IEA
CLEAN COAL CENTRE

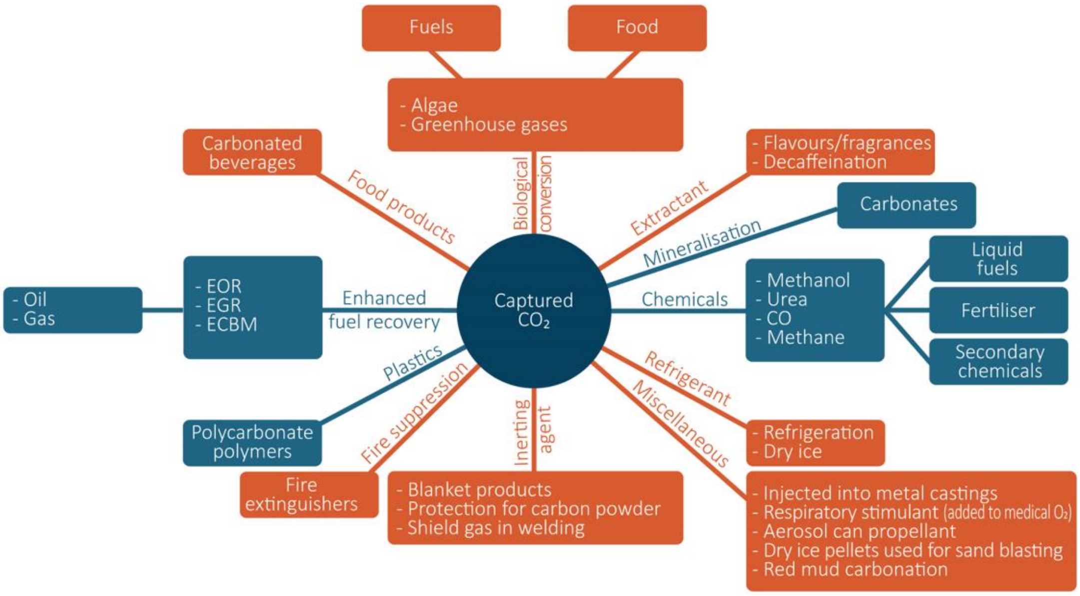
EXECUTIVE SUMMARY
NO 90 – OCTOBER 2018

DEVELOPMENTS IN CO_2 UTILISATION TECHNOLOGIES

Urgent action is needed to reduce greenhouse gas emissions from human activity. Carbon capture and storage (CCS) is a way to produce low carbon electricity from fossil fuels and to reduce CO_2 emissions from industrial processes such as gas processing, cement and steel making. CCS is key to fulfilling the goal of the Paris Agreement to limit global warming to below 2°C. However, current CCS technology is expensive and energy intensive. The economics could be improved by reducing the cost of the capture process, and/or creating a value-added product.

As an alternative to long term storage, the captured CO_2 can be used as a feedstock either directly or indirectly by conversion to produce marketable products. The direct use of CO_2 has been practised for several decades in a wide variety of industrial processes including CO_2-enhanced oil recovery, beverage carbonation, food processing, welding, as a cleaning agent in industry and as a solvent. Typically, these are small scale applications, the technologies are mature, and the supply chain is well established.

CO_2 can be converted into a wide variety of commercial products such as synthetic fuels, building materials, chemicals and polymers. There are many technological routes to convert CO_2 to commercial products such as catalytic, electrochemical, biological (using microbes and enzymes), photocatalytic and photosynthetic processes and mineralisation.



Potential utilisation of CO_2 (https://www.netl.doe.gov/research/coal/carbon-capture/co2-use-and-reuse)

The electrochemical conversion of CO_2 is a dynamic field of research. Many routes for converting CO_2 to products such as syngas, methane, methanol or dimethyl ether with the incorporation of renewable power in the process are being explored. Examples such as Sunfire GmbH's Blue Crude production process and ETOGAS process for methane production, have reached a semi-commercial stage of development with the possibility of shortly being commercialised on a large scale. Other processes are near pilot-scale demonstration and more are in invention and concept validation phase.

Photocatalytic and photothermal catalytic conversion of CO_2 is also being researched worldwide. In general, the focus is on the development of effective novel photocatalysts for converting CO_2 to chemicals with high energy efficiency, yield and selectivity. Most of the research is at bench-top scale. Currently, the achievable CO_2 conversion rates of the photocatalytic/photothermal catalytic systems are often very low and unfeasible for commercial-scale operation.

Processes for the catalytic conversion of CO_2 to methanol and other fuels via different routes have been developed and some are in pilot-scale demonstration or pre-commercial stage. For example, Icelandic Carbon Recycling International's 4000 tCH_3OH/y production facility has been operational since 2012, converting 5500 tCO_2/y. Other promising processes under development are at, or close to, demonstration at pilot scale or larger.

Several interesting bioconversion routes using CO/CO_2 are being explored, such as LanzaTech's industrial scale fermentation process. Its first commercial plant was commissioned for ethanol production in May 2018 and several more plants are in the pipeline. Engineered bacterium and enzymes are also in development, but these are still early stage small-scale experiments.

Technologies for producing construction and other materials through CO_2 mineralisation are more advanced. Several companies now provide commercial systems for CO_2-curing concrete and other carbonate materials production. CO_2-cured concrete is similar to, or better than, traditionally produced concrete and can store the CO_2 long term. These technologies are easy to install or retrofit in current production systems and are economically competitive. They are rapidly being adopted by concrete producers, mainly in North America. In addition, several commercial plants that use captured CO_2 to treat a wide range of industrial wastes such as cement dusts, steel slags and municipal solid waste incineration residues to produce carbonated aggregate are in operation or under construction. More processes are under development and some are soon to be demonstrated.

Significant advances in the co-polymerisation of CO_2 with epoxides to form cyclic and/or polycarbonates or polyols have been made. Some processes are already in commercial operation and others are on the way. The CO_2-derived polymer can contain up to 50 wt% CO_2 and result in final products with improved performance, strength and weatherability, and potentially lower costs.

Several life cycle analyses (LCA) have been conducted for different CCU processes, some based largely on assumptions. The results show that CO_2 derived polymers and CO_2-cured concrete have a better environmental performance and smaller carbon footprint than their traditionally produced counterparts. The LCA of CO_2-to-fuel appear to suggest that liquid fuels such as methanol produced from CO_2 have environmental benefits when renewable energy is used.

Current CO_2 consumption is estimated to be 0.222 Gt/y, which is rather small compared to the potential global anthropogenic CO_2 supply of >12.7 Gt/y. Drastic increase in demand for CO_2 is not expected in the near future. Despite this and other limitations, CCU has an important role to play in climate change mitigation. CCU is the key element to transform the current linear economy to a circular carbon economy and move manufacturing industries and the energy sector towards low-carbon production that reduces CO_2 emissions sustainably. CCU may promote the uptake of CCS by offsetting the costs. It provides expanded options and lower costs for climate change mitigation. CCU should form part of an overall strategy, along with improved efficiency, curtailed consumption, development of renewable power and CCS, to mitigate climate change.

The IEA Clean Coal Centre is a technology collaboration programme of the International Energy Agency (IEA). The objective of the IEA Clean Coal Centre is to provide definitive and impartial information on how coal can continue to be part of a sustainable energy mix worldwide.

Each executive summary is based on a detailed study which is available separately from www.iea-coal.org. This is a summary of the report: Developments in CO_2 utilisation technologies by Qian Zhu, CCC/290, ISBN 978-92-9029-613-3, 94 pp, October 2018