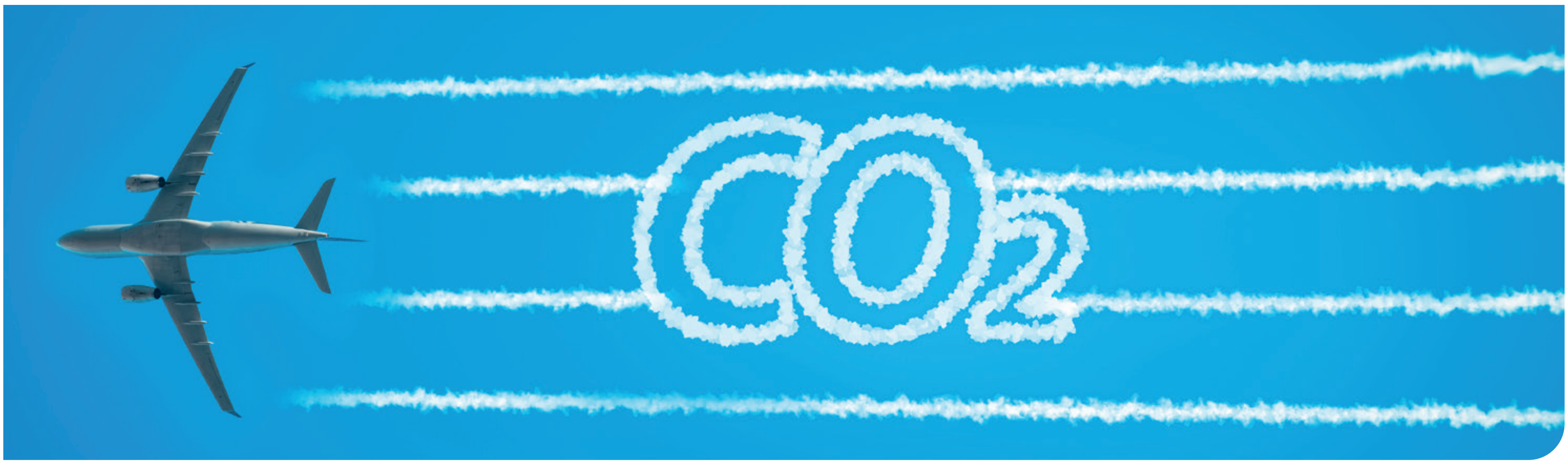
GAS ANALYSERS FOR CCS, DAC, AND E-FUELS



Carbon capture is the foundation of carbon dioxide (CO_2) capture and storage, or utilisation. Capturing CO_2 from a flue gas stream often relies on a solvent or solid adsorbent material that is sensitive to other chemicals in the raw flue gas such as sulphur dioxide (SO_2). So, the CO_2 separation, or capture, is often the last stage in a complex arrangement of flue gas treatment (FGT).

Measurement and control of the CO_2 purity through the CCTUS process and the analysis of critical impurities relies on gas analysis instrumentation. Some of the gas analysers are like those that have been used in continuous emissions monitoring (CEM) for decades. However, the measurement of CO_2 purity is an emerging requirement.

Much of the CO_2 captured from industrial processes today relies on a liquid amine solvent. It is a twin tower process where CO_2 from the flue gas is absorbed into the solvent in the first tower. The CO_2-lean flue gas then flows to atmosphere.

The CO_2-rich amine is pumped to a second tower where heat is used to strip the CO_2 out of the amine solvent. The regenerated, CO_2-lean amine solvent is pumped back to the absorber tower to collect more CO_2 and the process operates continuously with the solvent being recirculated from the absorber to the stripper.

Over time, the amine solvent is degraded through reactions with oxygen and other impurities in the flue gas. It is particularly sensitive to sulphur compounds such as sulphur dioxide (SO_2) and the flue gas from coal or heavy fuel oil combustion will contain a high level of SO_2.

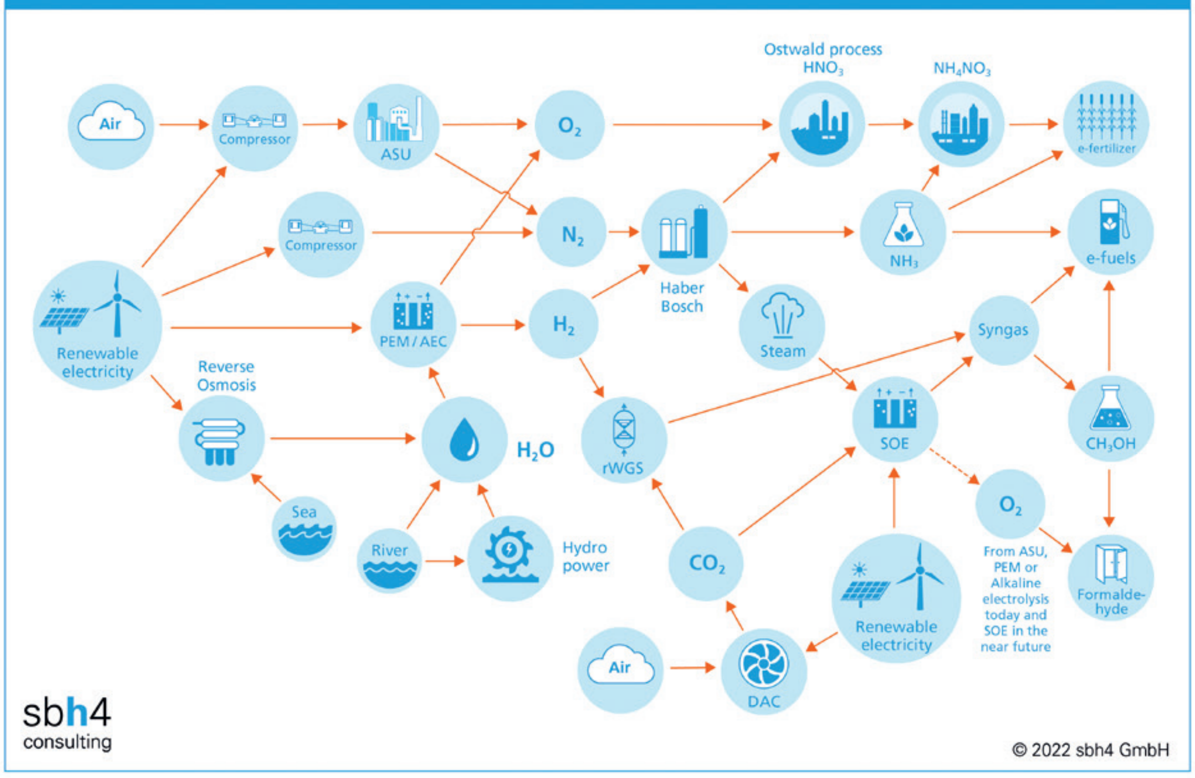
Removal of SO_2 is already implemented on many combustion plants in developed nations, to avoid the problem of acid rain. However, flue gas desulphurisation (FGD) is not universal, and it is only recently that developing nations such as China and India have implemented regulations to ensure that SO_2 emissions are reduced. It is likely that for some operators, implementation of CO_2 capture will require implementation of upstream SO_2 capture through FGD.

Hot/wet extractive, cold/dry extractive, and in-situ gas analysers for process control and CEM are all relevant for these various applications.

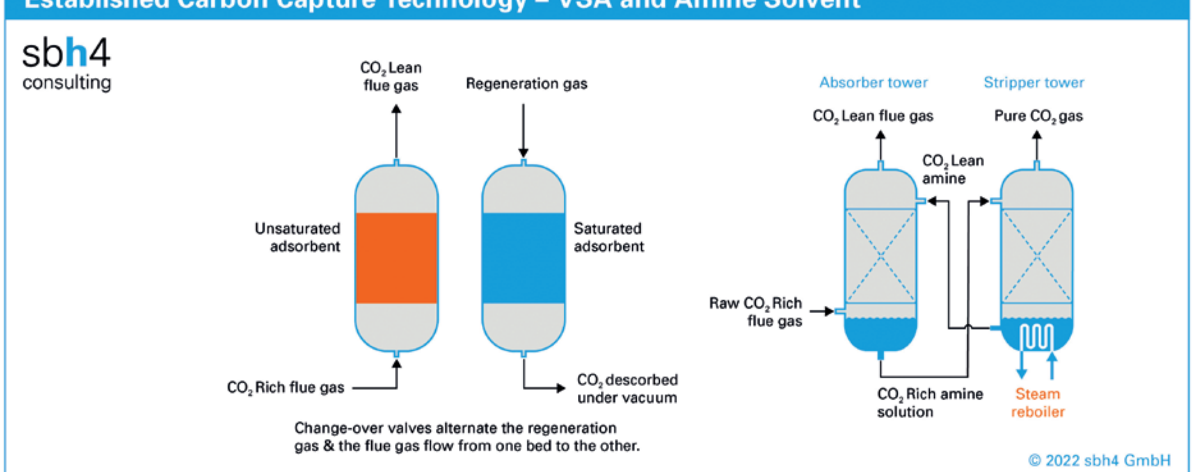
In addition to the measurement requirements between the raw flue gas and the CO_2 amine solvent absorption system, a CO_2 gas analyser in the 90 to 100% range must be used to measure the purity of the CO_2 liberated from the stripping tower. The CO_2 at this point in the process will be saturated with moisture. This must be monitored to control downstream processes such as CO_2 drying, liquefaction, or compression.

CO_2 can be purified and liquefied for transportation by road to other commercial utilisation applications. Prior to liquefaction, the CO_2 is dried on a regenerative dryer bed to avoid moisture freezing

Air, water and renewable electricity for integrated e-fuels, e-fertilizers and e-chemicals production



Established Carbon Capture Technology – VSA and Amine Solvent



	VSA – vacuum swing adsorption	Amine Solvent with tower contactors
Separation principle	Adsorption	Absorption
Specific energy demand	1.7 GJ/t_{CO2} (mostly power)	3 GJ/t_{CO2} (mostly heat from steam)
Typical temperature	40°C	40-60°C in absorber, 120°C in stripper
Typical pressure	Cycling between moderate pressure and vacuum	Ambient to 30 bar
Typical CO_2 removal	< 90 %	> 90 %
Typical CO_2 purity	< 95 %	> 99 %
Typical plant size (tonnes per year CO_2 removal)	> 1,000 - 500,000	40,000 - 4,000,000
Technology maturity level	Commercial with some demonstrations, eg Air Products Port Arthur SMRs, USA	Commercial from many suppliers

and blocking the cryogenic liquefaction system.

The alternative CO_2 transportation mode is compression to a supercritical fluid at around 90 bar and then transmission in a high-pressure steel pipeline. As with liquefaction, CO_2 and moisture analysis for pipeline transmission is essential. If moisture is present, it can react with CO_2 to form a corrosive acid which could damage the steel pipeline.

Drying takes place during the compression stages to remove the moisture. Most of the water is condensed in the intercoolers between the multiple gas compression stages. Prior to the last stage of compression, mono-ethylene glycol can be used to remove traces of moisture. Analysis of moisture and CO_2 at critical points in the drying process is vital.

Production of e-fuels such as e-kerosene or e-methanol involves the combination of green hydrogen and CO_2 to build hydrocarbon molecules. The CO_2 can be supplied either as liquid or pipeline from captured emissions. Alternatively, CO_2 can be directly captured from the air.

Green hydrogen is produced in a sustainable way using renewable electrical power and electrolysis. In many cases, it is being proposed that additional renewable electricity is generated to operate a direct air capture (DAC) facility to ensure that the CO_2 in the e-fuels is sustainable. Monitoring of the CO_2 purity between the DAC unit and any downstream catalytic processes is essential to ensure that high purity CO_2 is used in these sensitive Fischer Tropsch, methanol synthesis and reverse water gas shift reactors.

DAC technologies for direct air capture of carbon dioxide

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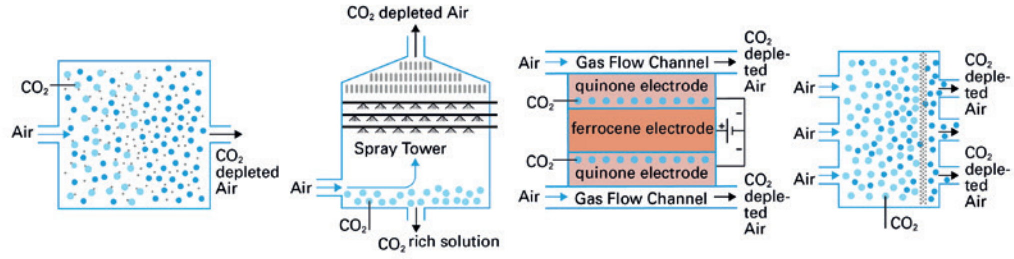
Notes: Only the CO_2 separation aspect of each DAC process has been shown



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	Climeworks	Carbon Engineering	Verdox	Carbyon
System type	Solid Sorbent	Liquid Absorbant	Solid Sorbent	Solid Sorbent
Technology	Amine-functionalised	Potassium Hydroxide solution/ Calcium Carbonation	quinone–carbon nanotube composite	Thin film coated amine- and/or bicarbonate-based porous membrane
Regeneration	Temperature / Vacuum	Temperature	Electro-Swing	Temperature
Specific Energy Demand	Heat: 2,000 kWh / t_{CO2} Electricity: 650 kWh/ t_{CO2}	NG: 2,777 kWh/t_{CO2} or Electricity: 1,500 kWh/t_{CO2}	Electricity (only cell, w/o BoP in particular ventilation): 568 kWh/t_{CO2}	TBD
Operating Temperature	80-100°C	900°C	Ambient	60-85°C
Technology maturity level	Commercial	Pilot	Laboratory	Theoretical

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