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CO_2 Capture and Mineralisation

gasworld Europe CO_2 Summit 2023

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8th March 2023, Telfs, Austria

Renewable electricity can avoid CO_2 emissions from fossil fuel power generation and decarbonise many other sectors

Power and energy transition

- But not all sectors can be decarbonised with green electrons!

- Some industrial processes release **unavoidable** geogenic, biogenic or process CO_2 emissions that must be decarbonised using carbon capture.

Geogenic CO_2 emissions from glass melting must be decarbonised

Geogenic CO_2 emissions from the calcination of magnesite and dolomite for refractory materials must be decarbonised

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Magnesite quarry for refractory materials production

Geogenic CO_2 emissions from the calcination of limestone in lime and cement making must be decarbonised

Process emissions from iron ore reduction in blast furnaces for iron making must be decarbonised

More than 1,000 SMRs produce grey hydrogen with process CO_2 emissions, many will be decarbonised

Image courtesy of Air Products and Chemicals, Inc - Edmonton Alberta Industrial Heartland SMR for pipeline

Conventional CO_2 capture technologies benefit from high pressure, but for high capture rates, low pressure post-combustion flue gas must also be processed

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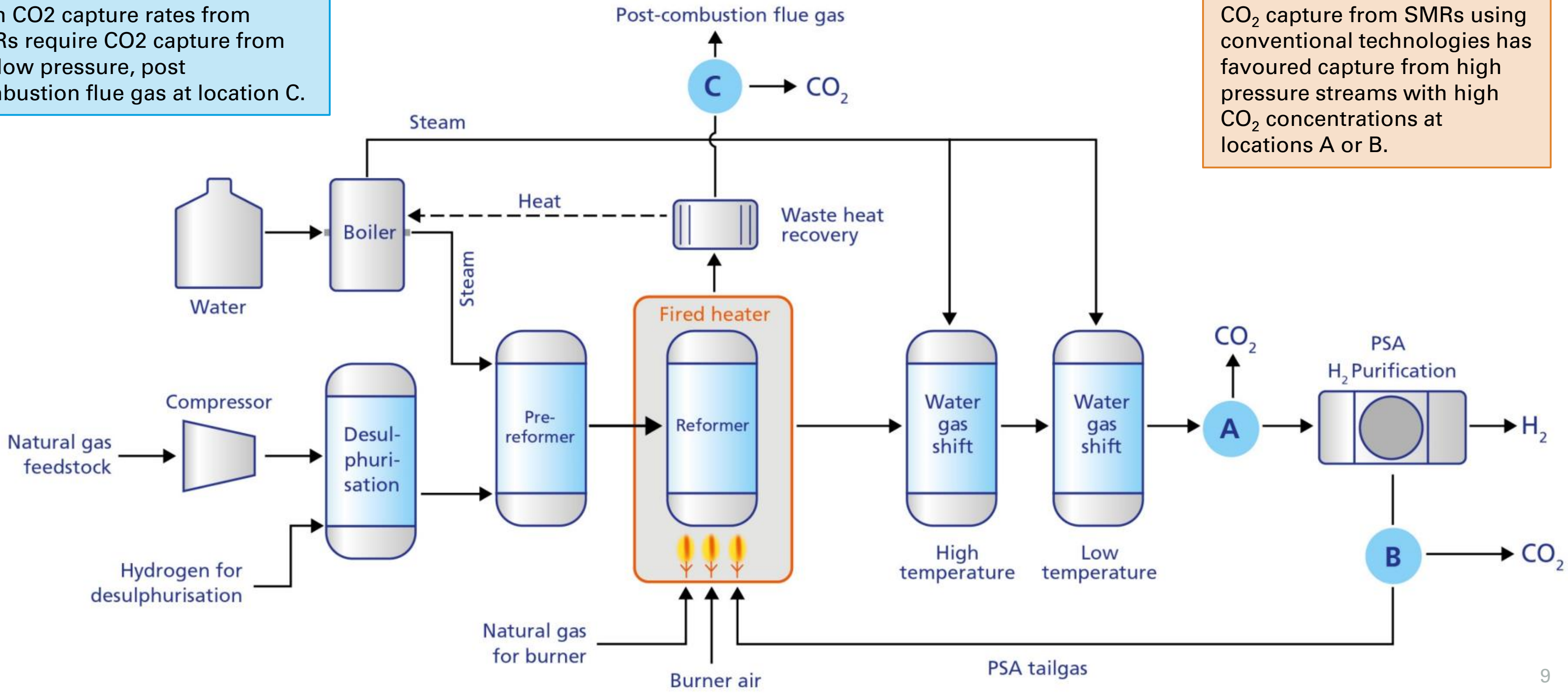
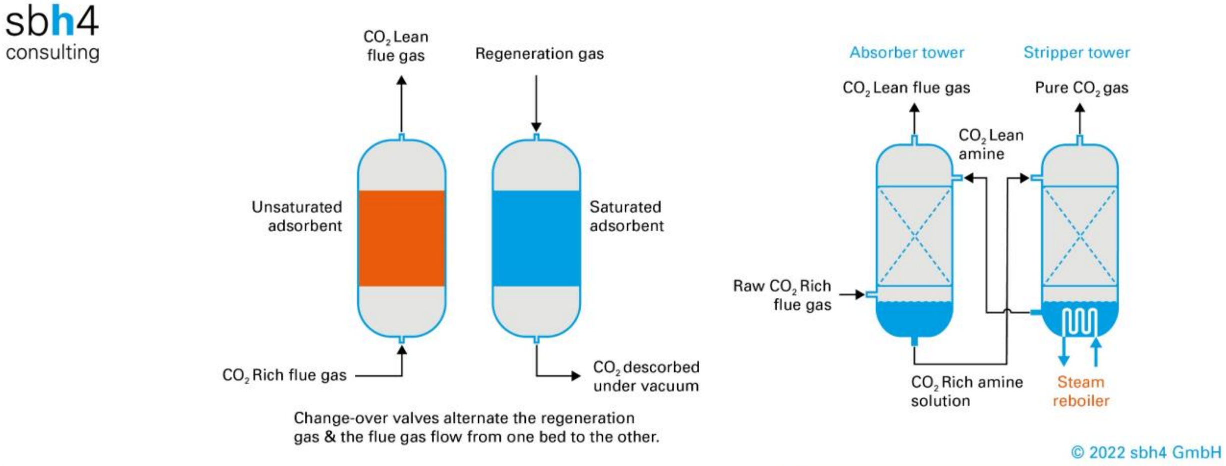
High CO2 capture rates from SMRs require CO2 capture from the low pressure, post combustion flue gas at location C.

CO_2 capture from SMRs using conventional technologies has favoured capture from high pressure streams with high CO_2 concentrations at locations A or B.



Conventional processes for CO_2 capture from SMRs and other industries require heat or power, in very large quantities



	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

Mineralisation of CO_2 using alkalis and the superoxide radical – a new approach to capture CO_2 to form commercial minerals

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Airovation Technologies patented CO_2 capture and mineralisation process – CCM

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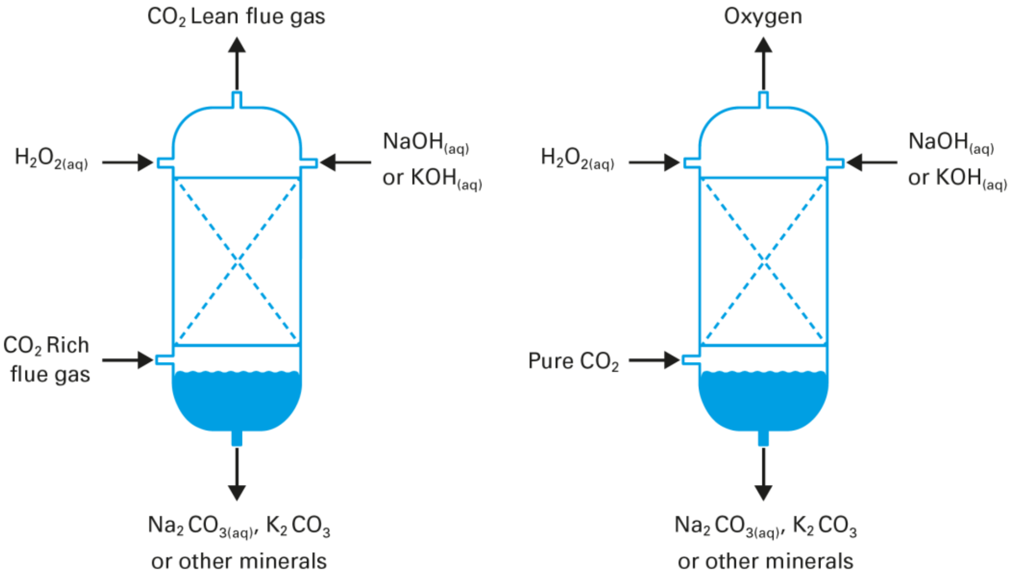
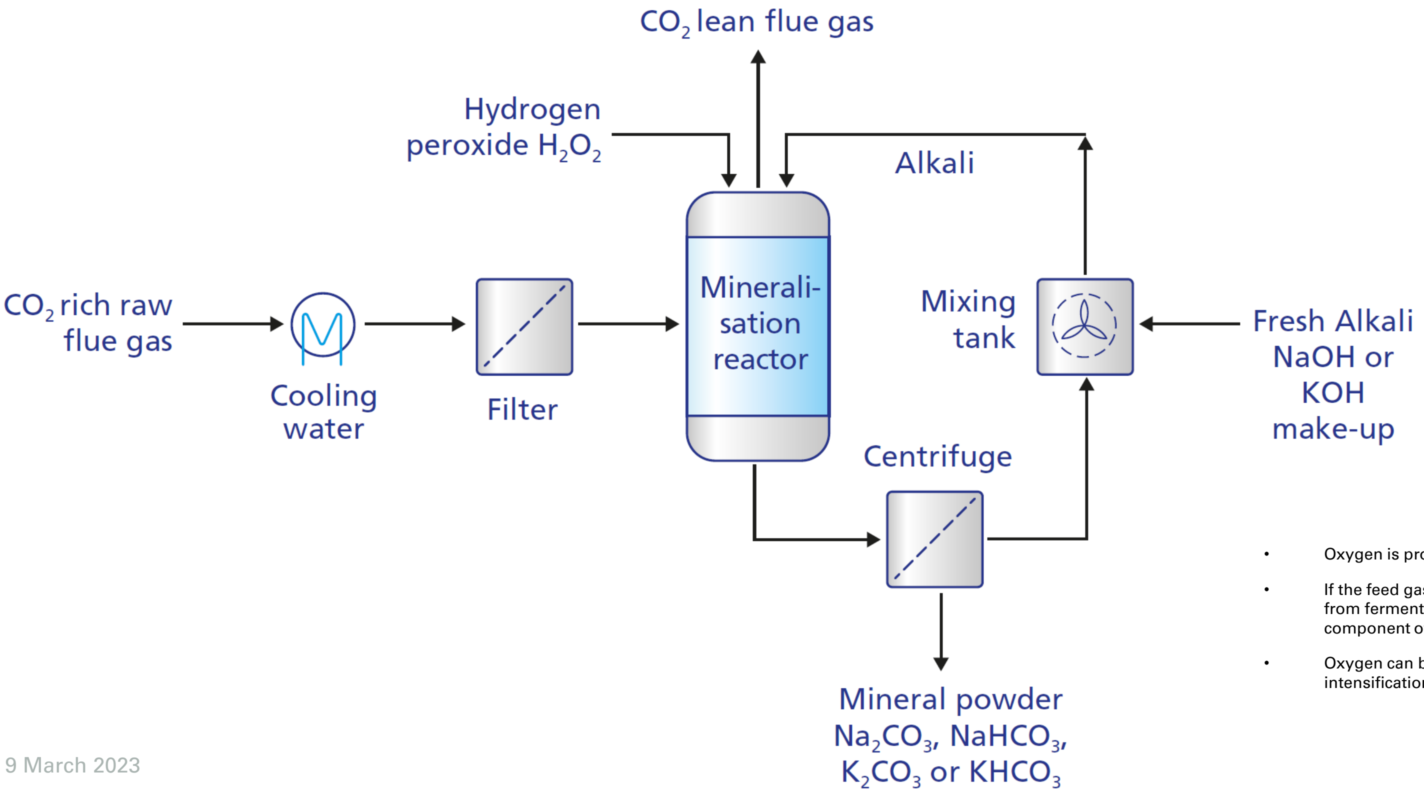


- CO_2 capture rate >95%
- Can capture CO_2 efficiently from low pressure, low concentration CO_2 streams in addition to higher pressure, higher concentration CO_2 flue gases
- Minimal heat and power requirement at the capture site
- Uses readily available commodity chemical feedstocks: NaOH or KOH, with H_2O_2 being dosed as a minor component with catalytic properties
- Selectivity between commercial grade Na_2CO_3, K_2CO_3, $NaHCO_3$ or $KHCO_3$ as mineral products
- For very high concentration CO_2 streams (eg from fermentation and distillation), oxygen is produced (and can be utilised for process intensification in the bio-reactor)

Mineralisation of CO_2 in lime water

Image courtesy of BBC Bitesize
https://www.bbc.co.uk/bitesize/guides/znwh8xs/revision/8

Airovation Technologies – patented CO_2 mineralisation process using alkalis and the superoxide radical



- Oxygen is produced during the process chemistry
- If the feed gas has a very high CO_2 concentration (eg from fermenters or bio-reactors), oxygen is the main component of the final flue gas
- Oxygen can be recovered and re-used for process intensification in bio-reactors and fermenters

Airovation Technologies – alkali mineralisation of CO_2 using the superoxide radical

Commercial carbonate and bicarbonate mineral products can be produced

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Life cycle analysis shows significant CO_2 emissions reduction due to displacement of existing energy intensive / CO_2 emissions intensive processes

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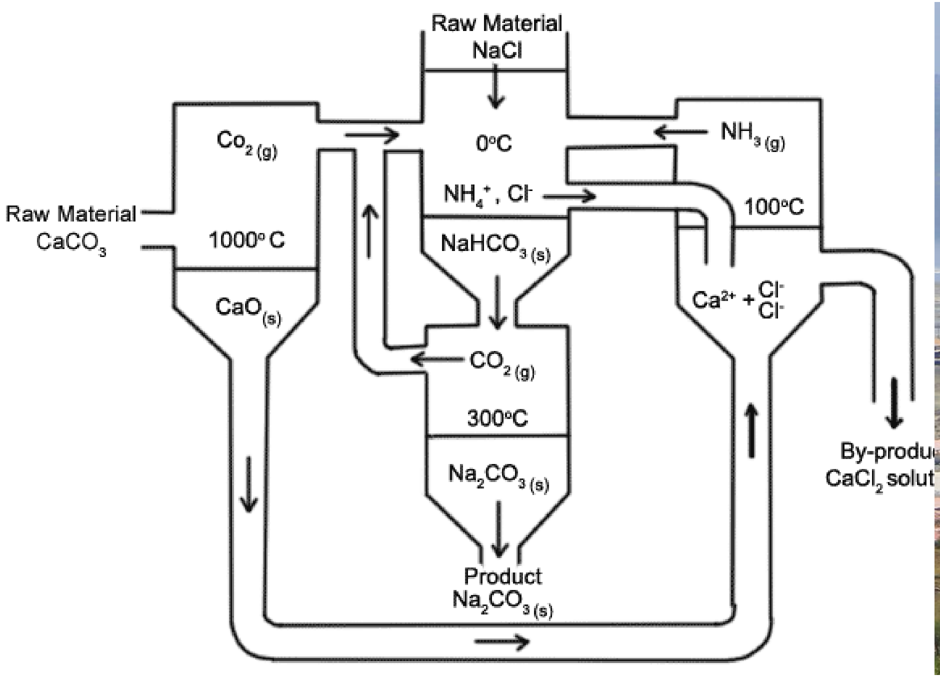

The Solvay process

Trona ore processing

https://everythingdynamicequilibrium.weebly.com/solvay-process.html

CCM – CO_2 mineralisation using alkalis and the superoxide radical to generate valuable materials

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- Carbon capture and mineralisation (CCM) is an example of CCUS – carbon capture, utilisation and storage
- CO_2 emissions can be converted to minerals with commercial value
- The powders generated through mineralisation can be utilised commercially as chemical feedstocks
- The powders generated through mineralisation can be utilised as industrial feedstocks to conserve natural raw materials and reduce the energy intensity of mineral processing, eg cement and refractory materials
- Mineralisation using alkali solutions can avoid stressing power and heat utilities at the CO_2 capture site
- Moving feedstock and minerals to and from the CO_2 capture site uses standard logistics infrastructure
- The sweet spot for mineralisation using alkalis and the superoxide radical will exist in many situations…
    - CO_2 emission source of any pressure and any CO_2 concentration*
    - Alkali and H_2O_2 feedstocks are available
    - A market for the mineralisation product exists
    - A market for the oxygen exists (if a very high purity CO_2 stream is used)

Example applications with ideal conditions: biotechnology and specialty glassmaking

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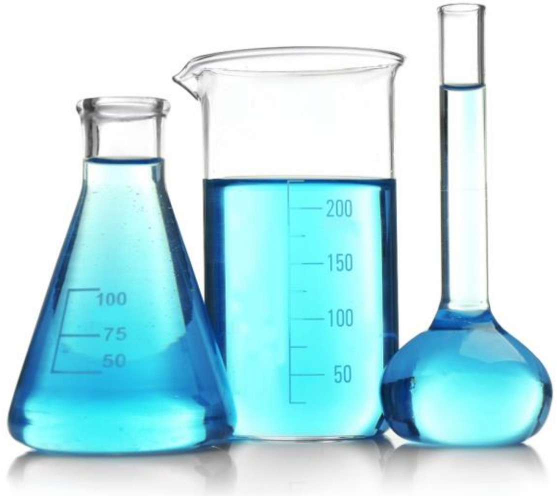
- CO_2 emissions avoidance
- Biogenic CO_2 capture and conversion to bio- materials
- $NaHCO_3$ production for water softening, other marketable minerals possible
- O_2 production for bio-reactor process intensification



- CO_2 emissions avoidance
- Geogenic (unavoidable) CO_2 emissions capture and conversion to materials
- Na_2CO_3 production as a feedstock for glassmaking (alternatively, other marketable minerals)
- Circularity in glassmaking materials

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Introduction to Stephen B. Harrison and sbh4 consulting

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Stephen B. Harrison is the founder and managing director at sbh4 GmbH in Germany. His work focuses on decarbonisation and greenhouse gas emissions control. Hydrogen and CCUS are fundamental pillars of his consulting practice. He has served as the international hydrogen & CCS expert and team leader for multiple ADB projects related to renewable hydrogen deployment and CCS in several Asian nations.

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 hydrogen and carbon dioxide from commercial, technical, operational and safety perspectives. For 14 years, he was a global business leader in these FTSE100 and DAX30 companies.

Stephen has extensive buy-side and sell-side M&A due diligence and investment advisory experience in the energy and clean-tech sectors. Private Equity firms, investment fund managers and green-tech startups are regular clients.

As a member of the H2 View and **gas**world editorial advisory boards, Stephen advises the direction for these international publications that focus on decarbonisation and CO_2 applications.