

# Captured Carbon as a valuable co-product of gasification and pyrolysis

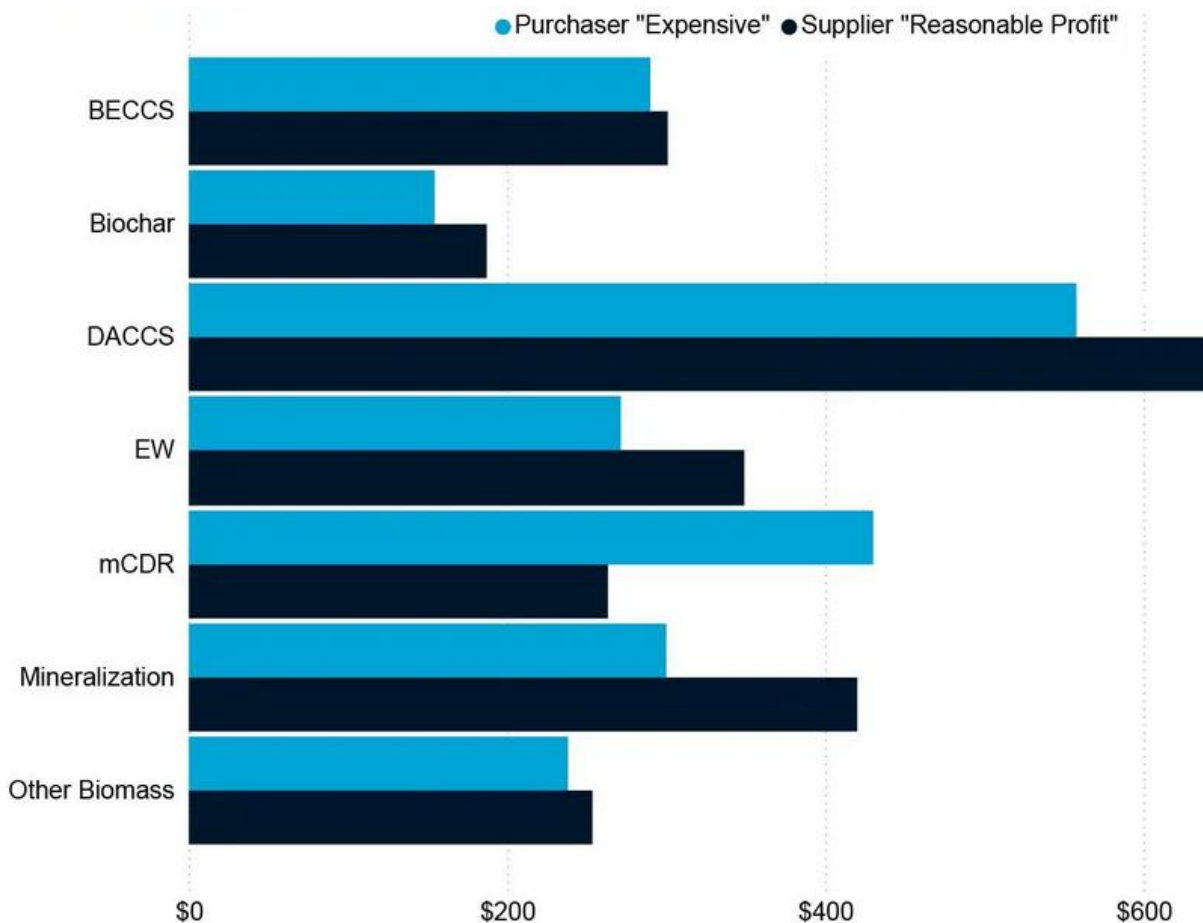
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sbh4 GmbH, Stephen B. Harrison

Gasification 2026, Berlin

26<sup>th</sup> March, 14:25 – 14:55

## 2025 cost perceptions for CDR methods



### BECCS or Biochar?

- ✓ BECCS allows a higher carbon yield for methanol, FTS fuels
- ✓ Biochar is perceived by both buyers and sellers to have the lowest CDR cost

# Captured Carbon as a valuable co-product of gasification and pyrolysis

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1. Case study in plasma gasification of hard-to-treat waste with CO<sub>2</sub> capture
2. Technology selection considerations for solvent-based CO<sub>2</sub> capture from gasifiers
3. Case study in pyrolysis with carbon “capture” in biochar

# 1. Case study in plasma gasification of hard-to-treat waste with CO<sub>2</sub> capture

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Captured CO<sub>2</sub> can enable sequestration for CDR  
or recycled for circularity

# Millenium technologies small-scale, decentralised plasma gasification - flexible across a range of problematic feedstocks, including hazardous and hard-to-treat wastes.



Shredded tyres



Wind turbine blades



RDF, 8 mm



Dried sewage sludge

- Solids, liquids and gases (eg syngas) can be processed
- For solids...
  - 10% moisture is ideal, up to 20% is acceptable
  - >60% organic, <40% inorganic possible
  - Pellets, flakes or particles (typical 20mm x 20mm)
- Hazardous wastes (eg halogens, phosphorus, sulphur)
  - F-Gas and PFAS destruction
  - Sulfonic acid (from surfactant production)
- Environmental management
  - Contaminated soil clean-up, eg oil spillages
  - Dried sewage sludge
- Hard-to-treat solid wastes with higher gate fees
  - SRF / RDF, Fabric waste, Plastic flakes
  - Ground tyres
  - Glass-fibre wind turbine blades

# Small industrial-scale, updraft, fixed-bed plasma gasifier for smaller volume, problematic, hazardous, and hard-to-treat wastes.



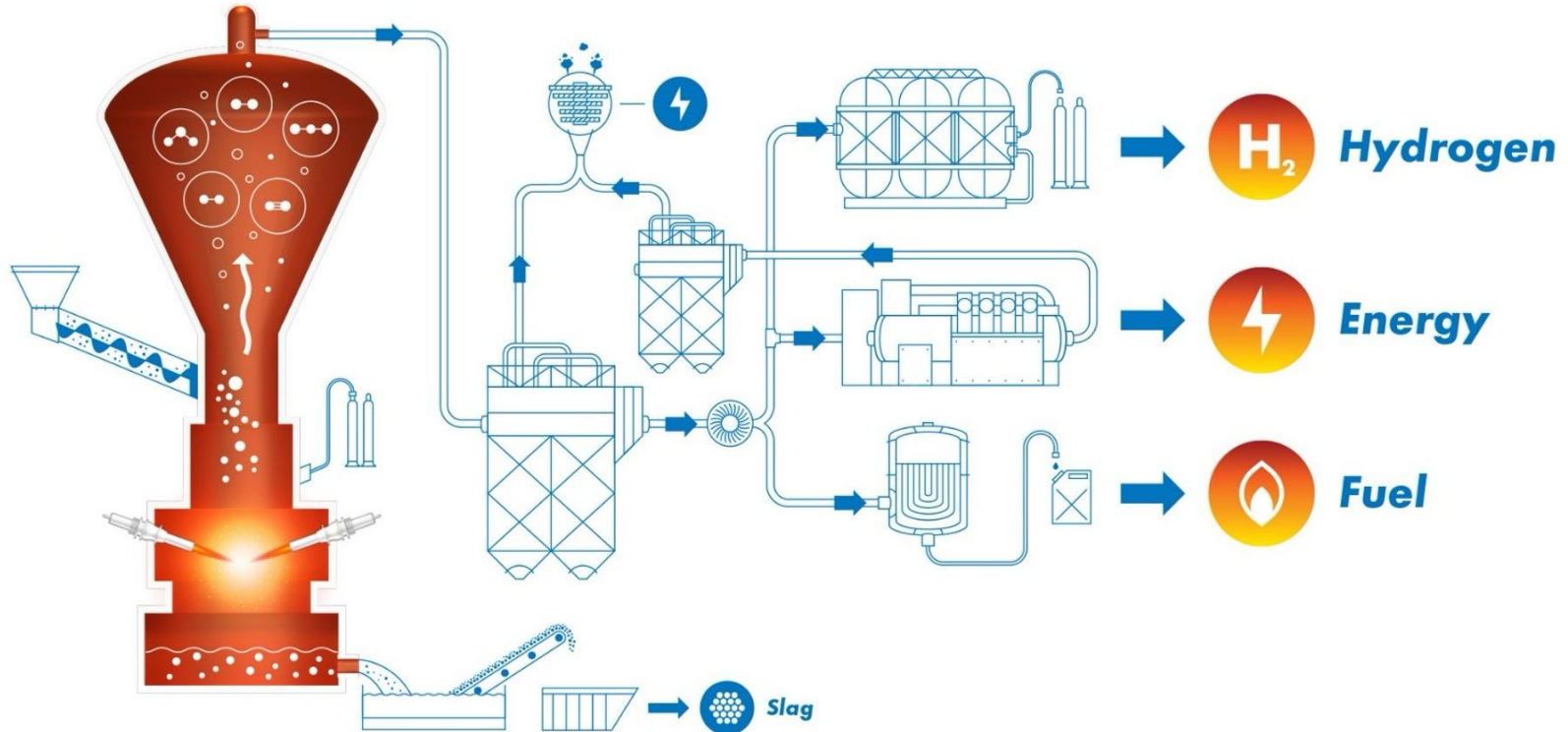
- Allothermal process maximises syngas yield and eases process control
- Cold start-up with natural gas burner to 800 °C for circa 8 hours, then plasma heats further to 1,200 °C
- High temperature operation reduces NOx and tars to very low traces
- Quick connect fittings for easy torch removal for electrode replacement (circa 10-minutes)
- Gasifier operation at 150 to 200 Pa under-pressure
- Scale up achieved with multiple torches, eg 5 x 85 kW torches for 0.5 tonne per day plant
- Syngas cooler for heat recovery followed by water spray quench for particulates knock-down
- Syngas clean up using wet caustic scrubbing
- Liquid slag leaves with overflow-based slag level control and is collected on a cooled conveyor

# Turbulent, non-transfer DC plasma torch pulsed with 20 to 30 kV with minimal current. Short jet, high spread & convection heat transfer, reduced hot spots, low-cost.



- Air plasma: 7 - 12 g/s at 10 bar
- Steam plasma possible for high SN, low-nitrogen ballast syngas (ideal for hydrogen generation with CO2 capture)
- CO2-enriched air plasma or CO2 injection after air plasma possible for CO2 recycling
- Torches 85 or 150 kW, 85 kW torch weights circa 10kg
- Low-cost hafnium-coated copper electrode with circa 100 hours life on air plasma
- Bulk gasification zone 1,000 – 1,200 °C
- Highly responsive for flexible load operation
- Plasma concept like the Westinghouse torch, but applied at a smaller scale and at different locations in the gasifier

Water gas shift converts CO to CO<sub>2</sub>, which can be captured and sequestered to yield low-carbon hydrogen. Depending on the feedstock, a portion of the CO<sub>2</sub> may be biogenic and can be monetised for CDR or may be recycled to the gasifier.



Millenium Technologies (wholly owned by JRD): currently raising capital and seeking partnerships for 0.5 tonne per input pilot scale deployment.



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## 2. Technology selection considerations for solvent-based CO<sub>2</sub> capture from gasifiers

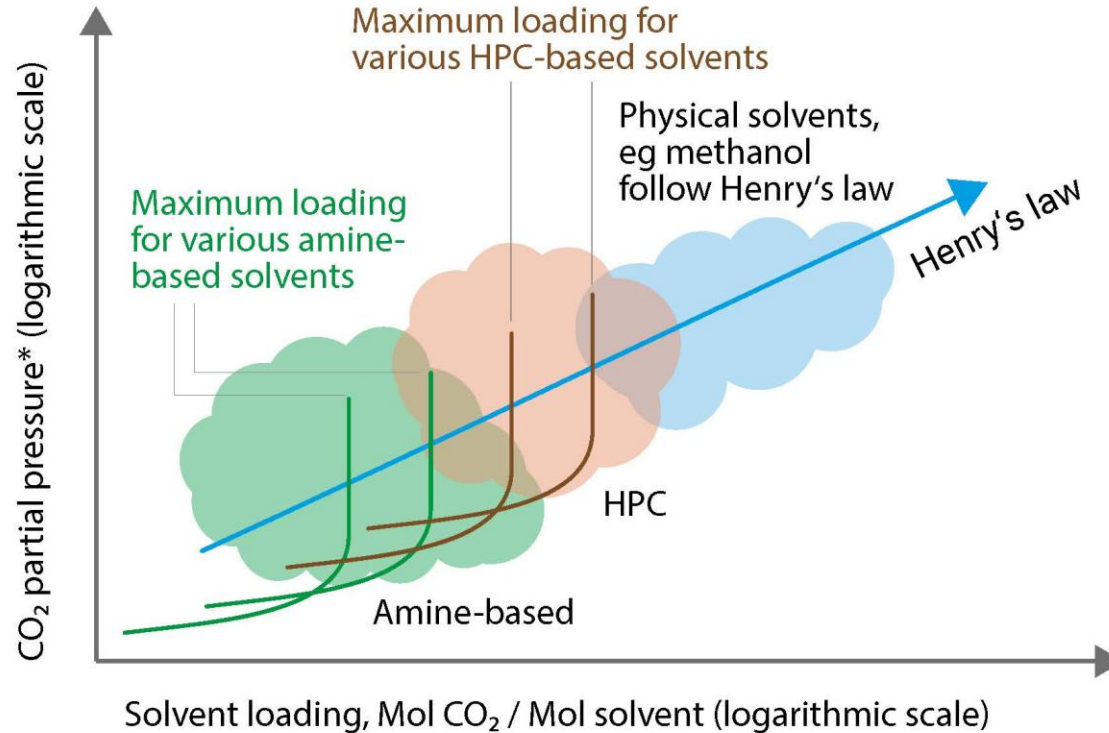
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What is the nature of the gas stream to be treated?

What is the scale of operation?

What are the local sensitivities to secondary emissions?

## CO<sub>2</sub> capture technology selection – rules of thumb for initial screening of liquid solvent systems.



\* CO<sub>2</sub> partial pressure = CO<sub>2</sub> molar concentration x stream pressure

Gasifier CO<sub>2</sub> capture applications can fit Amine, HPC and Physical solvent systems depending on the pressure and the amount of nitrogen ballast gas.

Chemical solvents (amine and HPC) react with the CO<sub>2</sub> (chemisorption) and require higher regeneration energies than physical solvents.

Physical solvents use physical absorption (physisorption) based on Henry's law. They require high partial pressure CO<sub>2</sub> but benefit from reduced regeneration energy.

Amine-based CO<sub>2</sub> capture at Heidelberg Materials, Brevik. Social acceptance is key. Under some circumstances, amine-based CO<sub>2</sub> capture systems release potentially harmful secondary emissions: aerosols containing the amine solvent & break-down products.



# Giammarco Technologies: 76 years of history using activated Hot Potassium Carbonate as a solvent for CO2 capture.



## 1950 The Origins



Discovery of activators for HPC solution (Arsenic, Amines, and Amino Acids)

## 1970 New Activators



Substitution of the arsenic activator with a glycine activator (organic and non-toxic)

## 1980 Breakthrough Scheme



Industrial application of GT low-energy regeneration system

## 1990 The Dual Concept Carsol Technology



**The Dual Concept**  
Introduction on the market of the GV dual activated solution (Amine plus Glycine)

**Carsol Technology**  
Acquisition of Carsol Activities

## 2000 Big Ammonia



The world two biggest twin Ammonia Plants: Fertiniro and Omifco  
- Super-intense Revamp activity

## 2010 Biogas



Establishment of Green Methane for Biogas Upgrading

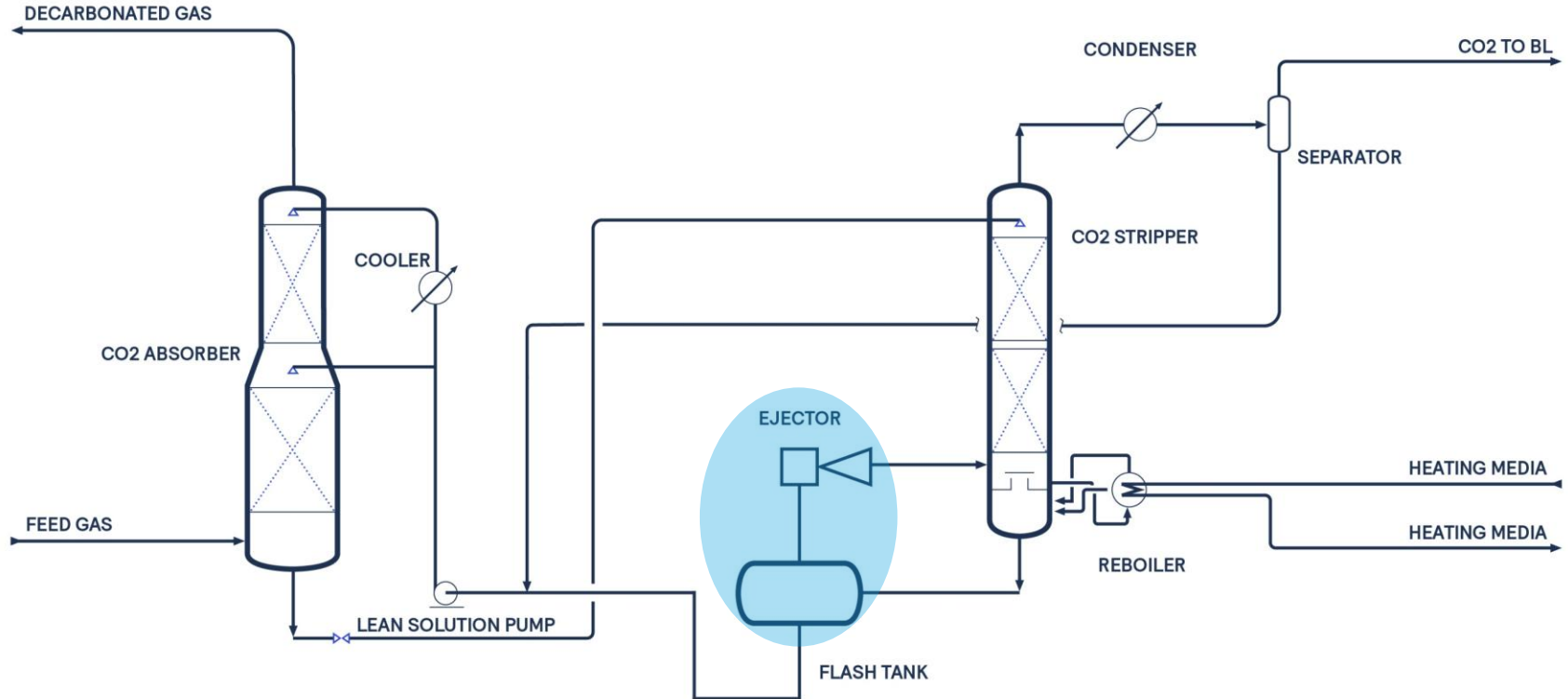
## 2020 Gasification



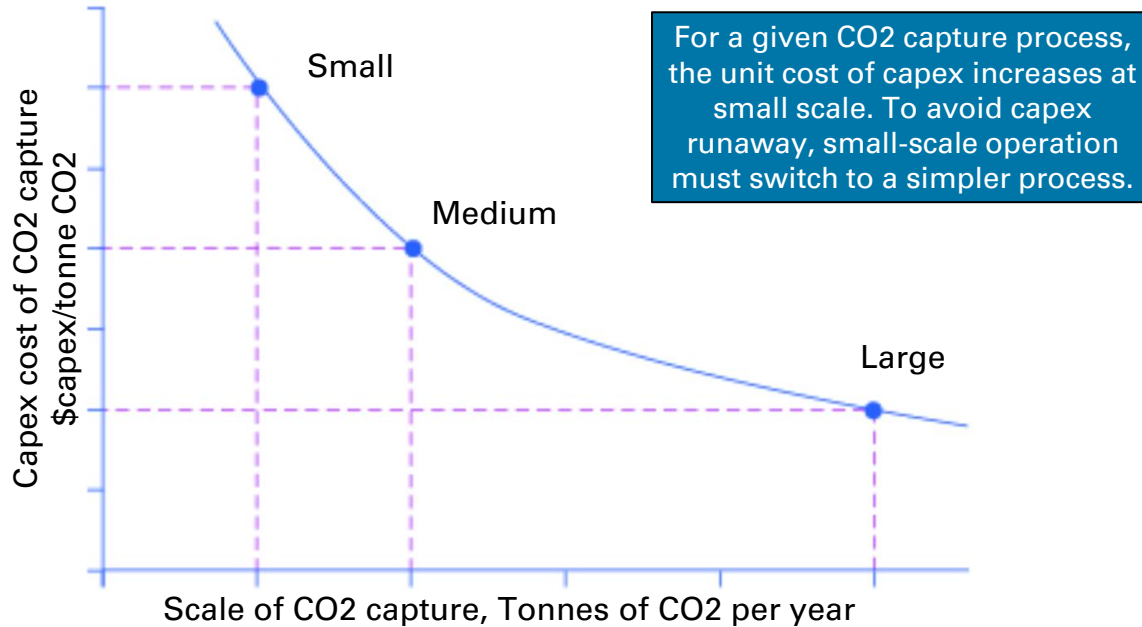
**Flexibility for New Markets**  
Expansion into new areas of operation:  
- Biomethane from AD  
- Biomass Gasification  
- Flue Gas Application

**Pilot & Demo Plant**  
To test new schemes

Giammarco Technologies HPC-NovaFlash®: high-efficiency Hot Potassium Carbonate CO<sub>2</sub> capture. A flash between the stripper and absorber columns reduces the HPC solvent regeneration heat energy input requirement. The flash tank return can either be with a steam-fed ejector, or electrically powered mechanical vapour recovery (MVR).

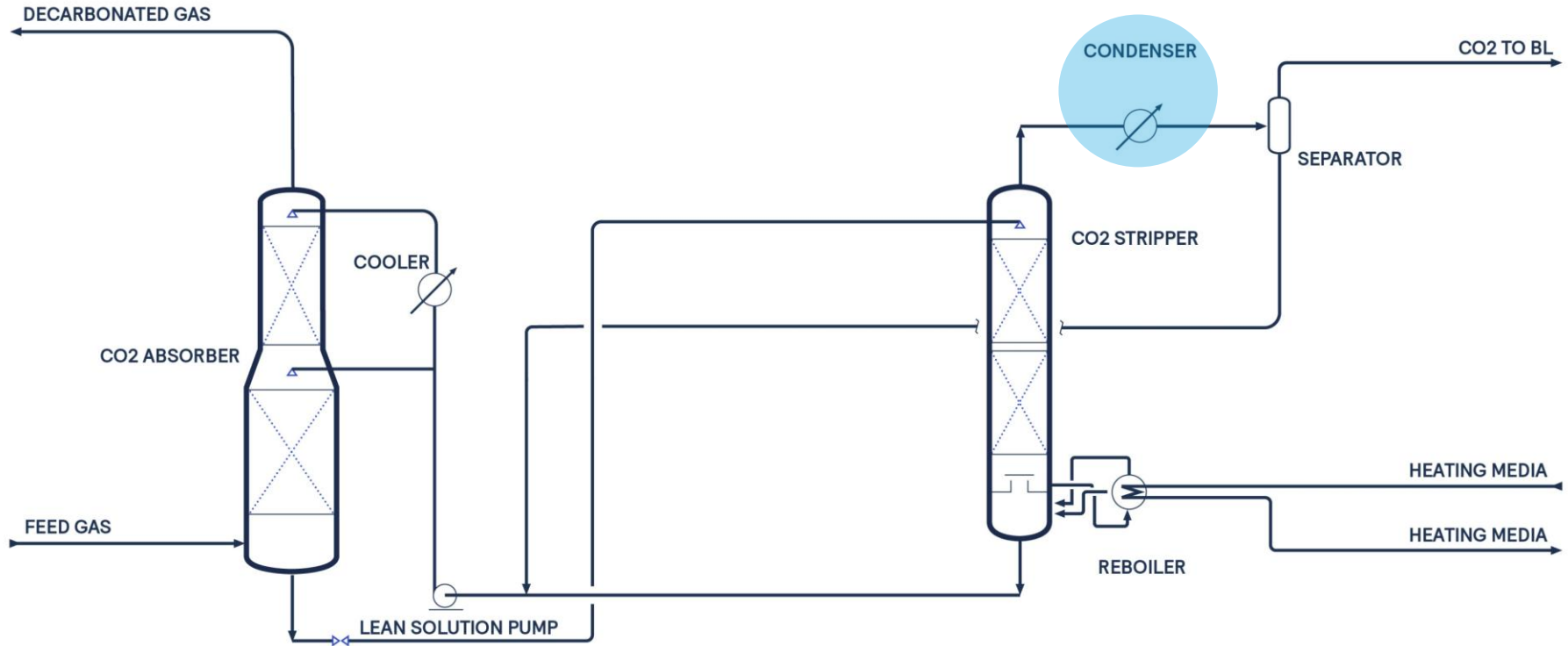


# At small scale, process simplicity (low-capex) beats optimum efficiency.



# Giammarco Technologies HPC-Genesys<sup>®</sup> - low capex Hot Potassium Carbonate CO<sub>2</sub> capture design for smaller gasification plants.

Depending on the operating pressure, waste heat from the condenser is available between 80 and 110 °C.



# Giammarco Technologies: multiple commercial references for CO2 capture using HPC.



Happy to meet with partners, developers and clients. Looking for EPCs to complement our Engineering Services with BOP engineering and construction.

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### 3. Case study in pyrolysis with carbon capture in biochar

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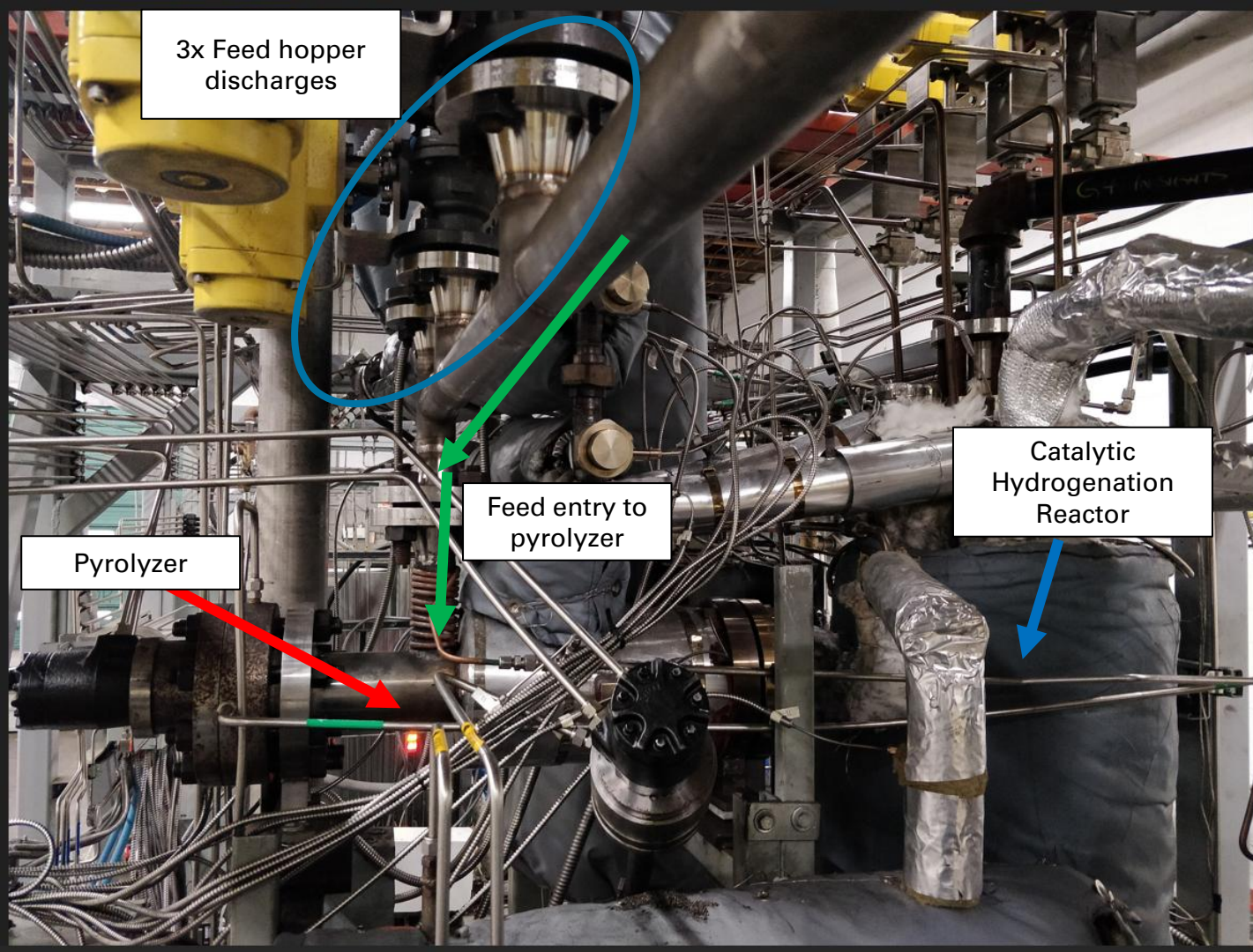
Locking carbon into biochar can enable sequestration  
where geological CO<sub>2</sub> storage is not proximate

Biochar is currently a larger contributor to CDR than BECCS. Through Exomad Green (Bolivia) and Varaha (India) the “global south” currently leads CDR.

 Exomad Green	29,616	BCR
 Varaha	20,594	BCR
 Biochar Life	10,228	BCR
 Gevo, Inc.	8,549	BECCS
 Vaulted Deep	4,844	Other BiCRS
 ACT Commodities	4,001	BCR
 Charm Industrial	2,243	Other BiCRS
 Carboneers	2,000	BCR
 Graphyte	1,538	Other BiCRS



- BCR – Biochar
- BECCS – Bioenergy carbon capture and storage
- BiCRS – Biomass carbon removal and storage



3x Feed hopper discharges

Feed entry to pyrolyzer

Pyrolyzer

Catalytic Hydrogenation Reactor

### G4 Biorefinery

- PyroCatalytic Hydrogenation (PCH)
- Demonstration at ATCO Gas Edmonton
- Biomethane at 99% purity for grid Injection
- 100 kg woody biomass yields 1GJ of biomethane
- 70% net energy conversion efficiency
- 15 Years of development
- 2,000 hours of operation
- 9 patents issued in US, Europe, Canada, China



# Scaled-up G4 Biorefinery: commercial plant configurations (available 2030+) with 750 tonnes per day of woody biomass input.

## Low-cost biomethane design

- 70 tonnes (3,800 GJ) per day bio-methane
- 300 tonnes per day biochar
- Biomethane \$2.93 per GJ\*
- NGCC power cost \$37/MHW
- 31 gCO<sub>2</sub>e/MJ\* biomethane carbon intensity

## High-hydrogen capacity design

- 80 tonnes per day bio-hydrogen
- 150 tonnes per day biochar
- LCoH \$2.26/kg\*
- 28 gCO<sub>2</sub>e/MJ\* H<sub>2</sub> carbon intensity
- Capex circa 2x low-cost biomethane design

## Assumptions for all design configurations

\$60/tonne biomass input (circa 100 to 200 km radius)

\$100/tonne for biochar sale for utilisation (eg soil)

\$150/tonne CO<sub>2</sub>e for CDR certificates

2.5 tonnes CO<sub>2</sub>e per tonne of biochar (80% carbon)

\$475/tonne total biochar value

*\*Biochar CDR offsets the bio-hydrogen / biomethane cost*

## Hydrogen plus biochar design

- 34 tonnes per day bio-hydrogen
- 300 tonnes per day biochar
- LCoH \$1.30/kg\*
- 18 gCO<sub>2</sub>e/MJ\* H<sub>2</sub> carbon intensity
- Capex 40% more than low-cost biomethane design

G4 Insights: currently raising capital and seeking partnerships for 40 tonne per day woody biomass input pilot scale deployment.

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Burnaby, BC, Canada

24 March, 2026



sbh4  
consulting

# Introduction to Stephen B. Harrison and sbh4 consulting

**Stephen B. Harrison** is the founder and managing director at sbh4 GmbH in Germany. His work focuses on decarbonisation and GHG emissions reduction. E-fuels, hydrogen, ammonia and CCTUS are fundamental pillars of his consulting practice.

Stephen has extensive M&A and investment due diligence advisory experience in the energy and clean-tech sectors. Private Equity firms, investment fund managers and green-tech start-ups are regular clients. He also supports operating companies in their mission to decarbonise their scope 1, 2 and 3 GHG emissions.

In 2023, Stephen evaluated seven CCTUS, hydrogen and e-fuels submissions to the European Commission's Third Innovation Fund. The fund allocated €2 billion to large-scale decarbonisation projects in Europe. In 2024 he supported the European Commission with venture capital investment due diligence and assessed eight Horizon grant applications. Again in 2025, Stephen is assessing seven Innovation Fund applications related to e- and bio-methanol production.

Stephen has served as the international expert and team leader for three ADB projects related to CCTUS and renewable hydrogen deployment in Pakistan, Palau and Viet Nam. He has also supported the IFC and world bank on e-fuels and green hydrogen strategy development projects in Namibia and Pakistan.

With a background in industrial and specialty gases, including 27 years at BOC Gases, The BOC Group and Linde Gas, Stephen has intimate knowledge of e-fuels, hydrogen, ammonia and carbon dioxide from commercial, technical and operational perspectives. For 14 years, he was a global business leader in these FTSE100 and DAX30 companies.

As a member of the H2 View and **gasworld** editorial advisory boards, Stephen advises the direction for the leading hydrogen-focused international publications. Through H2 VIEW, World Hydrogen Leaders and Sustainable Aviation Futures, he has led Masterclasses covering many hydrogen, SAF and hydrogen derivatives themes in virtual and live sessions.

Stephen was session chair for the e-fuels and hydrogen propulsion track at the Bremen Hydrogen Technology Exhibition in September 2023 and chaired the same stream at that conference in Hamburg in 2024. He was also conference chair for the CO2 utilisation Summit in Hamburg in 2023 and the same event in Berlin in 2024 and Antwerp in 2025.

