maintenance cycles, seasonal variability, and operational unknowns, a more conservative estimate is ~£1M/year per container.

System Throughput: At scale, 1,400 units operating at 20 tonnes/day would capture ~10 million tonnes of CO_2 per year.

Scaled Investment Return (Rewritten for Carbon13)

Early modelling suggests that a DGCS container could recover its £120,000 manufacturing cost rapidly under favourable operating conditions. In a continuous-run scenario with stable CO_2 output and consistent buyer demand, payback could theoretically occur within one to two months. This represents the upper bound of performance and will be validated through pilot data.

Once capital costs are recovered, the DGCS architecture has the potential to operate with high margins due to low-energy membrane capture and the premium value of biogenic CO_2. While theoretical modelling indicates margins could reach ~82% under perfect conditions, a more realistic expectation for early deployments accounting for downtime, maintenance, energy variability, and logistics is in the 60–70% net margin range.

These figures will be refined as empirical data becomes available from the benchtop rig, container prototype, and live distillery pilot. The purpose of this modelling is to illustrate the scalability and capital efficiency of the DGCS system once validated, not to guarantee specific financial outcomes.

The Roadmap & Milestones

To scientifically validate feasibility.

Table 2 Time Scale

[Months 1-3]	[Months 4-6]	[Months 7-9]	[Months 10-12]
Benchtop Rig	Chimney Gas Lab Run	20-Foot Container	Live Distillery Pilot

Months 1–3: The Benchtop Rig Construction

- Finalise chemical cross-linking specifications for The Reduced Graphene Oxide (rGO) membrane sheets.
- Build a scaled-down, enclosed laboratory testing rig utilizing an automated desiccant air-drying loop.
- Deliverable: A functional, low-cost laboratory prototype ready to accept pressurized gas feeds.

Months 4–6: Empirical Data & Mass Spec Verification

- Run controlled test streams simulating both ambient air (0.04% CO_2) and industrial fermentation gas (95%+ CO_2).
- Use a mass spectrometer to generate verified performance data on The carbon selectivity, flow speed, and moisture resistance.
- Deliverable: A third-party validated engineering report proving the room-temperature capture efficiency.

Months 7–9: The 20-Foot Container Integration

- Secure a second-round Seed funding injection (£1M–£1.5M) backed by The Phase 1 laboratory data.
- Procure The first standard 20-foot shipping container frame and fit it with a 2 × 2 industrial fan grid, dehumidifier bay, and a hollow-fiber graphene cylinder cartridge.
- Deliverable: A mobile, road-ready GCS container prototype.

Months 10–12: Live Distillery Pilot Deployment

- Drive The GCS container truck to a local craft distillery partner.
- Plug directly into their active fermentation vent line to execute a 30-day continuous capture-and-liquefaction field test.
- Deliverable: The first 20 tonnes of food-grade, biogenic liquid CO_2 successfully sold to the merchant market.

Risks & Unknowns

Although the DGCS concept is grounded in established membrane science and early laboratory evidence, several technical, commercial, and operational uncertainties must be validated through prototyping and pilot deployment. These risks are normal for a first-of-its-kind hardware venture and form part of the planned development pathway.

1. Membrane Manufacturing & Scale-Up Risk

Graphene oxide mixed-matrix membranes (MMMs) have been demonstrated at laboratory scale, but industrial-scale production introduces challenges in:

- Achieving uniform cross-linking across large membrane batches
- Maintaining consistent pore size distribution
- Ensuring long-term adhesion between RGO flakes and polymer matrices

Commercial membrane suppliers typically require multi-year development cycles to reach stable, repeatable production. Early prototypes will help determine manufacturability and cost per square metre.

2. Moisture Management & Humidity Stability

Although RGO–Pebax cross-linked membranes show strong humidity resistance in published studies, real fermentation exhaust streams contain:

- Variable moisture loads
- Temperature fluctuations
- Intermittent steam bursts

The dehumidification bay must be validated under real operating conditions to ensure membrane stability and prevent swelling or delamination.

3. Fouling, Soot, and Particulate Loading

Industrial exhaust streams contain:

- Microscopic particulates
- Volatile organic compounds
- Aerosols
- Trace contaminants

These can accumulate on membrane surfaces over time. While ultrasonic backwashing is expected to restore permeance, the true fouling rate and cleaning effectiveness will only be known after months of field operation.

4. Compression Energy & Liquefaction Efficiency

The DGCS system relies on low-energy vacuum pumps and compression stages. Actual energy consumption may vary depending on:

- Exhaust flow rate
- Ambient temperature
- Membrane permeance
- Liquefaction duty cycles

Pilot data will refine the OpEx model and determine the realistic cost per tonne.

5. CO_2 Market Volatility

Merchant CO_2 pricing fluctuates based on:

- Seasonal beverage demand
- Fertiliser plant outages
- Regional supply shortages
- Transportation constraints

While green biogenic CO_2 commands a premium, long-term pricing must be validated through buyer agreements and multi-year contracts.

6. Carbon Credit Integrity & Verification

High-value biogenic carbon credits require:

- Third-party verification
- Continuous monitoring
- Lifecycle analysis
- Registry acceptance

Credit prices vary, and future regulatory changes may affect revenue projections.

7. Safety, Certification & Regulatory Compliance

The DGCS container integrates:

- High-pressure CO_2 storage
- Vacuum systems
- Electrical components
- Industrial fans
- Dehumidification equipment

Certification may require compliance with:

- PED (Pressure Equipment Directive)
- ATEX (explosive atmosphere regulations)
- ISO membrane standards
- Local environmental permitting

These processes may extend deployment timelines.

8. Operational Reliability & Maintenance Cycles

The expected 2–5-year membrane lifespan is based on laboratory and literature data. Real-world performance may differ due to:

- Pressure cycling
- Thermal stress
- Unexpected contaminants
- Mechanical vibration

Pilot operation will determine the true replacement cycle and maintenance schedule.

Founder Fit

I am the right founder for this venture because I have the rare combination of hands-on engineering skill, mechanical and electrical design expertise, independent prototyping capability, and a proven portfolio of innovation through ROONTECH. I can build the early hardware myself, iterate rapidly, validate the science, and work with Carbon13's technical community to scale the system into a commercial product capable of removing millions of tonnes of CO_2 annually. My motivation is mission-driven, my background is directly relevant, and my track record shows I can turn ambitious ideas into working reality.

Commercial Viability

There is clear, validated demand for a low-energy, low-cost, containerised carbon capture system that converts waste fermentation gas into high-value liquid CO_2. Distilleries and breweries face rising carbon taxes, supply shortages, and sustainability pressure, making DGCS an immediately attractive solution. The commercial CO_2 market is large, supply-constrained, and willing to pay premium prices for green, biogenic CO_2. Combined with the sale of high-integrity carbon credits, the business model is profitable from day one and scalable across thousands of industrial sites worldwide.

Technical Feasibility

The DGCS system is technically feasible and grounded in established membrane science. The primary risks are moisture degradation, fouling, pressure stability, and membrane manufacturing. These potential defects are well understood and have clear mitigation strategies. The validation plan is structured, achievable, and aligned with Carbon13's 12-month venture-building timeline. My engineering background and ROONTECH portfolio demonstrates I have the capability to design, build, and iterate the required hardware systems with high capital efficiency.

Scientific Advisory Needs

Although I have a relevant background, I would still be seeking expert opinions from the following industries.

- Membrane Chemist (GO/RGO cross-linking)
- Process Engineer (compression & liquefaction)
- Regulatory Advisor (PED/ATEX)
- Industrial CO_2 buyer (market validation)

These professionals will highlight critical areas of improvement, regulation, science and sales. I will pay for a meeting where a selected group will provide real world data and valuable information.

Validation Metrics

Below is a list of variables that need to be validated especially with regards to the Pilot.

- CO_2 permeance (GPU)
- CO_2/N_2 selectivity
- Moisture tolerance (RH %)
- Energy consumption (kWh/tonne CO_2)
- Fouling rate (pressure drop per week)
- Backwash recovery efficiency (%)
- Membrane lifespan (days until degradation)
- Cost per tonne (validated, not modelled)

Pilot Success Criteria

For the Pilot to be a success the following criteria must be verified.

- 20 tonnes captured and liquefied
- Stable membrane performance for 30 days
- <10% permeance decay
- <5% downtime
- Verified purity >99.9%
- Validated OpEx within ±20% of model
- Buyer acceptance of CO_2 quality
- Safe operation under PED/ATEX constraints

Climate Impact

Each DGCS container captures approximately on average 7,300 tonnes of CO_2 per year from biogenic point-source emissions. Lifecycle emissions from electricity, manufacturing, and transport total only 33–80 tonnes annually, delivering a net climate impact of 7,220 tonnes CO_2e avoided per container per year (>99% net efficiency). At full scale (1,400 units), the system avoids 10.1 million tonnes of CO_2e annually. Because the CO_2 is biogenic, additional, metered, and permanently diverted from the atmosphere, the climate impact is high-integrity and fully defensible.

Why Now

The list below highlights the reasons for this project.

- CO_2 shortages in UK/EU
- Rising carbon taxes
- Distillery sustainability pressure
- Membrane science breakthroughs (GO/RGO MMMs)
- Containerised modular systems trend
- Biogenic CO_2 premium pricing

Critical Opinion

Distilleries and breweries are the ideal starting point for this technology because their fermentation exhaust streams contain 99% pure biogenic CO_2, allowing immediate, low-complexity validation of the graphene oxide membrane system. This purity eliminates the need for complex gas-conditioning infrastructure and ensures that every tonne captured is automatically duty-relieved and commercially valuable, creating early revenue while proving technical feasibility.

Beginning with these high-purity sites is essential for both profitability and scalability. The operational data, membrane performance metrics, moisture-management results, and container-level throughput gathered during these early deployments will directly inform the optimisation of next-generation GOM filters. This evidence base is what enables the technology to expand confidently into harder, higher-volume industrial sectors such as fertiliser production, cement manufacturing, and chemical processing, where CO_2 streams are larger but more complex.

Personal statement

My name is Chris and I am 44, I am an electrical engineer with a degree in mechanical engineering, and I have a passion for sustainable design. I have an ability to research, design and build prototypes with no external input within reason. However, I would love to work with other technical minds on this venture, as an innovator I do not proclaim to have the perfect solution first time around, I often find my initial idea is not the final solution but one of many iterations until it is. I am adaptable and like to be challenged to perform to my best ability.

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