sbh4 consulting

Making the case for BECCS from biomass CHP facilities

European Biomass to Power Summit

Stephen B. Harrison, sbh4 consulting

Hamburg, 4th December 2025

sbh4
consulting

Agenda

Hi, I'm Steve.
I work with biogenic CO2 emitters to maximise the value of their CO2.

09:35

Stephen B. Harrison
Managing Director
sbh4 Consulting

Making the case for BECCS from biomass CHP facilities

- Woody biomass versus other fuels – considerations for CO2 capture
- Energy efficiency and economics of CO2 capture – parasitic heat or power
- Captured CO2 specifications and the downstream value chain
- Generating revenue to create a business case for

sbh4
consulting

Woody or cellulosic biomass versus other fuels – considerations for CO_2 capture

Building the business case on the market conditions and good science.

Technology selection must fit the flue gas input and required CO_2 output.

Energy inputs can be heat, or power based.

Ørsted is planning to capture around 150,000 tonnes of CO_2 per year at the straw-fired Avedøre CHP Station in Copenhagen. Biomass fired CHP plants generally operate at atmospheric pressure and have a low/moderate CO2 concentration in the flue gas (generally 8% to 12% dry basis) – like coal.

sbh4 consulting

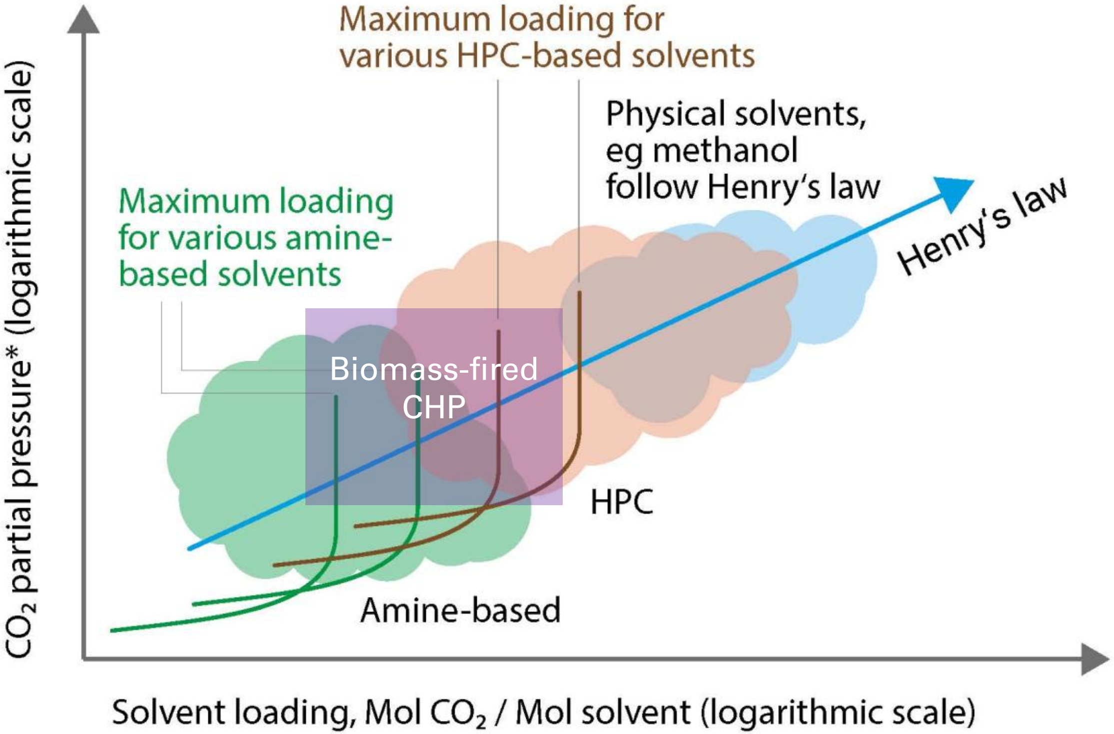
Key criteria for CO2 capture technology screening. The goal is minimum levelized cost per tonne of CO2 captured over the planned operating life: LCoCO2. This must be achieved within other constraints and boundary conditions, eg permitting, space, minimum TRL.

sbh4 consulting

- Flue gas / stream pressure – high pressure can favour systems that use a "flash" to "boil off" CO2 without using heat energy
- Flue gas / stream CO2 concentration – amine systems are good at very low (circa <8%) CO2 concentration, others not
- Flue gas / stream balance gas – eg high purity CO2 with moisture as the balance gas can use moisture condensation and direct CO2 liquefaction
- Flue gas / stream impurities - Amine systems have low tolerance for sulphur, so does PSA/VPSA… Rectisol and Chart CCC cope well with H2S or SO2. Amine systems will be degraded faster if there is a high oxygen concentration and amine systems can absorb hydrocarbons and VOCs, potentially resulting in hazardous situations
- Solvent / solvent degradation products aerosol emissions to air and water
- Variability of the flue gas / stream flow rate – some systems suffer poor mass transfer (eg flooding, weeping) at turndown. Amine solvents can absorb and accumulate flammable VOCs at low turndown
- Availability on the site of (waste) heat, steam and power
- Potential utilisation of waste heat for district heating
- Access to feedstocks and markets for the products of mineralisation processes
- Required CO_2 purity
- Requirement for overall CO2 capture rate
- Requirement for gaseous or liquid CO2 as the product
- Scale of operation
- TRL requirement for investment
- Available space (footprint and height)

CO_2 capture technology selection – rules of thumb for initial screening of liquid solvent systems.

sbh4 consulting



* CO_2 partial pressure = CO_2 molar concentration x stream pressure

Biomass-fired CHP facilities generally sit at the overlap of amine and HPC systems

Chemical solvents (amine and HPC) react with the CO2 (chemisorption) and require high regeneration energies.

Physical solvents use physical absorption (physisorption) based on Henry's law. They require high partial pressure CO2 but benefit from reduced regeneration energy.

- Selexol (Honeywell UOP, Glycol / PEG)
- Rectisol (Linde / AL, methanol)
- Purisol (AL (Lurgi), NMP)
- Sulfinol (Shell, Sulfolane and amines)

sbh4 consulting

Energy efficiency and economics of CO2 capture: parasitic heat or power

Amine-based solvents are a common choice for CO2 capture from coal and biomass-fired facilities. The standard amine solvent process uses heat from the power plant to regenerate the solvent.

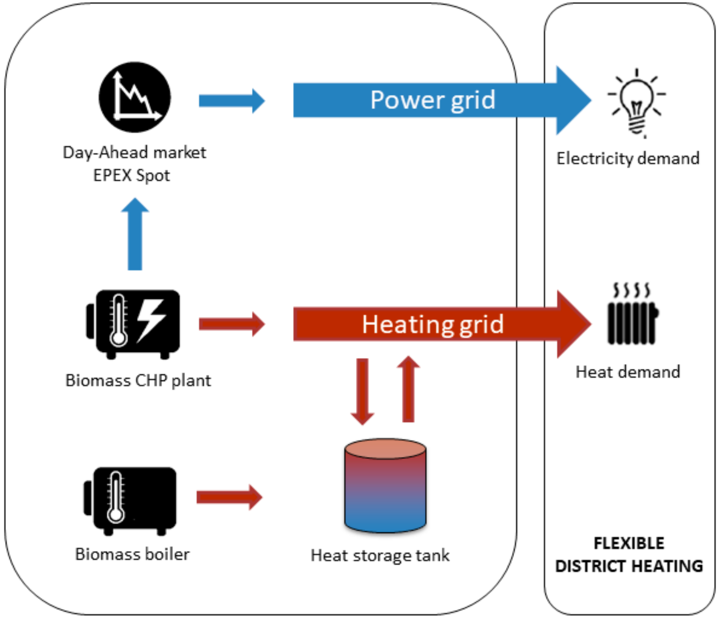
sbh4 consulting

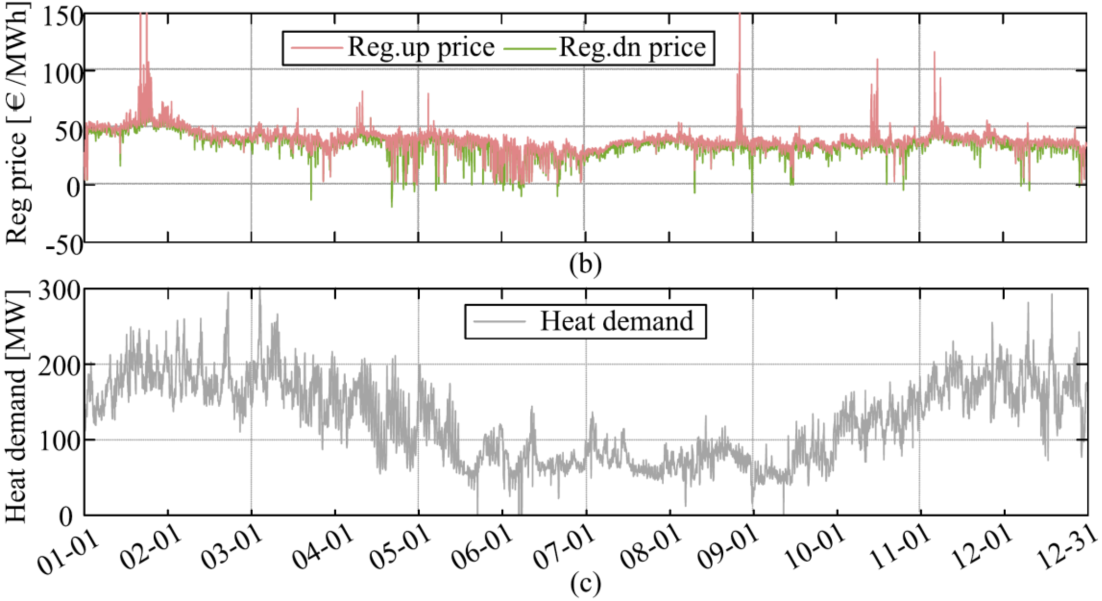
Petra Nova MHI CO2 capture

Sask Power Boundary Dam, Cansolve CO2 capture
https://www.aecon.com/our-expertise/construction/industrial/saskpower-boundary-dam-carbon-capture.

But… biomass-fired CHP often integrates district heating and power generation: both heat and power have value. Therefore, at different times of the day / year parasitic use of heat or parasitic power for CO2 capture will be favourable.

sbh4 consulting





https://www.mdpi.com/1996-1073/13/16/4134

https://www.sciencedirect.com/science/article/pii/S0306261921012794

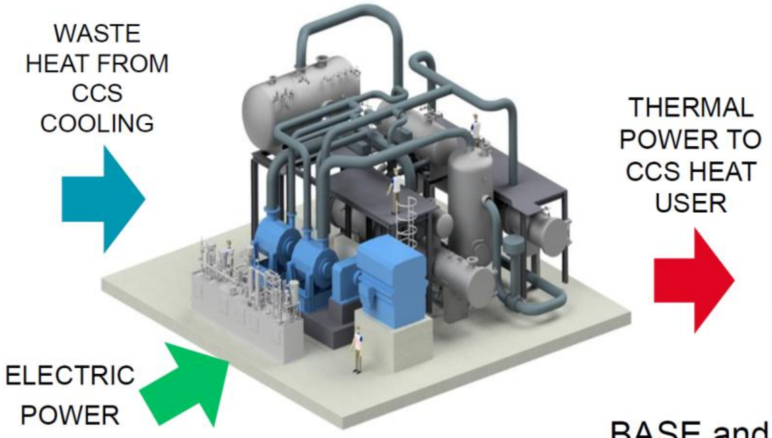
MHI amine-based system with a Turboden heat pump to upgrade low-temperature heat using electricity to minimise the parasitic heat requirement for steam generation.

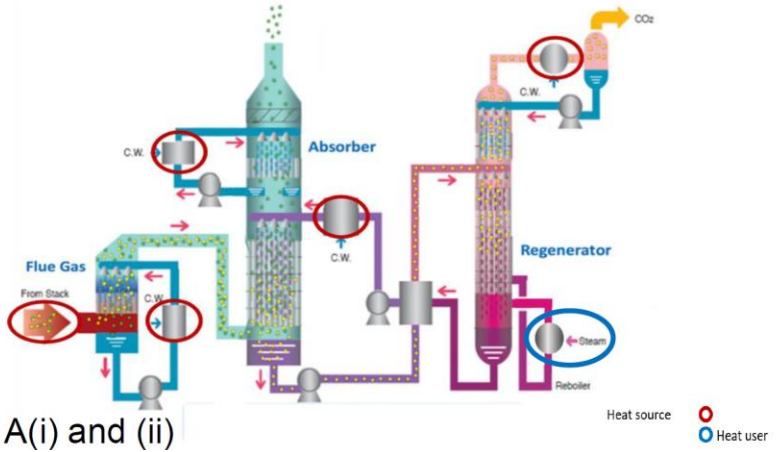
sbh4 consulting

- ✓ Major voices of OPEX: Heating energy for regenerator & Cooling energy for process
- ✓ Heat pump system: OPEX improve by utilizing waste heat energy for regenerator
- ✓ Avoid additional CO_2 emissions and water consumption

	Heat input to regenerator	Cooling duty
Duty (MW%)	40	100 (Base)
Temperature (deg.C)	110 to 120	40 to 70

Typical duty and temperature of heating and cooling in KM CDR Process™

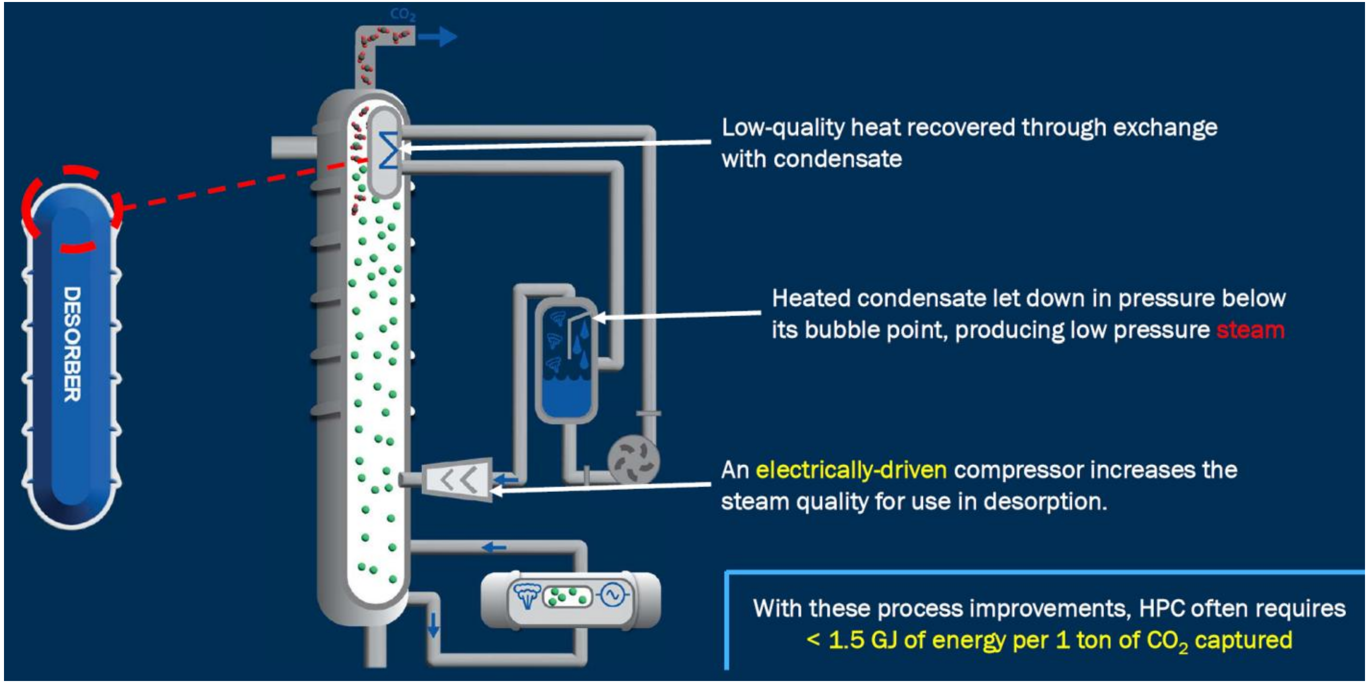




BASE and A(i) and (ii)

Switching from an amine solvent to HPC can reject heat at a higher temperature to feed district heating. HPC systems can implement also partial electrification with a MVR heat pump.

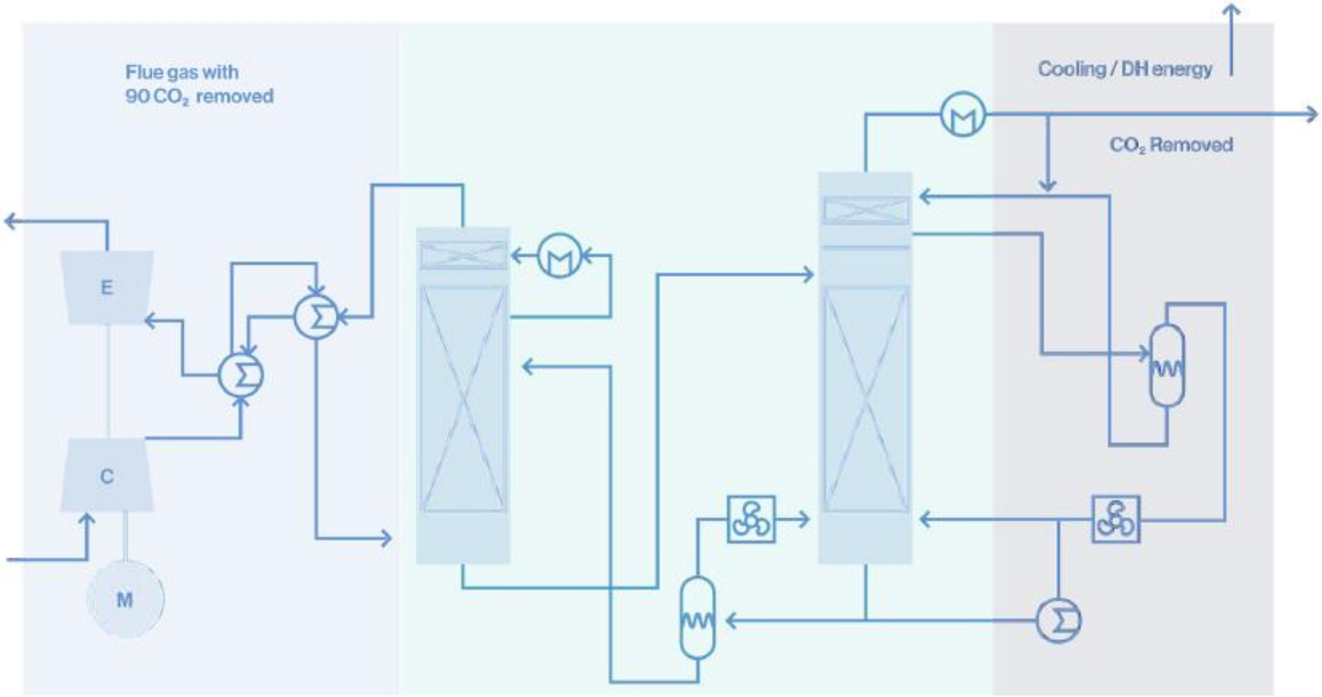
sbh4 consulting

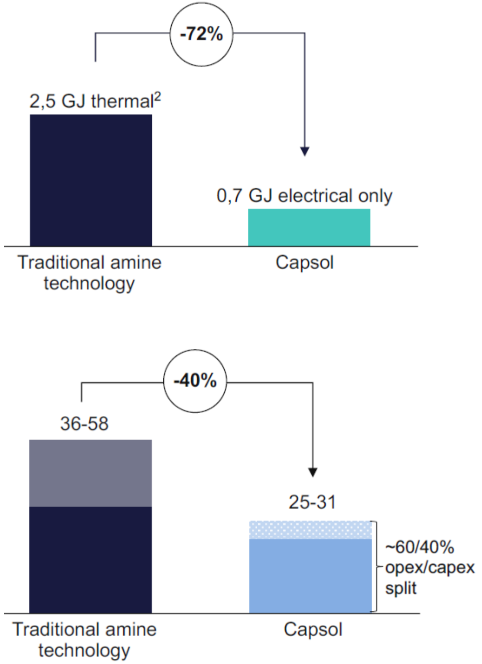


https://content-cdn.sessionboard.com/content/Zeebs6yjQSaqee7OTfyA_POWERGEN%20-%20CATACARB.pdf

Full electrification of HPC is also possible. CapsolEoP™ claims 0.7 to 1.5 GJ Electrical power required per 1,000 tonnes of CO2 captured. A flue gas compressor is key to operating the high-pressure HPC process with a flash between the absorber and stripper. Residual pressure energy is recovered from the flue gas using an expansion turbine.

sbh4 consulting

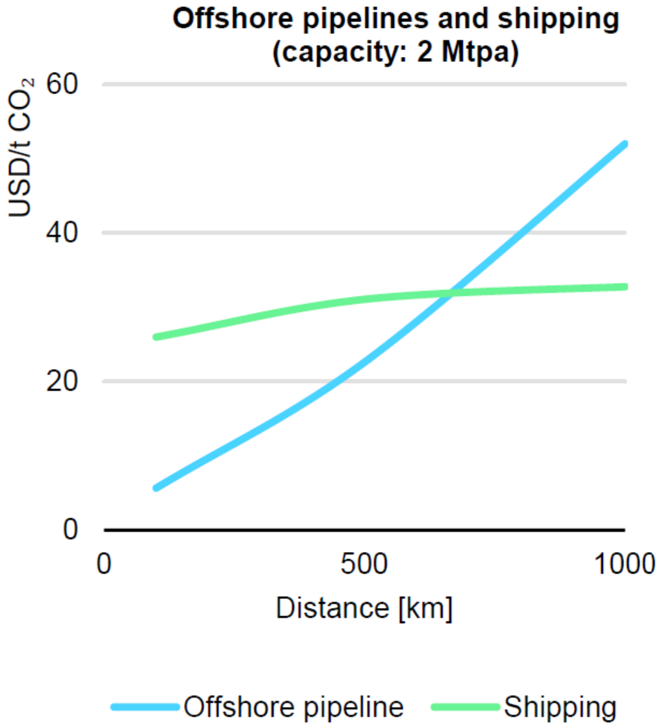




Captured CO2 specifications and the downstream value chain

Overland, CO2 pipelines are the most efficient mode of CO2 transportation. For offshore routes, it is likely that there is a crossover at longer distances favouring shipping over pipelines.

sbh4 consulting



https://iea.blob.core.windows.net/assets/d0cb5c89-3bd4-4efd-8ef5-57dc327a02d6/CCUSPoliciesandBusinessModels.pdf

Northern Lights liquid CO2 specification leans towards CO2 liquefaction and cryogenic distillation for purification.

Component	Unit	Limit for CO_2 Cargo within Reference Conditions[1]
Carbon Dioxide (CO_2)	mol-%	Balance (Minimum 99.81%)
Water (H_2O)	ppm-mol	≤ 30
Oxygen (O_2)	ppm-mol	≤ 10
Sulphur Oxides (SO_X)	ppm-mol	≤ 10
Nitrogen Oxides (NOx)	ppm-mol	≤ 1.5
Hydrogen Sulfide (H_2S)	ppm-mol	≤ 9
Amine	ppm-mol	≤ 10
Ammonia (NH_3)	ppm-mol	≤ 10
Formaldehyde (CH_2O)	ppm-mol	≤ 20
Acetaldehyde (CH_3CHO)	ppm-mol	≤ 20
Mercury (Hg)	ppm-mol	≤ 0.0003
Carbon Monoxide (CO)	ppm-mol	≤ 100
Hydrogen (H_2)	ppm-mol	≤ 50
Cadmium (Cd), Thallium (Tl)	ppm-mol	Sum ≤ 0.03
Methane (CH_4)	ppm-mol	≤ 100
Nitrogen (N_2)	ppm-mol	≤ 50
Argon (Ar)	ppm-mol	≤ 100
Methanol (CH_3OH)	ppm-mol	≤ 30
Ethanol (C_2H_5OH)	ppm-mol	≤ 1
Total Volatile Organic Compounds (VOC)[2]	ppm-mol	≤ 10
Mono-Ethylene Glycol (MEG)	ppm-mol	≤ 0.005
Tri-Ethylene Glycol (TEG)	ppm-mol	Not allowed
BTEX[3]	ppm-mol	≤ 0.5
Ethylene (C_2H_4)	ppm-mol	≤ 0.5
Hydrogen Cyanide (HCN)	ppm-mol	≤ 100
Aliphatic Hydrocarbons (C_3+)[4]	ppm-mol	≤ 1,100
Ethane (C_2H_6)	ppm-mol	≤ 75
Solids, particles, dust	Micro-meter (µm)	≤ 1

Original CO_2 spec (Water through Cadmium, Thallium)

Clarification from original CO_2 spec (Methane, Nitrogen, Argon)

Updated component (Nitrogen Oxides; Mercury)

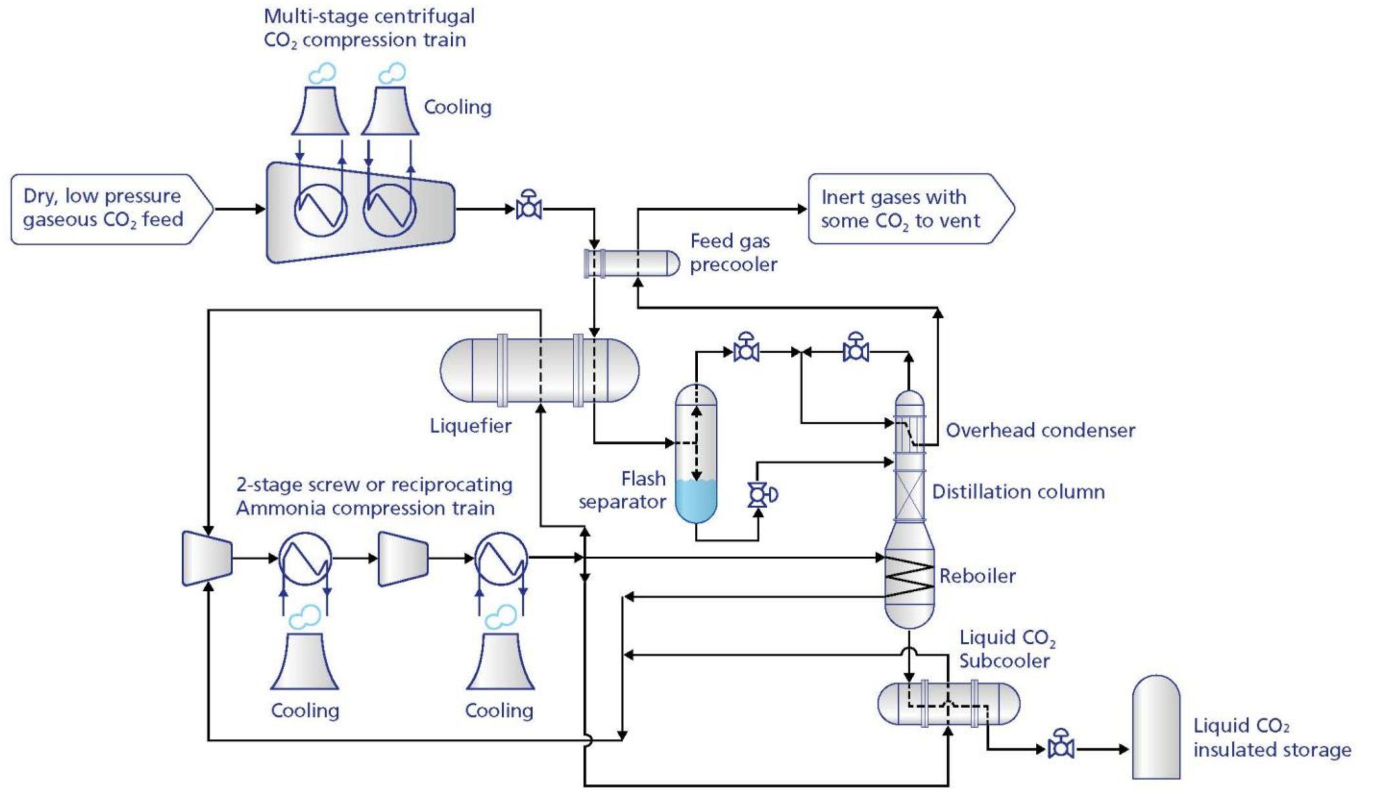
Moved to solids (Cadmium, Thallium)

New component (Methanol through Solids, particles, dust)

13 November, 2025

https://norlights.com/wp-content/uploads/2024/06/NorthernLights-GS-co2-spec2024.pdf

CO_2 Liquefier with Ammonia Refrigeration Cycle

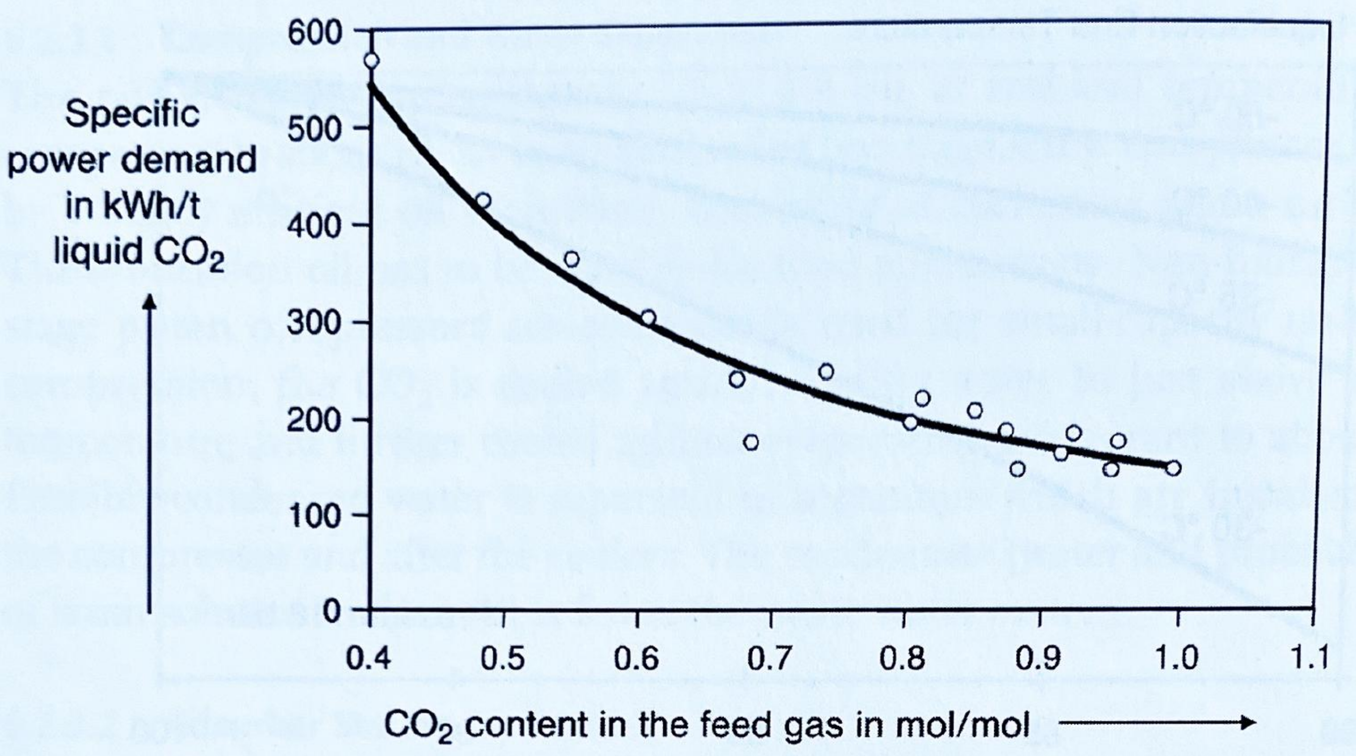


sbh4 consulting

- CO2 liquefaction uses electrical power for pumps, compressors and cooling tower fans
- The power can be supplied from renewable sources to minimize the CO2 intensity of the overall process
- Use of ammonia as a refrigerant gas is highly efficient and avoids the risk of F-Gas emissions with the associated GHG issues

High purity CO2 feed to the liquefier results in less overall power requirement for CO2 compression and liquefaction. But higher purity CO2 increases the energy requirement for CO2 capture. The holistic end-to-end CO2 capture and liquefaction system must be optimised.

sbh4 consulting



CO2 liquefaction

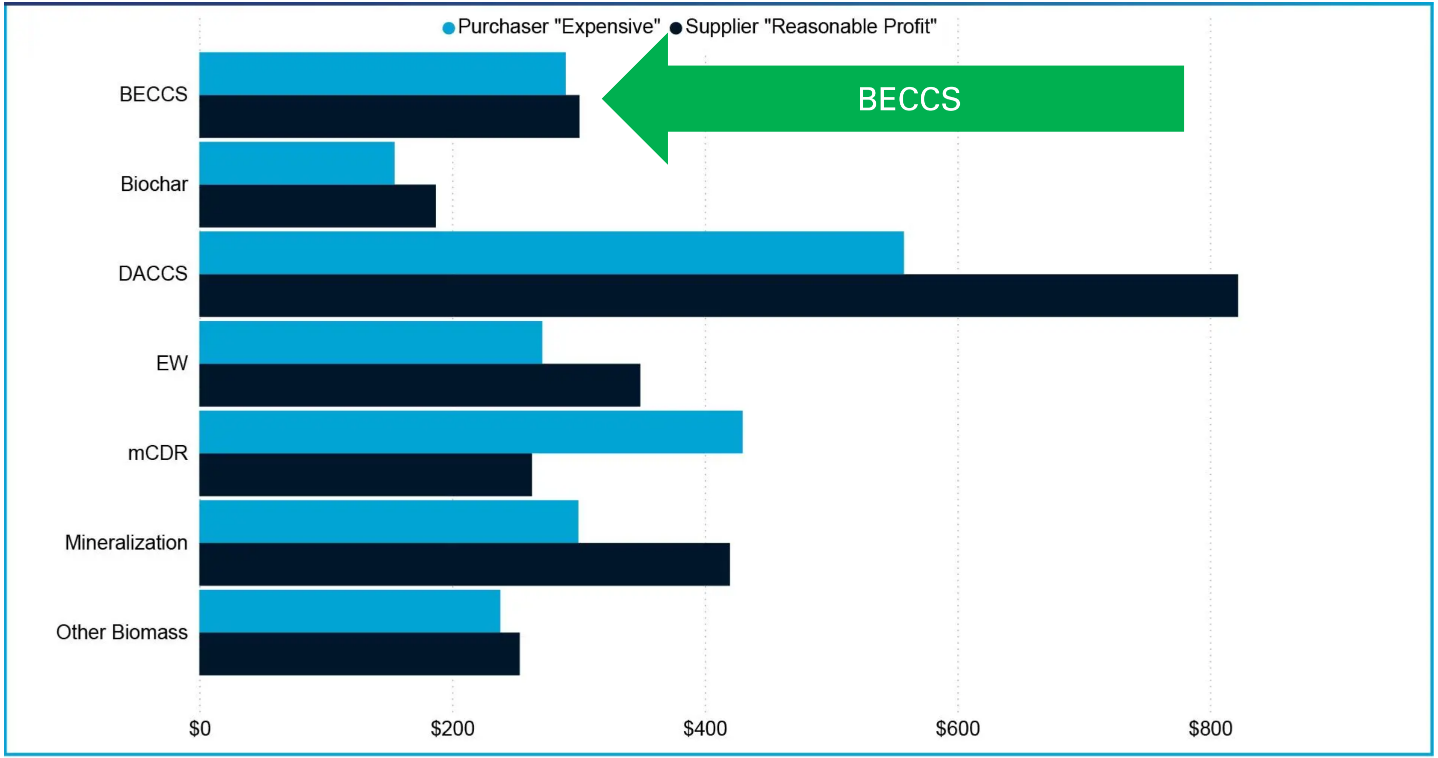
- High-efficiency liquefiers (ie 2-stage screw compressors with interstage cooling and ammonia refrigerant cycle) with a high purity CO2 feed can achieve in the order of 180 kWh/kg CO2, with liquid CO2 delivery at circa 20 bar.
- Circa 50% of the power is used to liquefy, and circa 50% to compress.

sbh4 consulting

Generating revenue from CDR and VCMs to create a business case for BECCS from biomass-fired CHP

The VCM is alive! Carbon Dioxide Removals (CDR) credits: 2025 price perceptions survey. BECCS is one of the most competitive technologies.

sbh4 consulting



https://www.cdr.fyi/blog/cdr-pricing-survey-jan-2025

sbh4

consulting

Introduction to Stephen B. Harrison and sbh4 consulting

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 **gas**world 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.