Q1 2020 | Startup Tracker

Carbon Capture Utilization & Storage

FutureBridge

WHAT'S INSIDE!

What are the major developments in CCUS sector ?

Which technology developers are exploring the possibility of introducing technologies for CCUS ?

How collaborative partnerships on CCUS between the public and private sectors marching ahead ?

Which are the latest government funding / investment / public – private partnership schemes ?

01 Emerging trends

Innovations in carbon capture and utilization

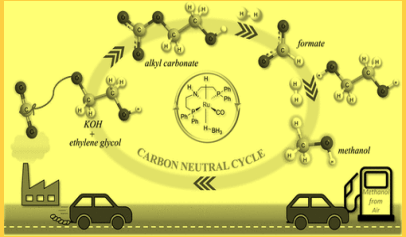


Image: Carbon neutral cycle

FutureBridge Insight

- **Most of the research has happened around metal-organic frameworks with zeolitic structure that process fantastic structural metrics and display excellent applications in many aspects, however, they are difficult to assemble, hence, further research on the chemical fixation of CO_2 is carried that reveals excellent heterogeneous catalytic activity and durability**
- **High temperature metal oxide based adsorbents are also researched that provide very high CO_2 capacities at elevated temperature**

Carbon Capture: Technology Developments

Enhanced electrocatalytic activity of primary amines for CO_2 reduction using copper electrodes

15th January 2020

Work highlights the use of copper electrodes that dramatically enhances current density (up to −18.4 mA/cm^2 at −0.76 V vs RHE) compared to glassy carbon electrodes (−0.63 mA/cm^2) using ethylenediamine as the catalyst

Hydroxide based integrated CO_2 capture from air and conversion to methanol

12th February 2020

Researchers have developed an integrated one-pot system, wherein CO_2 is efficiently captured by an ethylene glycol solution of the base and subsequently hydrogenated to CH_3OH at relatively mild temperatures (100-140 °C) using Ru-PNP catalysts. The produced methanol can be easily separated by distillation

Monolithic adsorbent-based rapid-cycle VPSA process for carbon capture

4th March 2020

Researchers have proposed an intensified 8-bed, 14-step vacuum pressure swing adsorption unit to capture CO_2 from a high partial pressure stream in a small-scale steam methane-reforming process. The productivity of the monolithic VPSA process in terms of its CO_2 production capacity is estimated to be 0.951 mol CO_2/m^3/s

DEVELOPMENTS Emerging Trends

This quarter has witnessed some major technological innovation w.r.t efficient capture and utilization techniques at research level. For example, (Heinz-Bernhard Kraatz, et al.) research work demonstrates potential to enhance amine catalytic activity for efficient CO_2 reduction using copper electrode

University of Southern California (G. K. Surya Prakash, et.al.) has postulated that the high capture efficiency and stability of hydroxide bases make them superior to existing amine-based routes for direct air capture and conversion to methanol in a scalable process

The University of Edinburgh (Stefano Brandani, et.al.) has proposed a monolithic adsorbent, rather than adsorbent pellets or beads; this allows the cycle time to be much shorter than that for pelleted adsorbent systems

On 11th March 2020, the UK government has announced that it will invest ~USD1bn in a CCS infrastructure fund as it seeks to establish CCS clusters in two sites by 2030; using consumer subsidies, the government will also support the construction of the UK's first privately financed gas CCS power station, hence, CCS will be important to decarbonising both power and industry in the UK

Government / public – private funds to support CCUS R&D activities

Liquid Wind secures funding for CO_2 utilization

18th December 2019

InnoEnergy, supported by the European Institute of Innovation and Technology would provide support and investment of 1.7M euros. Liquid Wind will use this funding to develop the e-methanol facility from the captured carbon dioxide in Sweden

Carbon Clean Solutions raises funding of $16 million

17th February 2020

Carbon Clean Solutions Ltd. has raised an equity funding from WAVE Equity Partners, Chevron Technology Ventures and Marubeni Corporation. This investment demonstrates the confidence of investors in Carbon Clean Solutions technology and its commercial scalability

Acorn project wins ~$3.3 million funding

18h February 2020

Acorn, run by Pale Blue Dot, will carry out engineering studies on how to convert gas landed at St Fergus to hydrogen while also removing associated carbon dioxide emissions over a period of 13 months. It is expected that hydrogen production from the captured CO_2 will begin in 2025

DEVELOPMENTS
Funding & Investment

"CCSL can reduce the cost of carbon capture from industrial emissions by more than half. This is the hardest 25% of GHG emission to control, and this affordable solution turns an economic liability into an asset. It has the potential to unlock hundreds of billions of markets for profitable at-source CO2 capture and beneficial reuse, and change the industry debate from an ethical and political imperative to a free-market driven financially rational decision. WAVE is truly excited to be working with the bright and innovative team of CCSL", Praveen Sahay, Managing Director at WAVE

FutureBridge Analyst Comments: Bilateral partnerships and funding will accelerate the demonstration of CCUS technologies; will identify, & reduce and or eliminate general and country-specific technical, regulatory, institutional, financial, economic, environmental, and social barriers to CCUS technology demonstration; and commerclization

Highlights of new execution of study agreement to implement a joint study into the development of gas fields using CCS technology

Japan Oil, Gas and Metals National Corporation (JOGMEC), JX Nippon Oil & Gas Exploration and PETRONAS sign the agreement to study the development of high CO_2 gas fields in Malaysia, utilizing CCS technology

- Under the agreement, JOGMEC will conduct the study by fully utilizing their knowledge and experiences to explore the feasibility of development of CO_2 gas fields
- In 2011, JX and JOGMEC succeeded in the implementation of CO_2-EOR pilot test in Vietnam

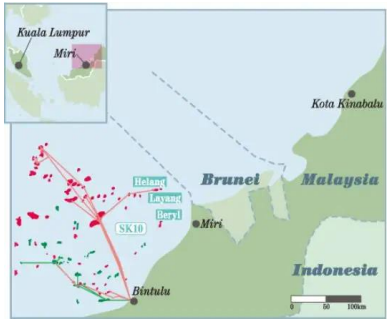
"Japan Oil, Gas and Metals National Corporation considers CO_2-EOR as one of its core technologies and relating technologies such as CCUS including CCS to be the key technology for environmentally friendly resource development. Through this study, we believe that valuable technical knowledge on resource development under low carbon constraints can be accumulated"

– JOGMEC

"If the development of such high CO_2 gas fields is confirmed by the study to be feasible and the parties to the SA agree, JX intends to move forward to the gas production with low environmental impact by CCS technology. JX intends by this study to maintain and strengthen its relationships with Malaysia, and to expand its business in the country while contributing to realize the low carbon emission and recycling-oriented world"

– JX

Highlights of the Project



Source: JX's gas fields in Malaysia

FutureBridge Insight

- There are a large number of gas fields containing high CO_2 concentration in Malaysia which have been discovered but left undeveloped due to technical and economic reasons
- Study also plans to look into the future possibility of exporting hydrogen produced from natural gas to Japan, hence, JX and JOGMEC will work together to seek the possibility of establishing new energy value chains
- JOGMEC and other partners such as JX Nippon Oil & Gas Exploration and PETRONAS will maintain and strengthen its relationships with Malaysia, and to expand its business in the country while contributing to realize the CCUS technologies

Highlights of key partnerships (Q1 2020)

key partnerships (Q1 2020)	
TOTAL	**January 2, 2020:** Total joins the Svante Inc., LafargeHolcim, and Oxy Low Carbon Ventures, LLC, to assess the viability and design of a commercial-scale carbon capture facility at the Holcim Portland Cement Plant in Florence, Colorado, U.S.
ADNOC	**January 20, 2020:** Abu Dhabi National Oil Company has signed a strategic framework agreement with Eni to explore new opportunities for collaboration in carbon capture utilisation and storage
Svante	**January 27, 2020:** Svante Inc. (formerly Inventys Inc.) partners with Climeworks AG on the development of carbon capture technology solutions
drax	**January 27, 2020:** Drax establishes partnerships with Econic Technologies to explore the CCU potential
Chevron	**February 7, 2020:** Chevron Technology Ventures partners with Svante to conduct a pre-front end engineering design study to assess the potential to trial Svante's technology for carbon capture at Chevron's facility
bp	**February 28, 2020:** BP, Eni, Equinor, Shell and Total form consortium to develop the Net Zero Teesside project
fortum	**March 02, 2020:** Fortum and Kvaerner join forces to identify projects and opportunities on CCS project
JOGMEC	**March 28, 2020:** Japan Oil, Gas and Metals National Corporation, JX Nippon Oil & Gas Exploration and PETRONAS sign the agreement for a joint study on the development of high CO_2 gas fields

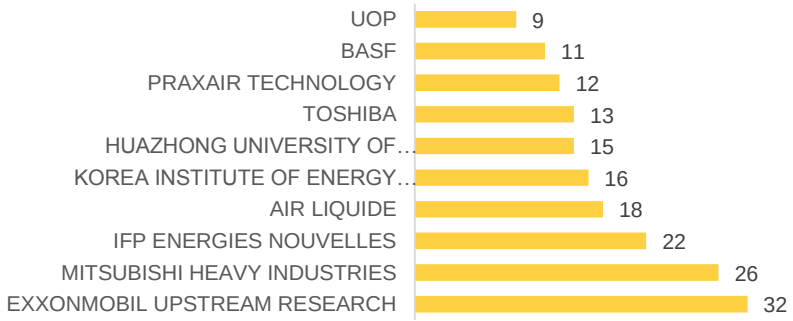
FutureBridge Analyst Comments: Public and the private sectors are joining hands together on joint execution plans and funding that is focused on ultimate efficacy and long-term impact of CCUS project. The joint partnerships to be major drivers for advancing CCUS technology economy

02 Quarterly academic review

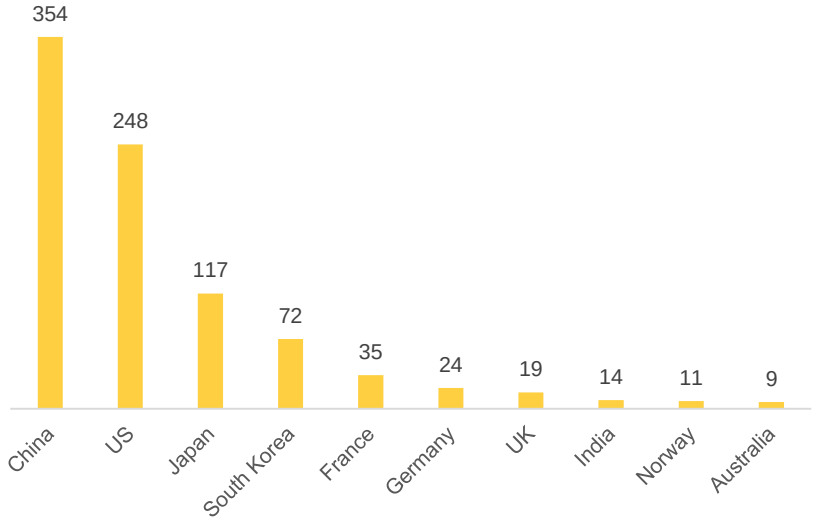
Patenting Activity – CCUS

Patenting Activity, Q1 2020	
Total number of patents published	882
Number of patents published in Jan	276
Number of patents published in Feb	292
Number of patents published in March	314
Patents Pending (%)	43%
Patents Granted (%)	57%

Top Assignees, Q1 2020



Top Countries, Q1 2020



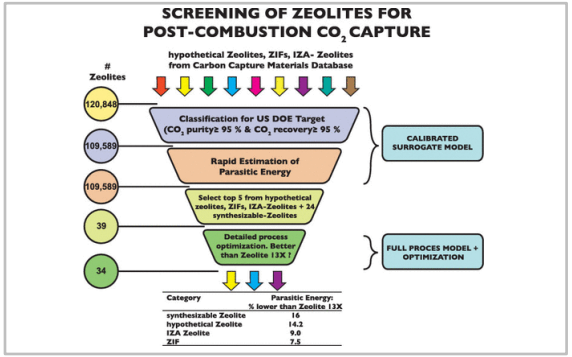
Source: Orbit

Zeolites material for post-combustion CO_2 capture by vacuum swing adsorption

UNIVERSITY OF ALBERTA

Technology description – Two-step screening process, published on Feb 24, 2020

Technology details



- Aim of the present work is to screen the carbon capture materials database, which contains a sub-set of the Deem's database of zeolite and zeolite-like materials and identify candidates that have the potential to reduce the parasitic energy consumption for dry post-combustion CO_2 capture using vacuum swing adsorption
- Batch adsorber analogue model, a surrogate model calibrated using rigorous full-scale process simulation, is used to classify sorbents that satisfy US-Department of energy (US-DOE) targets for CO_2 purity (≥ 95%) and recovery (≥ 90%)

Funding

UNIVERSITY OF ALBERTA
FUTURE ENERGY SYSTEMS

compute canada | calcul canada

FutureBridge Insight

- A large variety of solid sorbents such as zeolites, activated carbon and metal-organic frameworks are available for concentrating CO_2 and the search for the ideal adsorbent that results in the lowest cost of capture is a continuing endeavor, hence, zeolites find its wide-ranging industrial applications in post-combustion CO_2 capture by vacuum swing adsorption
- Study confirms the reliability of deploying surrogate models for screening large adsorbent databases, opening up opportunities for similar exercises for other valuable separations

"We need renewable sources of energy, but we will have these hydrocarbon systems for years to come. This technology can stop emissions now, and buy us time to complete the transition. Our role is to provide these tools to help chemists find better molecules, and our expertise is designing processes that use the molecules to capture carbon" – Arvind Rajendran, Professor at Department of Chemical and Materials Engineering, University of Alberta

03 Startup Tracker highlights

Funding distribution & activities (1/2)

Carbon Clean Solutions CCSL Limited

Post-combustion, CDRMax® Process

USD 16 Mn

1

Carbon Capture

Savings

Regeneration energy
40% less than MEA

Lean solvent flow rate
40% less than MEA

New packing
30% less pump HP

Construction materials
30% less on stainless

Footprint
20% less area

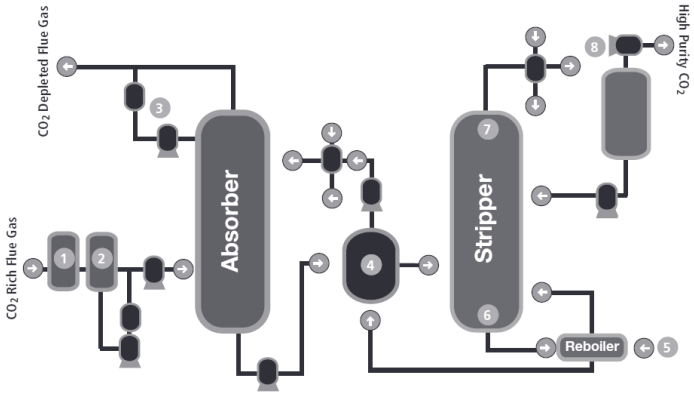
Patented design
10% less energy

Wash water emission
Non-aerosol, low ppb solvent level

Reclaimer
Ion exchange/thermal

Health & Safety
REACH & GHS compliant

CDRMax® Process Flow Diagram



FutureBridge Insight

- Carbon Clean Solutions Ltd. has raised $16 million in an equity funding from **WAVE Equity Partners, Chevron Technology Ventures and Marubeni Corporation**
- This investment will be used to deliver an existing pipeline of global projects to lower emissions from industry and in the development of “containerized” solutions to achieve $30 / tonne cost of CO_2 capture by 2021
- This investment demonstrates the confidence of investors in Carbon Clean Solutions technology and its commercial scalability
- This financing will also give the Carbon Clean Solutions access to customers globally through joint projects with firms such as Marubeni Corporation and they can jointly develop CCUS businesses

Funding distribution & activities (2/2)

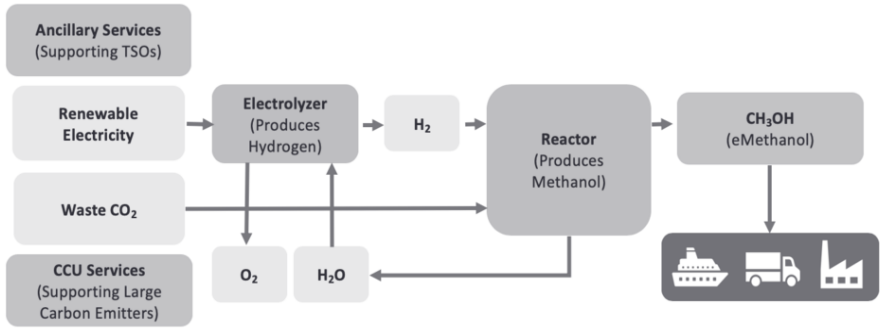
Liquid Wind

USD 1.7 Mn

1

Carbon Utilization

Carbon conversion & utilization (power-to-liquid) – Methanol



Partners

Carbon Clean Solutions Limited (CCSL) — Carbon capture

Haldor Topsoe — Reactor

nel — Electrolyzer

Axpo — Renewable electricity

COWI — Consulting

FutureBridge Insight

- **InnoEnergy**, supported by the European Institute of Innovation and Technology would provide support and investment of 1.7M euros
- Liquid Wind will use this funding to develop the world's first commercial scale e-methanol facility from the captured carbon dioxide in Sweden
- Liquid Wind will convert the captured carbon dioxide and renewable electricity into renewable liquid fuel, e-methanol, which will provide a viable and cost-effective alternative to fossil-origin fuels particularly for shipping vessels and heavy transport
- E-methanol facility, will be commercially available from 2023 and facility will capture 70KT of CO_2 and generate 54KT of fuel, enabling a significant CO_2 reduction of 90KT per year

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