

Mineralisation and CCUS

CO₂ capture with added value

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Much has been said about CCUS – carbon capture, utilisation, and storage. The need to decarbonise is clear. Renewable power generation and green hydrogen may do much of the heavy lifting when they scale up in the coming decades, but there are legacy assets that must also be decarbonised and there are several processes which will be used in the short and long-term future that release CO₂ (carbon dioxide) from within the process chemistry. For

example: CO₂ is released from sand and rocks during glass, lime and cement-making.

The benefit of capturing CO₂ emissions before they reach the atmosphere and cause global warming is widely accepted. But the possibility to store CO₂ underground in depleted gas fields or saline aquifers in so-called CCS schemes relies heavily on having the right sub-surface geological conditions. In addition to geological constraints, public opinion and political will must also be aligned

before underground CO₂ storage can be considered as a sequestration method.

Carbon capture and mineralisation, also known as CCM, is an alternative to classical CCS. In essence, CCM is a modern example of carbon capture, utilisation, and storage, or CCUS. The starting point is in principle the same: CO₂ emissions are captured before they are released to the air. However, instead of burying the CO₂ underground, it is reacted with chemicals to form inert mineral salts. The chemicals that react with the CO₂ to form the minerals can

also be used to capture the CO₂ from flue gas, thereby moving away from established carbon capture technologies that consume either high amounts of steam or electricity at the CO₂ capture location.

Airovation Technologies, based in Israel, has innovated a CCM process that reacts commonly available chemicals such as sodium hydroxide with CO₂ from flue gases to produce mineral salts. Gil Tomer, COO at Airovation Technologies, says, “Our unique mineralisation process produces valuable chemicals such as potassium bicarbonate and sodium carbonate, which have a wide range of commercial applications including fertilisers and glassmaking.”

Decarbonisation of geogenic CO₂ emissions requires carbon capture

The global cement-making industry is one of the largest emitters of carbon dioxide (CO₂) and is responsible for 8% of worldwide greenhouse gas emissions – four times more than the aviation sector.

Cement-making is regarded as a ‘hard-to-abate sector’ as much of its CO₂ emissions are intrinsically connected to the chemistry of cement production and cannot be mitigated using electrification with renewable power. At 900°C, the raw material limestone is decomposed into lime and CO₂.

Lime-making relies on the same raw material and initial processes used in cement-making. Similarly, refractory material production follows a similar process, but the raw material is magnesium oxide (Magnesite) rather than limestone.

Further, during glassmaking, the release of geogenic CO₂ is unavoidable. The sands and minerals used contain CO₂, which is released during glass-melting. The glassmaking industry must live with the fact that geogenic CO₂ is generated, even if heating from renewable electrical power or hydrogen is used to replace fossil

fuel fired burners. Tomer adds that “part of the decarbonisation solution in glassmaking and other mineral processing industries must therefore include CO₂ capture.”

Heating in glassmaking is challenging to decarbonise with hydrogen

The glass manufacturing industry is incredibly energy intensive. This is mainly due to the high heat requirement during processes such as glass melting. Over 70% of this energy is currently being supplied by fossil fuels, such as natural gas, which release post-combustion CO₂ emissions.

To drastically reduce these greenhouse gas emissions and achieve international climate protection goals, ‘green’ hydrogen combustion to create the high temperature flame for glass melting has been considered.

The Federal Association of the German Glass Industry (BV Glas) is investigating how green hydrogen can be used as fuel in glass manufacturing through its Hyglass project in Essen. This project, conducted in collaboration with the Gas and Heating Institute (GWI), is seeking to lay the foundations for using hydrogen in burners. Glass will always be an important raw material, and by replacing natural gas with hydrogen in the melting process, a reduction of CO₂ emissions of around 3.3 million tonnes per year could be achieved across Germany.

The initial results of the pilot project have confirmed findings from previous experience: Glass can be melted, but the quality of glass made using a hydrogen flame is simply different than that produced using a natural gas flame. The market must decide if the change is acceptable.

“As with the unavoidable need for carbon capture of the geogenic CO₂ emissions from glassmaking,” says Tomer, “for some grades of glass, CO₂

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capture may also be the best solution to mitigate the post-combustion emissions from the natural gas burner.”

CCM to support circularity in glassmaking

The idea of reacting the CO₂ in a liquid to form a new mineral chemical is fundamental to CCM. The mineral produced can have a much higher value than the CO₂ gas that is recovered from traditional solvent absorption or alternative adsorption technologies.

CCM is at the heart of the Airovation Technologies process for CO₂ capture and the minerals produced include:

- Sodium carbonate (Na₂CO₃)
- Sodium bicarbonate (NaHCO₃)
- Potassium carbonate (K₂CO₃)
- Potassium bicarbonate (KHCO₃).

The above mineral salts have a breadth of applications. Sodium carbonate, also known as soda ash, is the tenth-most widely used inorganic chemical in the world. For example, it is extensively used in flat glass and container glassmaking. It can constitute up to 30% of the glass melt feedstock by mass. This application for Na₂CO₃ provides the opportunity for circularity within the glassmaking process, and the glassmaker can avoid the transportation and procurement costs of high tonnages of soda ash.

Tomer confirms that, “We have signed a memorandum of understanding with Phoenicia Glass Works to operate a pilot-scale carbon capture and mineralisation process. ▶



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Collecting soda ash at Lake Magad, in the Great Rift Valley, Kenya.



► This will reduce Phoenicia's global warming carbon emissions, contribute to a circular economy, and reduce the company's dependence on soda ash imports."

Phoenicia CEO Michel Ben Simon said, "Phoenicia is thrilled to support an Israeli start-up and to co-operate in the execution of this pilot. The pilot represents a crucial step toward turning Phoenicia into the operator of the greenest factory in the State of Israel."

Potassium salt minerals are broadly known as potash. Potassium carbonate is also used for glassmaking. Beyond that, it finds application in the production of soaps and detergents. Potassium bicarbonate is widely applied as a fertiliser, especially to neutralise acidic soils and simultaneously increase the potassium level.

The chemistry behind the Airovation Technologies process

Tomer declares that "we have innovated a chemical oxidation process based on the in-situ generation of highly concentrated superoxide radicals in an aqueous environment." The superoxide radical is extremely reactive and rapidly catalyses the removal of CO and CO₂ from flue gas streams, with capture rates exceeding 95%.

The carbon capture reaction consumes either sodium hydroxide (NaOH) or potassium hydroxide (KOH) as a strong aqueous alkali solution, and as a contact medium through which the flue gas is passed. These alkalis are produced worldwide using chlor-alkali electrolysis of brine, so the feedstocks for the Airovation Technologies CCM process are widely available.

Hydrogen peroxide (H₂O₂) is consumed to generate the superoxide radicals that catalyse the carbonation reactions. Hydrogen peroxide can readily be purchased as a standard 30%

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solution in water. The proprietary aspect of the Airovation Technologies process, which enables the high capture rates within a very compact space, is the in-situ generation of the superoxide radical. Tomer confirms that "this unique aspect of the process has been researched extensively by several of our team members. It has also been patented internationally and presented in a paper published by the Royal Society of Chemistry¹."

Process design and operating conditions can be adjusted to determine whether NaHCO₃ or Na₂CO₃ is produced. Notably, the pH is a crucial factor that is used to control the product formation pathway. "We will be able to tune the process to control the selectivity of the reactions," adds Tomer. "This avoids the need for any subsequent separation processes between the mixed formation of Na₂CO₃ and NaHCO₃."

Tomer closes by adding that "our R&D programme and product development pipeline extends deep into the future. Beyond the sodium and potassium carbonate and bicarbonate minerals that are in focus today, we are working on enhanced heat recovery, additional minerals, and applications for those products for the future." **GW**

REFERENCES

[1] New Technology for post-combustion abatement of carbon dioxide via an in site generated superoxide anion-radical, RCS Adv., 2014, 4, 36544