Carbon Capture Journal

CCUS in Asia

Decarbonisation of Indian industry: Transitioning to a sustainable, low-carbon economy

Dalmia Cement and Carbon Clean Solutions build carbon capture plant

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Siemens and Evonik convert CO2 to fuel using bacteria

Putting CO2 to Use: Creating value from emissions

MIT engineers develop a new way to remove CO2 at any concentration

Chemical-looping: the answer to the cost and energy penalties of CCS?

New electrochemical process can recycle millions of tonnes of CO2 a year

Carbon storage essential for climate action but is no 'free pass' for oil and gas industry

With a major oil and gas conference having taken place last month there have been a lot of announcements around the industry's role in a zero-carbon future.
By Rebecca Bell, SCCS Policy & Research Officer

Inevitably, there was discussion about whether maximising oil and gas production from the North Sea was the best way to transition to net-zero (a resounding "no" from pretty much everyone outside the industry), and, equally inevitably, carbon capture and storage (CCS) was drawn into the debate.

Oil and Gas UK stated that the sector was "supporting the development of carbon mitigating technologies, which offset emissions resulting from the use of oil and gas in the wider economy [such as CCS]". This implication that CCS is, firstly, just about dealing with fossil fuel emissions, and secondly, that CCS can offset emissions from fossil fuel use, presumably so that extraction and consumption can carry on as usual, is deeply flawed.

CCS does have strong ties with the oil and gas industry: what we know about the UK's geology, and its potential to store CO2, builds on decades of research in the oil and gas industry. The CO2 storage sites that are most well understood, and therefore ready to be used, are in mature oil and gas fields.

Wells and pipelines that have reached the end of their oil and gas lifespan have the potential to be re-used for CO2 transport and storage. The skills and expertise in the North Sea workforce are exactly what are needed to get CCS going in the UK.

At a recent conference in Aberdeen the chief executive of the Oil and Gas Authority, Dr. Andy Samuel, said delivering CCS for the UK was "remarkably achievable" and that North Sea depleted oil and gas fields held "massive potential" for CO2 storage.

However, this doesn't mean that deploying CCS gives oil and gas companies a free pass. The oil and gas sector's ability (some might say, responsibility) to deploy CCS does not absolve it of its historical responsibility for greenhouse gas emissions, but it does offer an opportunity to start to redress the balance.

CCS will be a crucial part of a just transition to a low-carbon economy – it can provide jobs for offshore workers and those in the oil and gas supply chain; it will also help retain jobs in industry, by allowing industry to decarbonise without ceasing production; and it will enable us to continue using oil and gas while alternatives are developed. But this transition also has to include a move away from business-as-usual for oil and gas companies.

One way to make this happen would be to establish CO2 storage certificates (as recommended by the Parliamentary Advisory Group on CCS that require oil and gas companies to store (or pay someone else to store) an amount of CO2 equivalent to a fixed and rising proportion of the CO2 associated with the fossil fuels they produce. This would ensure that hydrocarbon producers begin to offset some of the emissions from the fossil fuels they supply.

CCS is part of a hierarchy of actions to reduce emissions, and it needs to happen alongside substantial decreases in energy demand, behaviour change across the board, increases in renewable power generation, process improvements and innovation in technology. CCS can't solve climate change on its own – and it mustn't be used as an excuse for inaction in other areas – but it will be essential.

The main value of CCS is in its ability to decarbonise parts of the economy where it is difficult to reduce emission by other means. Primarily, this means industry, where there is a high demand for heat that can only be met with fossil fuels, or where the process is such that CO2 is unavoidable, such as cement production.

Once CCS is in place, it opens up more options for decarbonisation. As part of a low-carbon transition, it means that low-carbon hydrogen can be made in bulk from natural gas, giving the option to use hydrogen in heating and transport as an alternative, or a complement, to electrification.

It also means that CO2 from biogenic sources – such as anaerobic digestion, fermentation and distilling – can be captured and stored, providing "negative emissions", which will be crucial to achieving net-zero greenhouse gas emissions.

There is a climate emergency, but it isn't practical to stop hydrocarbon production straight away until we have alternatives in place for the energy and products we need. That word "need" is the key: there will be a role for oil and gas as we transition to a net-zero economy, but we must do everything we can to reduce the demand for fossil fuels. This means not wasting energy, food and resources and tackling our "throwaway" culture.

Scotland has a huge capacity for carbon storage – hundreds of years' worth of our emissions – that can also create a new source of income as part of a just transition. But we simply cannot continue with business-as-usual. The sooner we all play our part in the low-carbon transition, and share our expertise with other countries, the better our chances of tackling the global climate emergency.

More information

www.sccs.org.uk
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Front cover:

In Evonik's module for the Rheticus project test facility, bacteria convert synthesis gases into specialty chemicals such as butanol. Source: Evonik (pg. 20)

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Decarbonisation of Indian industry: Transitioning to a cleaner economy

A discussion paper from The Energy and Resources Institute (TERI) looks at the need for Indian industry to transition to resource efficient, sustainable and low-carbon production, especially in hard-to-abate sectors.

The discussion paper 'Enabling Decarbonisation of Indian Industry' was presented at the Sustainable Action Dialogue: New York on Leadership Coalition on Energy & Industry Transition, organised by TERI on the sidelines of the United Nations Climate Action Summit 2019.

Heavy industry at the centre of India economy

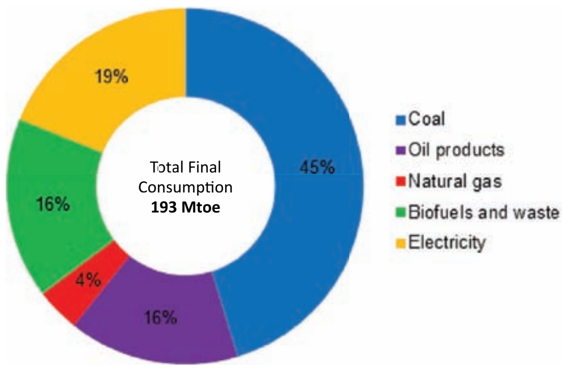
The industrialisation of the Indian economy has been responsible for a significant proportion of economic growth since 1947, says the paper, with strong industrial policy being cited as a key driver for alleviating poverty. Industrialisation in India has been a slow but continuing process, which increased more rapidly with the liberalisation of the Indian economy in the 1990s (Siddiqui, 2015).

This experience and the experience internationally, illustrates the centrality of the heavy industry sectors for providing the materials to support a modern economy. These include iron & steel, cement (and concrete), petrochemicals, aluminium, fertilisers, and bricks. Demand for these materials is set to grow rapidly out to 2050, continuing to drive substantial economic growth.

Consumption of these materials is fundamental to delivering the infrastructure improvements that India requires to modernise. Steel consumption, for example, is set to quadruple between 2020 and 2050, as a result of greater demand in the buildings, automobiles, infrastructure, metal goods and industrial equipment end-use sectors.

If India is to remain globally competitive and achieve sustainable growth, within the constraints of the environment, future industrial strategy should prioritise greater resource efficiency in the heavy industry sectors. Beyond energy efficiency, these sectors should also consider the adoption of new technologies to further reduce emissions in order to keep temperatures within the limits agreed under the Paris Agreement.

Based on research at a global level, it seems technically possible to reduce emissions from these sectors to near zero levels, although many of the technologies require further development to reach commercial scale (ETC, 2018). The paper lays out the current status of Indian industry, before covering the mitigation options that could reduce emissions out to 2050 and beyond.



Total final consumption for Indian industry, 2016 Total Final Consumption 193 Mtoe Source: (IEA, 2019)

Current status of Indian industry

Total final energy consumption in India in 2016 was 572 Mtoe, with industry demanding 193 Mtoe, or a 34% share (IEA, 2016). Industry's total energy consumption has grown rapidly over the past decade, driven by high levels of economic growth. Despite strong growth in services, heavy industry will continue to be a strong driving force behind the Indian economy over the next decade, growing rapidly out to 2030 and beyond.

In terms of the final energy consumption mix in industry, coal consumption dominates, making up 45% of industrial energy consumption, which is predominantly used in the production of iron & steel and cement, as well as in the large and disparate Medium and Small Enterprise (MSME) sector. The next most commonly used fuels are oil, electricity, biofuels, and waste, which are used throughout the sub-sectors. Other fuels, such as natural gas, are largely restricted to the fertiliser and petrochemical industry and not widely used as a result of their relative cost to coal.

However, the use of natural gas in industry is likely to increase in the future as a result of air pollution from the combustion of coal. For example, in large metro areas such as Delhi, which are facing high levels of air pollution, the Government has mandated that industries should switch to natural gas in place of more polluting fuels.

India has a number of policies in place to incentivise greater energy efficiency across the economy. These have been put in place under the National Mission for Enhanced Energy Efficiency (NMEEE), which is a key component of National Action Plan on Climate Change (NAPCC). The main policy affecting the industrial sector is the Perform, Achieve and Trade (PAT) scheme.

The PAT scheme is a regulatory instrument to reduce specific energy consumption across energy intensive industries. It was developed by the Government as a cost-effective way of implementing energy efficiency measures. Large consumers of energy (referred to as

Designated Consumers) are given energy reduction targets to be met over a certain time period. The scheme also uses a certification scheme, whereby excess energy savings are translated into tradable instruments, similar to emissions trading schemes found elsewhere around the world.

During the first PAT cycle (2012–2015), participating industries over-achieved the target by 30%, saving just under 9 Mtoe of energy, or around 1.25% of India's total primary energy supply. This translates to a CO_2 saving of 31 million tonnes, or just under 2% of India's total CO_2 emissions.

The scheme is continuing to set new targets for efficiency improvements, drawing in Designated Consumers from a broader set of sectors, including refineries, railways and electricity distribution companies (DISCOMS). In future, it may be necessary to shift from energy efficiency targets to CO_2 targets, to facilitate further emissions reduction across these sectors.

Carbon capture, usage and storage in India

Deploying CCUS is likely to be a vital technology in abating emissions within the HTA sub-sectors, particularly for cement. It is most cost-effective when used to capture CO_2 from large industrial sources, as this reduces the requirement to build out significant pipeline infrastructure, i.e., building fewer, larger pipelines, instead of more, smaller pipelines.

There is also the potential to use some of the captured carbon in this process, known as carbon capture and use (CCU). Carbon can be used to produce renewable methanol, for mineral carbonation, to produce polymers or in existing commercial industrial uses (e.g. EOR, drinks, horticulture) (Element Energy, 2014).

To improve the business case of CCUS networks, it may be possible for several different users to share the cost of the infrastructure in 'industrial clusters'. For example, a large cement plant could share a CCUS network with a hydrogen production facility, where some of the carbon is captured and used in the production of basic chemicals.

India is at an early stage of developing domestic CCUS expertise and infrastructure but pilot projects are beginning to be established, primarily in the oil and gas (for EOR) and fertiliser sectors (Gupta & Paul, 2019).

Options for decarbonising industry

Despite these challenges, there are several promising technology solutions which could support deeper decarbonisation of the HTA sectors, beyond that of improving energy efficiency or reducing demand. These include the option of 'fuel switching' away from fossil fuels to low or zero carbon fuels, deploying carbon capture and storage (CCS) technology and the use of biomass as a feedstock in the manufacture of petrochemical products.

Many of these technologies are yet to be proven commercially at scale and will require sustained support from government and industry to achieve significant levels of deployment.

For some processes, particularly those requiring large amounts of high-temperature heat and/or process inputs such as a hydrogen feedstock or reacting agent, hydrogen may be a better low carbon route. The HYBRIT project being run in Sweden is investigating the potential of using hydrogen for direct reduction of iron ore (SEI, 2018). Using hydrogen in this way also has the potential benefit of being able to provide demandside flexibility, through the storage of hot iron briquettes and/or the storage of hydrogen.

This would be beneficial for India, which is forecast to require large amounts of flexibility in future as the share of renewable electricity generation increases (Udetanshu, Pierpont, Khurana, & Nelson, 2019). However, for hydrogen steel to be cost-effective and truly low-carbon would require significant cost reductions in electrolysers and an abundance of low cost, renewable electricity (SEI, 2018).

Biomass can also be used as a substitute for coal across the harder-to-abate sectors, either through direct combustion or via conversion into biofuels. In the steel sector, for example, biomass can be used to substitute coal in the blast furnace basic oxygen furnace (BF–BOF) route. This is already used in countries with abundant access to biomass resources, such as Brazil, where small blast furnaces use 100% charcoal instead of coke (Fick, Mirgaux, Neau, & Patisson, 2014).

The main barrier to the wide-scale adoption of biomass use in India is the cost and availability of biomass, whilst ensuring sustainable land management practices (Mandova, Gale, Williams, Heyes, Hodgson, & Miah, 2018). A comprehensive assessment of competing biomass uses (e.g. biofuel for aviation) will need to carried out before the potential of biomass use in industry can be understood.

Conclusion: future framework for decarbonising Indian industry

The paper sets out the current status of Indian industry and its need to transition to resource efficient, sustainable and low carbon production in order to support future growth. We then discuss a number of challenges that need to be overcome for the HTA sectors, which are specific to the Indian context.

It then outlines the steps that can be taken to reduce emissions in these sectors, covering energy efficiency, increased material efficiency and step-change technologies, such as hydrogen and CCUS. To conclude, the policy framework in the harder-to-abate sectors, to facilitate an industry transition, must focus on:

• Continued improvements in energy efficiency, whether that be near-term international benchmarks or future step-change technologies;

• Achieving a high degree of material circularity, understanding scope for material substitution and reducing material intensity where possible and;

• Developing longer-term technology roadmaps and collaborative RD&D programmes at the global scale for the HTA sectors and associated technologies.

More information

Download the full paper:
www.teriin.org

Asia news

Dalmia Cement and Carbon Clean Solutions build carbon capture plant

www.dalmiacement.com

www.carboncleansolutions.com

Indian cement major Dalmia will build a large-scale, 500,000 tonne/year carbon capture facility at its cement plant in Tamil Nadu.

Dalmia Cement Limited has signed a Memorandum of Understanding with Carbon Clean Solutions Limited which will provide technology and operational services for the plant based on its patented CDRMax Technology.

Currently, small-scale carbon capture plants have been commissioned at a small number of cement plants in China and Europe. However, a large-scale demonstration plant of this capacity has not yet been planned or announced in the cement industry. Dalmia Cement and CCSL will explore multiple utilisation streams for the CO2 that is captured from this large-scale plant, including direct sale for use in other industries, and manufacture of chemicals.

Mr. Mahendra Singhi, Managing Director and Chief Executive Officer, Dalmia Cement (Bharat) Limited said: “It is time to resolve the climate crisis. At Dalmia Cement, a progressive business enterprise that foresees the future today, we are committed to becoming a carbon negative cement group by 2040. Capturing process emissions from cement manufacturing will be critical towards reaching net zero by 2040 and therefore, our approach is to set up a large scalable demonstration project on carbon capture with multiple utilisation streams.”

“We are very excited to partner with Dalmia Cement on this industry-leading demonstration project. Decarbonising the cement industry is absolutely key to reaching ‘net zero’ emissions. By combining our low-cost modular CO2 capture technology with viable CO2 reuse alternatives, we plan to deliver a full solution to early movers like Dalmia Cement”, said Aniruddha Sharma, CEO and co-founder of CCSL.

The cement industry is considered a Hard To Abate sector due to the emissions produced by the calcination of limestone, which is required to produce cement. Cement in turn is the cheapest available material used for production of concrete, the world’s most important building material. And whilst certain types of cement do not require calcination of limestone for production, this is subject to the availability of alternative minerals. Therefore, the only viable solution for reducing emissions from this sector is to capture the process-related CO2.

Japanese & Saskatchewan Companies Join Forces to Advance CCS

ccsknowledge.com

www.japanccs.com

A Memorandum of Understanding was signed by Japan CCS Co. and the International CCS Knowledge Centre to collaborate in the development, demonstration and deployment of CCS/CCUS.

With a shared interest and desire to take impactful action on climate change by significantly cutting carbon emissions, organizations representing Japan and Saskatchewan have agreed to collaborate on accelerating the use and understanding of carbon capture utilization and storage (CCS/CCUS).

CCS/CCUS is recognized by the UN Intergovernmental Panel on Climate Change (IPCC) as a necessary technology to meet global climate change goals under the Paris Agreement, and is an indispensable component in the portfolio of technologies required to achieve the two degree scenario.

The MOU signals a path forward to collaborate in the development, demonstration and deployment of CCS/CCUS thereby reducing greenhouse gas (GHG) emissions and providing energy security.

Japan CCS Co., Ltd. is conducting on behalf of the Japanese government the Tomakomai CCS Demonstration Project to demonstrate the viability of full-chain CCS in Japan. Valuable knowledge and experiences are being acquired.

As a pioneer in CCS/CCUS, the Canadian based, International CCS Knowledge Centre joins forces with Japan CCS Co. to facilitate the sharing of the experience and lessons-learned acquired from the construction through operation and maintenance of SaskPower's Boundary Dam 3 CCS Facility - the world’s first commercial scale, post-combustion CCS/CCUS facility on a coal-fired power plant.

The International CCS Knowledge Centre and Japan CCS Co. will work closely to exchange information and knowledge of CCUS acquired through of the conduct of their projects, in order to share and disseminate such information with a view to advancing the deployment of CCUS in the world.

New material captures carbon dioxide and converts it into useful chemicals

www.kyoto-u.ac.jp

A new material that can selectively capture carbon dioxide molecules and efficiently convert them into useful organic materials has been developed by researchers at Kyoto University.

The research was conducted along with colleagues at the University of Tokyo and Jiangsu Normal University in China. They describe the material in the journal Nature Communications.

The work highlights the potential of porous coordination polymers for trapping carbon dioxide and converting into useful materials, opening up an avenue for future research into carbon capture materials.

"We have successfully designed a porous material which has a high affinity towards CO2 molecules and can quickly and effectively convert it into useful organic materials," says Ken-ichi Otake, Kyoto University materials chemist from the Institute for Integrated Cell-Material Sciences (iCeMS).

The material is a porous coordination polymer (PCP, also known as MOF; metal-organic framework), a framework consisting of zinc metal ions. The researchers tested their material using X-ray structural analysis and found that it can selectively capture only CO2 molecules with ten times more efficiency than other PCPs.

The material has an organic component with a propeller-like molecular structure, and as CO2 molecules approach the structure, they rotate and rearrange to permit C02 trapping, resulting in slight changes to the molecular channels within the PCP -- this allows it to act as molecular sieve that can recognize molecules by size and shape. The PCP is also recyclable; the efficiency of the catalyst did not decrease even after 10 reaction cycles.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Projects and policy news

Energy firms cooperate on large scale CCUS network in UK's Humber

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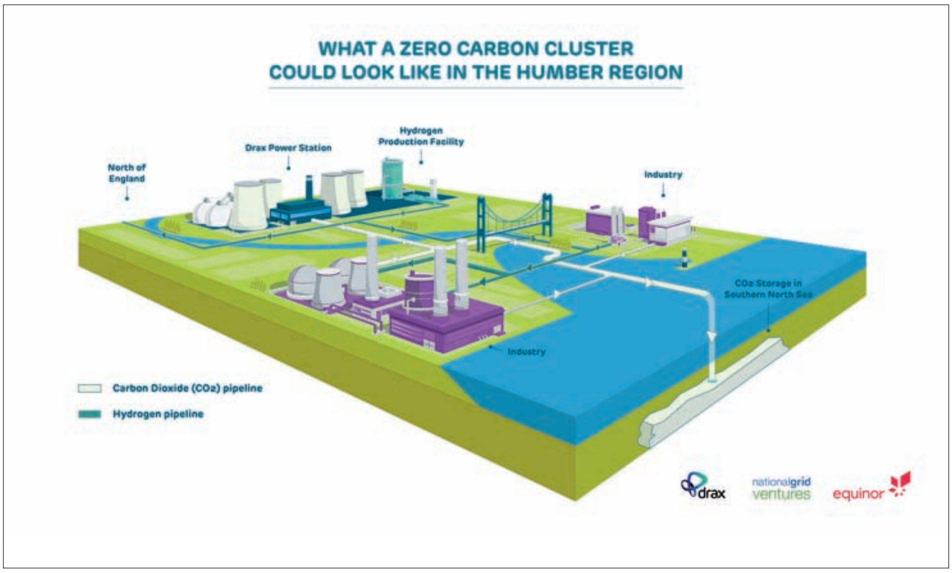
National Grid Ventures, Drax Group and Equinor have signed an MoU, committing them to work together to explore how a large-scale CCUS network and a hydrogen production facility could be constructed in the Humber in the mid-2020s.



UK's Humber could become the world's first net-zero carbon region

The partnership could lead to the Humber becoming the world's first net-zero carbon region and home to a new world-leading hydrogen economy.

This is the first significant action from industry since the UK Committee on Climate Change (CCC) recently published its Net Zero report, which found that CCUS and hydrogen technology developed in regional industrial clusters is essential if Great Britain is going to achieve a 'net zero' carbon economy by 2050.

The three companies will work together to explore the:

• opportunity to scale-up the innovative bioenergy carbon capture and storage (BECCS) pilot project at Drax Power Station, to create the world's first carbon negative power station in the 2020s

• potential development of a large-scale hydrogen demonstrator within the Drax site by as early as the mid-2020s

• strategic opportunities in developing a cutting-edge hydrogen economy in the region.

Commenting on the partnership, Jon Butterworth, Chief Operating Officer, Global Transmission, National Grid Ventures, said, "We all agree that we must act now to start delivering a 'net-zero' carbon economy and we're delighted to be working together with Equinor and Drax. This is a project of great potential for the UK and the Humber region, and we look forward to leveraging our skills and expertise to enable this transition.

"We have seen rapid progress in decarbonising energy through established technologies such as wind power, solar and electricity interconnectors. CCUS and hydrogen create a new pathway to greater decarbonisation of the energy system and provide a platform for decarbonising other areas of our economy; which will be to the benefit of current and future generations."

A study outlining the technical, economic and societal opportunities for CCUS and hydrogen in the Humber region will be published by the partners later this year.

Oil and Gas Climate Initiative and key governments further commit to CCUS

oilandgasclimateinitiative.com

www.cleanenergyministerial.org

The members of the Oil and Gas Climate Initiative (OGCI) and senior government representatives from Clean Energy Ministerial Carbon Capture, Utilization and Storage Initiative countries reaffirm their support for a worldwide CCUS industry.

The meeting, which takes place during OGCI's annual stakeholder dialogue event in New York, will be attended by high-level representatives from the UK and the US and CEOs from OGCI member companies, in recognition of the need for strong public-private co-operation.

CEM CCUS Initiative countries and OGCI member companies intend to explore opportunities to support the commercial development of CCUS through the various stages of development. This will notably include sustained dialogue on policy and regulatory frameworks, aiming for commerciality of identified hubs and projects. This could also consider, as appropriate, mechanisms for risk management at each operational phase, knowledge sharing, storage appraisal activities, corporate and project finance and engagement with civil society.

In a joint statement, the heads of the OGCI member companies said: "Investment in CCUS must be scaled-up urgently to support achieving global climate and energy goals and the Paris agreement. This collaboration represents a unique and necessary opportunity to bring governments and industries together to help create viable market conditions to advance CCUS and its contribution towards a net zero economy. CEM CCUS Initiative countries and industry members within OGCI intend to bring their respective expertise and support to advance CCUS development and deployment across the globe."

In a joint statement, the CEM CCUS Initiative countries said: "Governments within the CEM CCUS Initiative stress the need for close collaboration with key industries to accelerate carbon capture. CCUS technologies are well-known, but the speed of deployment is nowhere near where it should be. Accelerating CCUS requires seamless public-private cooperation and we are looking forward to driving forward strategic CCUS hubs and projects with OGCI.”

This joint declaration builds on the OGCI “Kickstarter” initiative, which is designed to unlock large-scale commercial investment in CCUS by enabling multiple low-carbon industrial hubs.

There are already five hubs under evaluation by OGCI member companies, located in the UK, Norway, the Netherlands, United States and China, which would capture carbon dioxide from several industrial companies and bring economies of scale by sharing transport and storage infrastructure.

Velocys’ Bayou Fuels project to produce negative emission fuels

www.velocys.com

The company has signed an agreement with Oxy Low Carbon Ventures to capture CO2 from Velocys’ planned Bayou Fuels biomass-to-fuels project in Natchez, Mississippi, and securely store it underground in a geologic formation.

OLCV, a wholly owned subsidiary of Occidental, will take, transport and store CO2 captured from the Bayou Fuels facility, when it is completed, enabling the production of transportation fuels that have a net negative carbon intensity, making it the first facility of its kind in the world.

The Bayou Fuels project will take waste woody biomass and convert it into transportation fuels, such as diesel for heavy trucks and sustainable aviation fuel, using Velocys’ proprietary Fischer Tropsch process. The integrated technical solution designed by Velocys is ideally suited to carbon capture, usage, and storage (CCUS); the CO2 is captured before it enters the atmosphere.

OLCV is uniquely positioned to transport and store the CO2 by leveraging Occidental’s industry leadership in CO2 storage and utilisation. This combination of CCUS-ready technology and Occidental’s expertise in storing CO2 enables the Velocys facility to produce net negative carbon intensity fuels.

Integrating CCUS into the Bayou Fuels biorefinery increases certain targeted revenue streams, such as those derived from the California Low Carbon Fuels Standard, and U.S. 45Q tax credits that incentivise the installation of carbon capture equipment on industrial facilities. This has a meaningful positive impact on returns. It also helps to de-risk the project and others that follow it.

The proposed CCUS solution can be replicated at other sites under development, including Velocys’ UK project which recently submitted a planning application to build Europe’s first commercial scale waste-to-jet fuel facility.

Henrik Wareborn, CEO at Velocys said, “We want this facility, and others that will follow, to be as environmentally friendly as possible and offer attractive opportunities for partnerships with major energy companies. We don’t just want to deal with waste materials and produce cleaner burning fuels – we want the process that produces the clean fuels to be as sustainable as possible as well."

"That is why we will be capturing CO2 as a by-product from the gasification process at our Mississippi facility. This will make the facility a net negative emitter of carbon dioxide, which is highly desirable from both an environmental and an investment point of view."

"This carbon negative solution could be replicated at other Velocys sites, so we hope our proposed UK facility in Immingham will be able to benefit from this technology, subject to UK Government support for CCUS deployment and the availability of transportation and storage infrastructure in the Humber region.”

Aker Solutions targets growth in low carbon

www.akersolutions.com

Aker Solutions aims to generate about half of its revenue from renewable or distinct low carbon solutions by 2030, according to the company's 20/25/30 strategy.

The oil and gas industry will remain Aker Solutions' biggest market, but over the next decade the company will have a more balanced portfolio of products and technologies that either generate renewable energy or removes or substantially reduces CO2 emissions.

"The world will continue to see rising energy demand and the challenge for our industry is the need to deliver this with a significantly lower carbon emissions," said Luis Araujo, chief executive officer of Aker Solutions. "No company is better positioned than Aker Solutions to deliver the solutions to realize renewable energy offshore and at the same time decarbonize the oil and gas industry."

In all forward-looking scenarios, the industry will need to provide more energy, with a lower carbon footprint. The pace of the energy transition will be dictated by a number of drivers, such as electrification, efficiency gains, low-emission fuels and accelerated cost reductions of renewables. Still, demand for oil and gas is expected to grow over the next decade, although not as fast as the expected growth in renewable energy.

In its updated enterprise strategy, Aker Solutions set out its growth ambitions within the energy industry and beyond. The company aims to derive 20 percent of its revenue from renewable energy and 25 percent from distinct low-carbon solutions by the year 2030. Summarized, the update is labelled "20/25/30".

The renewable energy solutions will primarily come from floating wind while the low carbon segment is a set portfolio of existing Aker Solutions offerings, including: carbon capture, utilization and storage (CCUS), subsea gas compression, electrification of production assets and unmanned platforms.

Aker Solutions has developed and invested in renewable energy and low carbon solutions for many years, and the company has delivered or is involved in several projects in these segments, including CCUS.

Aker Solutions has developed CCUS since delivering the Sleipner storage solution in 1996. Today, the company is well positioned to realize the first industry-scale carbon capture facility at a cement plant with Norcem Heidelberg in Norway.

Aker Solutions is also delivering its modular Just Catch plant to a waste-to-energy plant in the Netherlands, where the CO2 will be utilized as a fertilizer. Finally, the company is deploying its subsea expertise in the groundbreaking Northern Lights CO2 storage project in the North Sea.

"Growth in segments such as renewables and CCUS increases the addressable market for Aker Solutions," said Araujo. "Our ambition is to become the recognized leader in low carbon offerings and sustainable solutions. We will achieve this through realizing our long-term ambition of 20/25/30."

Shell, OGCI, IOGP, Pale Blue Dot, Equinor, discuss carbon capture

Representatives of Shell, OGCI, IOGP, Pale Blue Dot and Equinor discussed where they think carbon capture and storage is going, at a session during Offshore Europe in Aberdeen, one of the world's biggest oil events. By Karl Jeffery.

The discussion was in a special carbon capture conference session during Offshore Europe, one of the world's largest oil and gas exploration and production events, held in Aberdeen in September.

Owain Tucker, global deployment leader for CCS at Shell, said that from the oil industry point of view, "CO2 is just another liquid". If the oil and gas industry was to inject as much liquid CO2 as it currently injects of water, that would be less CO2 than humanity currently emits to the atmosphere. CO2 has been stored in the subsurface in the US since the 1970s and 2600km of CO2 pipelines have been built there, he said.

The largest CO2 capture project in the world started operation in July 2019, Australia's Gorgon project, he said, capturing 3.4m tonnes / year. Mr Tucker is enthusiastic about the "Porthos" carbon capture project around the Port of Rotterdam, where a number of emitters can share the same infrastructure.

Shell's "Quest" project in Alberta involves taking CO2 from three hydrogen manufacturing units, then conditioning it, drying it and injecting it under Alberta. The injection rate is not consistent, for example one hydrogen unit may be shut down for a while. But the CCS system proves capable of handling a variable load, he said. Since start up in August 2015, it has captured 4m tonnes over 4 years.

This project was once in competition with the UK'S Longannet carbon capture project, to be the world's first project. Longannet was cancelled in 2011. "Some opportunities are missed," he said.

On the next carbon capture project on the same site, Peterhead, an enormous amount of research was done. "We turned over every stone," he said. There was new technology developed to monitor possible CO2 releases on the seabed, and development of fibre optic technology for wells.

But in the end, carbon capture ended up fairly similar to any other oil and gas project. There are complexities, but many oil and gas projects do have complexities, like high pressure and temperature, heavy oil (which needs heating), waxy crude and hydrogen sulphide. "CO2 itself is pretty straight forward," he said. The challenge is working out how to scale it up.

In terms of safety of CO2 storage, Mr Tucker says that if a gas field can hold gas for 50m years, that should be a good enough test that it can hold CO2. It is hard enough to get CO2 through an inch of slate, and we are talking about 1km of shale.

But convincing the public is very hard – sometimes the more testing you do, the less convinced people are. One medical professional, not working in the field, once said to Mr Tucker, "'you've done so much work [on safety], it must be dangerous'".

Amines are the most mature technology for carbon capture and "quite economical," he said, and it is much easier to "engineer costs down" on the more mature technology.

The Net Power technology, with CO2 as a drive fluid in the power plant, is "very exciting", but has "a number of years to go", currently in pilot plant mode.

To get carbon capture moving, there needs to be an "effective carbon price mechanism", stopping valuing at zero or "a few euros". For example, the US has a tax credit of $50 / tonne for every tonne of CO2 stored. There should also be policies which reward negative emissions, such as where biofuels are used with carbon capture.

OGCI

Julien Perez, vice president strategy and policy with the Oil and Gas Climate Initiative (OGCI), said his organisation is trying to make a "virtual cycle" between its investments in technology and creating an enabling environment for low carbon technology.

In 2018, it was joined by ExxonMobil, Chevron and Occidental Petroleum, and developed a methane target. It formed an engagement plan with the United Nations. In 2019, it delivered its methane target. There is uncertainty about how much methane is emitted by man-made activity, he said.

A working estimate is that 60 per cent of emitted methane is man-made, breaking down to 20 per cent from fossil fuel production, 24 per cent agriculture, 11 per cent waste and 5 per cent other.

The IPCC (Intergovernmental Panel on Climate Change) estimates that this methane is responsible for a quarter of the temperature rise. "So, acting on methane can be a quick win in the Paris goals," he said. OGCI is a founding member of an organisation called 'global methane alliance'.

It has made an number of investments in technologies to better manage methane, including GHGSat, a satellite system for monitoring greenhouse gas emissions; Clarke Valve, a company which makes control valves for oil and gas equipment which minimises fugitive emissions; and Kairos Aerospace, an aerial methane detection service startup.

Mr Perez said he could see a "clear growth trend" in methane detection technologies, and a there is a business opportunity for companies which can help provide a better picture of what is going on.

Currently 30m tonnes of CO2 are stored globally in the big carbon capture projects. This needs to rise 30x to 1 gigatonne in 10 years, he said. Getting there needs investment, as well as skills managing complex projects, and subsurface capability – all of which the oil and gas industry is "uniquely placed to provide".

OGCI is trying to tackle barriers – including policy and regulatory – and aiming to demonstrate that CCS can be economically viable. It has investments in projects to recycle CO2, including Solidia Technologies, a company with technology to make cement with less CO_2, and Econic, which makes polymers out of CO_2.

It also worked on the Clean Gas Project in Teesside, UK. It has invested in the Wabash Valley Resources plant in Indiana, which gasifies coal to make ammonia and power. It takes advantage of the "extremely favourable regulatory environment" for carbon capture in the US. The company held a "CCUS Investment Day" in Chicago on Sept 12-13.

IOGP

Wendy Brown, Environmental Director of the International Association of Oil and Gas Producers (IOGP), said that measuring methane emissions from oil and gas operations is an enormous challenge – and there is a 6-fold difference in the various estimates. Some people say the industry underestimates its emissions.

International Energy Authority (IEA) data for 2018 of the industry's greenhouse gas emissions estimates that 53 per cent come from venting (intentional leaks), 34 per cent come from fugitives (unintentional leaks), 17 per cent from flaring and 8 per cent from energy combustion. The equivalent figures for Europe are 64 per cent venting, 21 per cent fugitives, 5 per cent flaring, and 10 per cent from energy combustion.

Reasons for data to be inaccurate include that it is based on companies which have better performance than average (such as OGCI / IOGP members), but also that emissions recorded by satellite may be misallocated to the industry, actually coming from agriculture or coal mining.

IOGP set up a "methane task force" to look at the various factors, focusing on UK, US and Australia. It is also a signatory to a "Methane Guiding Principles Organisation", which includes 19 companies and 13 organisations, developing methane policy frameworks and best practices, led by BP.

For example, it can advise that companies "phase out high bleed pneumatic devices". A global methane toolkit is being prepared, including manuals, a gap assessment tool, and a methane cost model, which helps you prioritise work.

Shell is leading a global outreach program, with a half day training for executives, and a master class for practitioners, on technologies for methane.

If you list methane monitoring technologies from the furthest from the ground to the closest, you find the methods furthest away have the widest coverage area, but the methods closed to the earth have the better resolution, she said. The list is satellites, manned aircraft, drones and ground based. A lot of ground detectors are designed to detect leaks but not quantify them.

For flaring, an interesting technology is Flare Gas Recovery and Ejector. The technology compresses surplus gas to the point where it can be recovered into production or used as fuel gas. Technology from a company called Transvac is used by PDO and Saudi Aramco.

The Netherlands Oil and Gas Exploration and Production Association (NOGEPA) did a study of cost effectiveness of various CO_2 mitigation methods and found that about half of all emissions from operations can be removed with technology which costs the equivalent of Eur 20 per ton CO_2 removed.

"So, eliminating methane leaks can be some of the most cost-effective ways to provide drastic reduction in emission intensity. There's lots of opportunity to test and pilot new technologies," she said.

Acorn

Sam Gomersall, commercial director of Pale Blue Dot Energy, which leads the Acorn carbon capture project, said that Acorn aims to be the first major carbon capture and storage project in the UK, while also making large volumes of clean hydrogen.

The Acorn project has St Fergus, an industrial location North of Aberdeen, as its base. It is "ideal for CCS and H2 plants," he said. The project team envisage that offshore gas could be reformed in St Fergus into hydrogen plus CO_2, with CO_2 sent back offshore for sequestration. The hydrogen could then be injected directly into gas transmission systems.

Most gas domestic and business appliances can work effectively with fuel which is up to 20 per cent hydrogen. This is currently not allowed under regulations, but "the regulations are in the process of being changed."

Acorn has funding from the Scottish government, as well as oil companies Total and Chrysaor. Carbon capture is in "quite a mature place" in terms of technology, he said. It is the business model which is currently lacking."

When asked what CO_2 price would get carbon capture off the ground, Mr Gomersall said it depends on many different parameters. At one extreme, there are some industrial locations where nearly pure CO_2 is released to the atmosphere. So there would be no "capture" cost, just a storage cost.

Equinor

The "Northern Lights project" in Norway involves Shell, Equinor and Total, planning to sequester 1m tonnes CO_2 per year in the first phase and designed for 5m tonnes per year, said Anna Korlko, Low Carbon Technology Lead, Equinor.

The FEED should be completed in September 2019, with injection wells to be drilled in Nov-Dec 2019, and a final investment decision in Q2 of 2020.

Another project is "H21", which aims to provide hydrogen for heating in the UK, by injecting hydrogen into the national gas grid.

It could potentially decarbonize 14 per cent of UK heat, thereby reducing emission by up to 20m tonnes a year, she said. There would be 12 GW of hydrogen production capacity. Hydrogen could be stored at the Aldbrough gas storage facility in East Yorkshire. This has a capacity of 8 TWH, equivalent to 62,000 Australian "mega batteries".

Equinor estimates that 2035 prices for gas will be $50 / KWH, emitting 100g CO_2 per KWH, whilst hydrogen will cost $75 / MWH, emitting 15g CO_2 per KWH. So, a small increase in cost for a big cut in CO_2 emissions. And it means that society can still use fossil fuels for heat, so much cheaper than electrification for everything. It also provides "optionality" to the user.

Equinor did a feasibility study in 2019 for a project to generate power from hydrogen in the Netherlands, receiving natural gas by pipeline from Norway, and then CO_2 back to Norway for sequestration, keeping surplus hydrogen in an underground cavern. The hydrogen could also be used for transport. The CO_2 reduction was calculated at 2m tonnes per year.

People are starting to talk about "blue" hydrogen from natural gas, and "green" from renewables, and suggesting "blue" may be taking market share from "green". But Equinor sees them as complementary, when you consider that green costs three times as much as blue, she said.

EY and DNV GL: the future of energy

Paul Bogenreider, energy futurist with EY, and Liv Hovem, CEO of oil and gas with DNV GL, presented their vision of the future at the Aberdeen and Grampian Chamber of Commerce Business Breakfast at Offshore Europe on September 3. By Karl Jeffery.

Paul Bogenreider, economist and 'energy futurist' with professional services firm EY, said he sees the future of energy as more evolution than revolution. "As much as we might want to have a rapid transition, the energy transition is going to happen one car at a time, one solar panel at a time," he said.

The key factor driving change – or not – is whether consumers can be persuaded to change, and what they really want.

The future of energy is ultimately determined by people's purchasing choices and what companies bring to the marketplace. Governments have some influence on this through their decisions about taxes and other policies, but maybe the climate change discussions focus too much on governments.

And we need to bear in mind that "people like energy pretty much the way that it is," he said. What people have now is what they like. Electricity from renewables has disadvantages over fossil fuels in terms of price, reliability and convenience. Persuading non climate enthusiasts to switch from a five minute gasoline fuelling of a vehicle to a 30 min electric charging won't be easy.

"The energy complex we have today has enabled enormous improvements in quality of life. It's going to be very difficult to give that up," he said. Today's energy industry is also "enormously profitable" for many companies.

In terms of technology, we are not far away from a point where electric vehicles can compete with gasoline vehicles, and society can function without climate change being a problem. But the bigger problem is likely to overcoming people's current habits, not technology.

The financial machine also needs to change. "Energy is an efficient machine which funnels money out of savings accounts into the oilfield. The energy transition is the most significant capital re-allocation in the history of mankind," he said. "Capital markets are not equipped to move that quickly."

The energy transition will not actually affect oil and gas people very much, Mr Bogenreider believes . Wells are already depleting faster than the demand for fossil energy is reducing, so the oil and gas industry still needs to attract investment for new developments, and so offer competitive returns.

Currently renewable energy is growing at a rate where it takes 10 years to supply a further 1 per cent of people's energy needs. To reach the targets, "you have to go up 1 per cent every year for the next 20 years," he said.

You don't need every business to become carbon neutral, because with carbon capture and storage, we can achieve zero carbon overall using offsets.

But getting CCS started needs "some brave projects to move forward", he said, so the costs come down. And without any carbon price, "I struggle to visualise what the profit model [for carbon capture] looks like," he said.

"My intuition tells me biofuels will be fairly critical," he said. " If you transition from petroleum to biofuels, you create a closed loop system."

DNV GL's predictions

Liv Hovem, CEO oil & gas business area, DNV GL, said that the company wanted to make a single prediction of the future, not just a range of forecasts or scenarios.

In its 2019 "Energy Transition Outlook", published in September 2019. It predicts that global oil demand will peak in the mid-2020s. But gas will still account for 30 per cent of the energy mix in 2050 and oil 17 per cent. There will be "significant uptake" for solar and wind, and electricity consumption will double by 2050. 63 per cent of energy will come from renewables.

Gas demand in 2050 will actually be higher than it is today – although we will see gas and renewables working closely together. "Neither can make it by themselves," she said.

A growing number of countries are setting targets to be zero emission, including Britain – although DNV GL predicts that Britain will miss this target.

Overall emissions will miss the Paris climate goals, leading to a 2.4 degree increase in temperature, DNV GL predicts.

DNV GL believes that the main reason carbon capture has not been installed yet is cost, but if technology was installed on a similar scale to renewables and wind, these costs could come down.

"It is a bit of chicken and egg situation. This requires some bold decisions," she said. "Our forecast says CCS will not be implemented at scale before 2040 unless there is a carbon price. So future lies largely in the hands of policy makers."

But "more than 40 per cent of oil and gas professional believe there will never be a global carbon price," she added.

But can industry find other ways to implement carbon capture and storage? Ideas circulating include finding ways for hydrocarbons to support renewable energy, making hydrogen offshore by electrolysis from renewables or from gas + CCS.

She noted that offshore wind was barely being considered just a decade ago – that illustrates how fast things can change."Our industry is rapidly innovating towards a common goal. It is inspiring but we need much more of it."

Ms Hovem a little more optimistic about persuading people to change, saying that "people do adapt quickly to new technology. "I see people around me do this. It is just a mindset."

Ms Hovem said she is interested in technology which can be implemented using existing infrastructure – because one of the biggest obstacles to new technology is the need to build new infrastructure to support it.

Total's CEO Patrick Pouyanné on carbon

Patrick Pouyanné, President and CEO of oil major Total shared his views on how the oil and gas industry should approach carbon – and what Total is doing – at an Offshore Europe plenary session. By Karl Jeffery.

"It is quite an important moment for industry, everything is changing very quickly," said Patrick Pouyanné, President and CEO of oil major Total, speaking at a plenary session at Aberdeen's Offshore Europe event on September 3.

"We can all see the scale of the challenge we face [delivering] reliable, affordable and clean energy. All these words are important, but society puts emphasis on the last one. All citizens are asking us to find ways to solve climate change," he said.

The North Sea oil and gas industry made big efforts to improve since 2014. A $30 oil price "could have been an end to the basin. These efforts saved the basin [with the] principle of discipline. Barrels per head count improved 57 per cent from 2014 to today," he said.

"But it remains one of the most expensive places to operate. And the North Sea is not the best around the world for safety."

When it comes to carbon, "improving energy efficiency of operations is key," he said. "Everyone should know carbon dioxide emissions of every site. It is a way to motivate people to contribute to the challenge."

"I'm a supporter of what the UK government did for carbon prices. UK has demonstrated it is not so complex," he said. The price was "£20 tax per tonne – not $100 – and it worked [in disincentivising coal]."

With carbon capture, "we could see a future of North Sea becoming a sort of giant cave of CO_2." To get there, "we need to intensify activity, for pilots, R+D, CCUS chain."

"It will be fundamental if we want to produce steel, concrete around the world."

Mr Pouyanné was asked if the company can give dividends to shareholders and also be sustainable. "Shareholders will not just want dividends today, they want dividends tomorrow," he replied. "Dividends for me are a consequence of being sustainable. We never increased a dividend in 30 years."

"If I want to be sustainable, I need to invest in oil, oil which is profitable, competitive. We don't explore in the Arctic, because it is not competitive."

"We have invested $10bn in being a low carbon power producer [covering] gas or renewables. This will continue to grow. We invest $1.5bn to $2bn this year in this business unit. Some people tell me it's too small. But it is not so small compared to a utility."

"The challenge is finding [low carbon power] projects, he said. "You have to get access to land to make your projects."

Total has set up a purely online electricity retail company, which now has 6m customers in France and Belgium. It has a very low-cost model, with 600 staff, replacing a company which had 10,000 employees. "I can tell you we make money – we don't make big money," he said.

It needs a certain scale to work. "It is a business where you need to amortise fixed costs – marketing."

The company needs to continually improve its portfolio of oil and gas projects. "We are in commodity business. I don't set the price of oil. I can act on my break even," he said.

The company has "rotated" more than 30 per cent of its upstream portfolio over the past few years. "We replace high cost assets by low cost assets. It's fundamentally a business of assets."

The company acquired Maersk Oil in 2017 and Anadarko's operations in West Africa in April 2019, as part of efforts to acquire more low-cost assets. But now the company is more in a divestment phase. "We need to divest $10bn" he said.

Total manages its risk to geopolitical upheaval by having operations in many parts of the world. It has a background of being obliged to develop outside its home country, France, because France did not have oil. At the moment, "number one for investment is Russia, number two is US. I try to balance between Mr Putin and Mr Trump."

More information

View the full conference agenda and more information about the event:
www.offshore-europe.co.uk

Putting CO_2 to Use: Creating value from emissions

A report from the International Energy Agency (IEA) considers the near-term market potential for five key categories of CO_2-derived products and services: fuels, chemicals, building materials from minerals, building materials from waste, and CO_2 use to enhance the yields of biological processes.

Globally, some 230 million tonnes (Mt) of carbon dioxide are used every year, says the report. The largest consumer is the fertiliser industry, where 130 Mt CO_2 is used in urea manufacturing, followed by oil and gas, with a consumption of 70 to 80 Mt CO_2 for enhanced oil recovery. Other commercial applications include food and beverage production, metal fabrication, cooling, fire suppression and stimulating plant growth in greenhouses. Most commercial applications today involve direct use of CO_2.

New pathways involve transforming CO_2 into fuels, chemicals and building materials. These chemical and biological conversion processes are attracting increasing interest from governments, industry and investors, but most are still in their infancy and face commercial and regulatory challenges.

The production of CO_2-based fuels and chemicals is energy-intensive and requires large amounts of hydrogen. The carbon in CO_2 enables the conversion of hydrogen into a fuel that is easier to handle and use, for example as an aviation fuel. CO_2 can also replace fossil fuels as a raw material in chemicals and polymers. Less energy-intensive pathways include reacting CO_2 with minerals or waste streams, such as iron slag, to form carbonates for building materials.

Highlights

• New pathways to use CO_2 in the production of fuels, chemicals and building materials are generating global interest. This interest is reflected in increasing support from governments, industry and investors, with global private funding for CO_2 use start-ups reaching nearly USD 1 billion over the last decade.

• The market for CO_2 use will likely remain relatively small in the short term, but early opportunities can be cultivated. The use of CO_2 in building materials is one such opportunity, but may require further trials and updating of standards for some products. Public procurement of low-carbon products could help to create early markets for CO_2-derived products with verifiable climate benefits.

• CO_2 use has potential to support climate goals, but robust life-cycle assessment is essential. CO_2 use applications can deliver climate benefits where the application is scalable, uses lowcarbon energy and displaces a product with higher life-cycle emissions. Quantification of these benefits can be challenging and improved methodologies are needed to inform future policy and investment decisions.

• CO_2 could be an important raw material for products that require carbon. Some chemicals require carbon to provide their structure and properties while carbon-based fuels may continue to be needed where direct use of electricity or hydrogen is challenging (for example, in aviation). In the transition to a net-zero CO_2 emission economy, the CO_2 would increasingly have to be sourced from biomass or the air.

Early markets are emerging but the future scale of CO_2 use is uncertain

The future market potential for CO_2-derived products and services is difficult to assess. The early stage of technology development and anticipated reliance on policy frameworks for most applications makes estimating the future market very challenging. Theoretically, some CO_2 use applications, such as fuels and chemicals, could grow to scales of multiple billions of tonnes of CO_2 use per year, but in practice would compete with direct use of low-carbon hydrogen or electricity, which would be more cost effective in most applications.

The barriers to near-term scale up of CO_2 use are commercial and regulatory rather than technological. This analysis considers the near-term potential for increasing the market to at least 10 Mt CO_2 use per year for each of the five categories of CO_2-derived products and services: fuels, chemicals, building materials from minerals, building materials from waste and CO_2 use to promote plant growth. This level of CO_2 use would be almost as much as the current CO_2 demand for food and beverages.

For CO_2-based fuels and chemicals, production costs are currently several times higher than for their conventionally-produced counterparts. This is mainly due to the costs associated with hydrogen production. Commercial production is possible in markets where both cheap renewable energy and CO_2 are available, such as in Chile or Iceland. CO_2-derived polymers could be produced at lower cost than their fossil counterparts, but the market is relatively small.

Building materials produced from CO_2 and minerals or waste can be competitive today. Early markets for CO_2 use in concrete manufacturing are emerging, with CO_2-cured concrete delivering lower costs and improved performance compared to conventionally-produced concrete. The production of building materials from waste and CO_2 can also be competitive as it avoids the cost associated with conventional waste disposal. The CO_2 used in building materials is permanently stored in the product, with additional climate benefits derived from lower cement input in the case of CO_2-cured concrete. For some concrete products, trials and updating of product standards may be required to support broader deployment.

Using CO2 can support climate goals, but with caveats

CO_2 used is not the same as CO_2 avoided. CO_2 use does not necessarily reduce emissions and quantifying climate benefits is complex, requiring a comprehensive life-cycle assessment as well as understanding of market dynamics. CO_2 use can provide climate benefits where the application is scalable, uses low-carbon energy, and displaces a product with higher life-cycle emissions. Longer term, in a net-zero CO_2 emission energy system, the CO_2 would have to be sourced from biomass or the air to achieve climate benefits. CO_2-derived products that involve permanent carbon retention, such as building materials, can offer larger emissions reductions than products that ultimately release CO_2 to the atmosphere, such as fuels and chemicals.

Improved understanding and quantification of CO_2 use applications and their emission reduction potential is required. To inform future policy and investment decisions, there is a need for robust life-cycle analyses based on clear methodological guidelines and transparent datasets. In recent years, several expert groups have started to develop such guidelines; however, it remains challenging due to the early stage of development of many CO_2 use technologies.

CO_2 use is a complement, not an alternative, to CO_2 storage for large-scale emissions reductions. CO_2 use is not expected to deliver emissions reductions on the same scale as carbon capture and storage (CCS), but can play a role in meeting climate goals as part of an “all technologies” approach. In International Energy Agency (IEA) scenario analysis with limited deployment of CO_2 storage, CO_2 use within the energy system increases (including for the production of methanol and synthetic hydrocarbon fuels) but delivers less than 13% of the emissions reductions that would otherwise be provided from CO_2 storage. The potential for negative emissions from CO_2 use is also very limited.

Cultivating early opportunities while planning for the long term

The future prospects for CO_2 use will largely be determined by policy support. Many CO_2 use technologies will only be competitive with conventional processes where their mitigation potential is recognised in climate policy frameworks or where incentives for lower-carbon products are available. Public procurement can be an effective strategy to create an early market for CO_2-derived products with verifiable climate benefits, and can assist in the development of technical standards.

The market for CO_2 use is expected to be relatively small in the short term, but early opportunities can be developed. These early opportunities include building materials, but in some cases also polymers and industrial CO_2 use in greenhouses. Industrial areas where low-cost raw materials, low-carbon energy and consumers are located together, and where existing CO_2 pipelines can be used to advantage, can provide early deployment opportunities.

Further research, development and demonstration (RD&D) is needed. This is particularly for applications that can contribute to a future net-zero CO_2 emission economy, including chemicals and aviation fuels derived from biogenic or atmospheric CO_2. This should be in conjunction with RD&D for low-carbon hydrogen production.

Recommendations

The market for CO_2 is expected to remain relatively small in the short term, but has potential to grow in the longer term, especially as a raw material for products that will continue to require carbon, such as aviation fuel and chemicals. Governments can identify early opportunities to build markets for captured CO_2 to enable technologies to mature over the coming decades and support future investment in sectors where CO_2-derived products could play an important role.

Several measures are recommended for the short term:

• Support greater understanding and improved quantification of CO_2 use applications and their benefits to the climate. To inform policy decisions there is a need for robust lifecycle analyses based on clear methodological guidelines and transparent datasets. Governments could establish international working groups with experts to facilitate knowledge sharing, development of standards and best practice guidelines.

• Identify and enable early market opportunities for CO_2 use that are scalable, commercially-feasible and can deliver emissions reductions. The use of CO_2 in building materials for non-structural applications, such as roads and floors, is one such opportunity, but in some cases also in polymers and in greenhouses to promote crop growth. Certification of polymers and the revision of waste regulations to allow conversion of waste into building materials is warranted, provided their environmental integrity can be assured.

• Consider the implementation of public procurement guidelines for low-carbon products. This can create an early market for CO_2-derived products and assist in the establishment of technical standards and specifications. The procurement guidelines should be underpinned by a robust emissions accounting and MRV framework to ensure climate benefits are actually achieved. In parallel, several other measures can be taken to prepare the market for the longer term:

• Facilitate multi-year test trials for CO_2-derived building materials. This is required to demonstrate reliable performance and gain broader acceptance for these products, in particular in markets for structural materials that have to support heavy loads, for example in high-rise buildings. If trials are successful, close collaboration between governments and industry is needed to update and extend existing product standards and codes.

• Support RD&D for future applications of CO_2 use that could play a role in a net-zero CO_2 emissions economy, including in aviation fuels and chemicals manufacturing. This should be in conjunction with RD&D for low-carbon hydrogen production and CO_2 capture from biomass and the air. Support for international RD&D programmes and knowledge transfer networks can facilitate accelerated development and uptake of these technologies. Governments could also provide direct funding for demonstration of technologies with good prospects in terms of scalability, competitiveness, and CO_2 emissions reductions.

More information

www.iea.org

CEDIGAZ report hails new era for CCUS

According to a new report by CEDIGAZ, CCUS is coming back into the limelight, especially in the US and in Europe, in the wake of the Paris agreement, boosted by a growing interest in hydrogen, rising carbon prices, new supporting policies and new business models. www.cedigaz.org

There are currently 20 new, large-scale, CCUS projects planned around the world, nine of them in Europe, says the report. While projects developed in the middle of the 2000s mainly targeted coal-fired power plants and stored the captured carbon, the focus of the new projects is different as they tend to concentrate on industrial and manufacturing processes and on carbon utilization rather than just storage. Several projects involve production of clean hydrogen from natural gas, a cheaper option than hydrolysis using renewable power. New business models aim at reducing costs by dis-integrating the CCUS value chain into its three components of capture, transport and storage, and by addressing clusters of industrial facilities to achieve economies of scale.

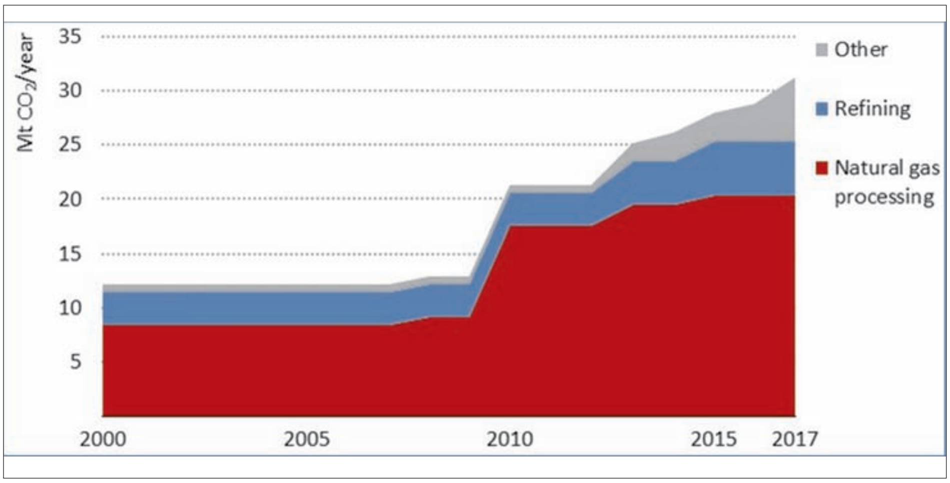
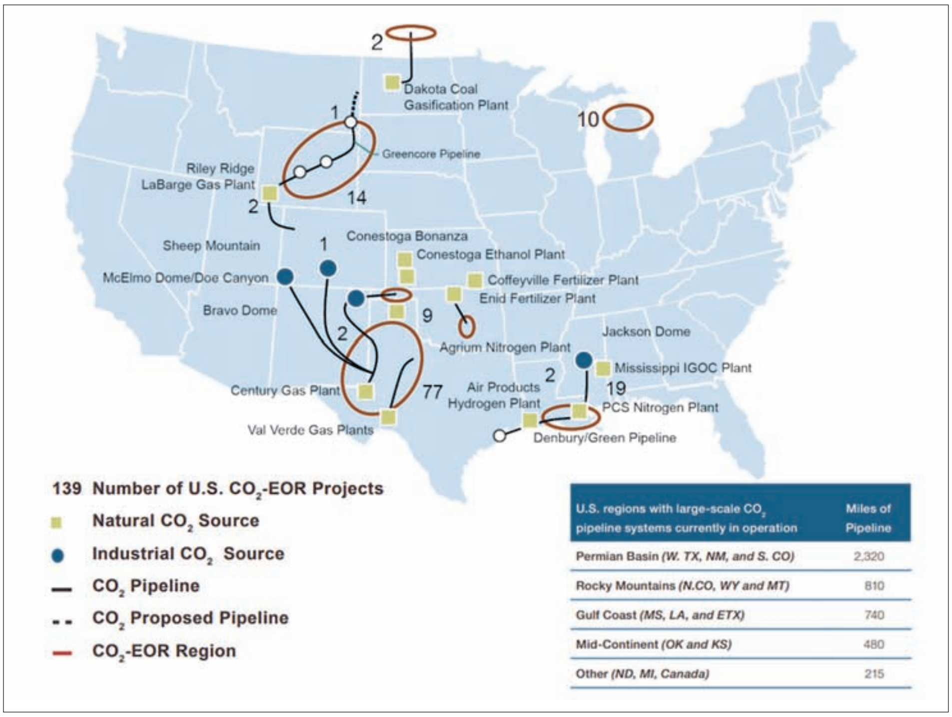


Figure 1: Volumes of CO2 captured globally

The US is the most advanced globally in terms of CCUS supporting policies. In February 2018, the US Congress passed substantial tax credits to encourage private investment in the deployment of CCUS. In addition, in September 2018, California amended its Low Carbon Fuel Standard (LCFS) program with a CCS Protocol. While insufficient to incentivize CCUS in existing facilities (retrofitting) or in the largest US emitting sectors like power plants or cement and steel production, they should help deploy CCUS on the "low hanging fruits" which could lead to cost reduction for further projects through the learning curve and the deployment of shared infrastructure.



U.S. regions with large-scale CO_2 pipeline systems currently in operation	Miles of Pipeline
Permian Basin *(W. TX, NM, and S. CO)*	2,320
Rocky Mountains *(N.CO, WY and MT)*	810
Gulf Coast *(MS, LA, and ETX)*	740
Mid-Continent *(OK and KS)*	480
Other *(ND, MI, Canada)*	215

Figure 2: Current CO2-EOR operations & infrastructure in the US

As Europe's new energy strategy aims at a carbon neutral economy by 2050, large-scale deployment of CCUS appears necessary. The EC is supporting CCUS through a range of policy initiatives and has pledged to invest €10 billion in CCUS and other low-carbon technologies. Nine projects are currently under development, making Europe the leader in the renewed global effort to promote CCUS. They focus on energy intensive industries and those with inherent process emissions of CO2 (e.g. cement). Gas-fired power plants are also targeted and several projects involve clean hydrogen production from natural gas. The business model of European CCUS projects is to develop multi-user "hub and cluster" facilities in industrial regions, tied-in to shared transport and storage infrastructure.

With different policy approaches and different incentives, the US and Europe both look to achieve global leadership in CCUS technologies and both recognize the crucial role of carbon management and CCUS in the future.

The report is free for CEDIGAZ members

Gas, renewables and CCS must work together to achieve energy transition

Gas and renewables must work together alongside greater uptake of carbon capture and storage to secure a rapid energy transition, according to a new forecast by DNV GL.

The 2019 Energy Transition Outlook provides an independent forecast of developments in the world energy mix to 2050. By this time, gas will account for nearly 30% of the global energy supply, providing the world with a base of secure and affordable energy, and with manufacturing feedstock.

DNV GL's Outlook reveals there is no single pathway to a decarbonized energy mix. A combination of energy sources – primarily gas and renewables – will be the quickest route to delivering a supply of affordable, decarbonized energy in the lead-up to mid-century. Gas will increasingly complement variable renewables, meeting demand in peak periods such as winter in colder climates.

As gas secures its place as the world's largest energy source from the middle of the next decade, its production and consumption must be decarbonized to help achieve targets for climate change mitigation.

CCS – the only currently-available technology to deeply decarbonize hydrocarbon use – will not be employed at-scale until the 2040s unless governments develop and enact more definitive policies on its use, according to the Energy Transition Outlook.

"All major routes to successfully decarbonizing gas rely on the large-scale uptake of carbon capture and storage. The future of CCS largely lies in the hands of policy-makers setting a higher carbon price than the cost of the technology. Industry can also play a role in stimulating quicker adoption by focusing on finding ways to reduce the cost of CCS technology," said Liv A. Hovem, CEO, DNV GL – Oil & Gas.

"Large-scale uptake of carbon capture and storage technology will unlock significant opportunities for hydrocarbon and renewable energy technologies to work together to decarbonize the energy mix. The energy industry must however also shift its mindset from 'gas vs renewables' to 'gas and renewables' for success," Hovem added.

Approaches to integrating hydrocarbon and renewable technology for decarbonized gas production and consumption include:

• Introduction of new, carbon-free forms of gas, such as hydrogen, to national gas networks;

• Power-to-gas, with existing gas pipelines used to transport hydrogen produced from electrolysis of seawater using offshore wind power, or from offshore-based methane reformers;

• Gas-to-wire, where gas is used to produce power offshore for transport to shore via nearby windfarm cabling;

• Offshore platform electrification, with offshore windfarms installed nearby, platforms can import renewable electricity directly.

The natural gas supply and demand outlook

According to DNV GL's analysis, global oil demand will peak in the mid-2020s and gas demand will keep rising to 2033. Gas demand will then plateau, and the fuel will remain dominant until the end of the forecast period in 2050, when it will account for over 29% of the world's energy supply.

Significant investment will be required to ensure production meets demand, including realising the potential from stranded gas reserves and for reserve replacement. DNV GL forecasts global upstream gas capital expenditure to reach USD 737 billion (bn) in 2025, and USD 587 bn in 2050. Other important forecasts for the future of natural gas include:

• Unconventional onshore gas will increase from 2019 right through to the end of the forecast period, growing by 68% from 2017 production levels. Production will principally come from North America

• Conventional onshore gas production will be maintained at today's output rates until the late 2030s. It will then decline slowly to mid-century, ending at about 19% lower than 2017. Production has already begun to fall in North America, but it will continue to rise in North East Eurasia until 2033

• Offshore gas production will rise until 2040, when it will be 58% greater than in 2017. In 2050, it will still be more than a third (39%) higher than in 2017, with the Middle East and North Africa providing the greatest production volumes

• Power generation will be the main consumer of gas in most regions, challenged by manufacturing (mainly petrochemicals) in China, India, and Latin America.

DNV GL highlights that the long term, sustainable future of the oil and gas industry is dependent on its license to operate today.

"Our sector will only have the opportunity to decarbonize if it maintains society's trust through a sharp focus on safe operations and environmental performance. Companies' ability to display the highest standards of safety and sustainability today will win the public support that the industry needs to decarbonize for tomorrow," added Hovem.

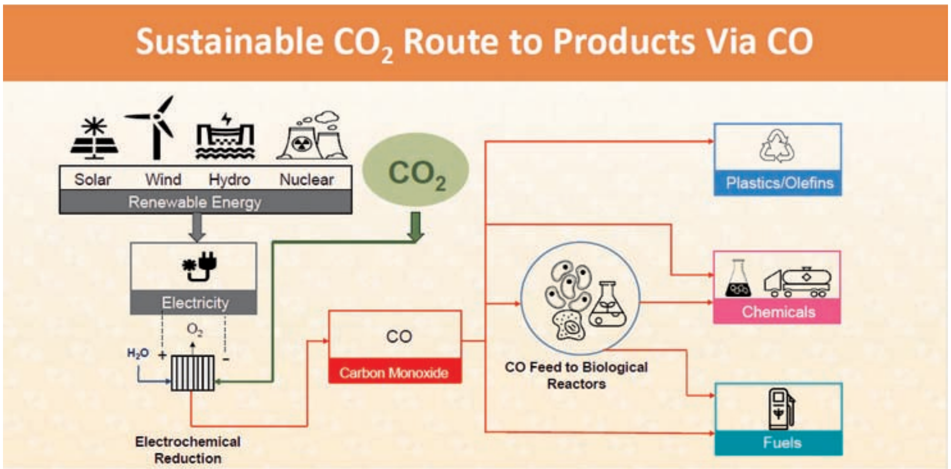
More information

DNV GL's suite of 2019 Energy Transition Outlook reports are available to download free of charge. The main ETO report covers the transition of the entire energy mix to 2050 globally, and in 10 world regions. It is accompanied by three supplements forecasting implications for the oil and gas; power supply and use; and maritime industries.

eto.dnvgl.com/2019

New electrochemical process can recycle millions of tonnes of CO2 a year

Electrolysis of CO2 using renewable energy can produce high energy chemical feedstocks that will significantly reduce the carbon footprint of downstream hydrocarbon products, reducing the need for extracting/importing fossil fuels.



Minimizing the release of carbon dioxide (CO2) greenhouse gas to the environment, while still providing the liquid fuels and other hydrocarbons that current civilization relies on, will require the large-scale commercialization of processes analogous to photosynthesis. Water and carbon dioxide will need to be combined with renewable energy from carbon-neutral sources, such as wind or solar, to produce hydrocarbons in a sustainable manner. Initially, this CO2 will come from high CO2 concentration sources such as steel mills, cement furnaces, and ethanol fermenters. Ultimately, it may become necessary to capture CO2 from ambient atmosphere in order to reduce global concentrations to early industrial levels.

Research scientists at Dioxide Materials in Boca Raton, Florida have developed novel electrochemical technology that converts CO2, water and renewable energy to produce green fuels and chemicals in order to enable a low carbon future.

The process recycles waste CO2 into renewable fuels by mimicking nature. The fuels we use today came from CO2 captured by plants. The plants use energy (sunlight) to convert CO2 and water into a reactive form: sugar or cellulose. The reactive material is then transformed at high pressures and temperatures underground to yield coal, natural gas or petroleum. Dioxide Materials' process is similar, yet it makes fuel faster and more efficiently than vegetation. While vegetation usually only converts about 1% of captured energy into fuels, Dioxide Materials' process converts approximately 60%.

The Team has created a platform technology that is scalable and can be used to convert CO2 into many products, meeting a number of different customer needs. For example, the CO2 electrolyzers can efficiently produce carbon monoxide (CO), a component of syngas, to make "greener" chemicals and fuels, such as gasoline, methanol, dimethyl ether (a diesel substitute), formic acid, formaldehyde, acrylic acid and many other chemicals we use today. "And, the chemical can be made at a lower cost than current methods in many cases," stated Prof. Rich Masel, PhD, CEO and Founder of Dioxide Materials.

Currently the main industrial-scale use of CO is in synthesis gas, a mixture of CO and hydrogen, which is currently produced from natural gas or coal. Synthesis gas is used in a variety of downstream processes, including the production of methanol and ammonia. Producing CO from CO2 instead, can be attractive to two types of customers: those facing high natural gas prices and having the availability of renewable energy (e.g. in Europe and Asia), and those looking to lower their environmental carbon footprint. Dioxide Materials will largely be targeting two customer groups: those producing synthetic fuels from synthesis gas (e.g. via Fischer-Tropsch synthesis) and those producing fermentation products via gas fermentation.

Dioxide Materials has the most energy efficient electrolyzers reported so far. The team has developed new materials that enable the process:

• Novel Sustainion® anion exchange membranes that are both alkali stable and having at least twice the ionic conductivity of the nearest competitor. The anion exchange Sustanion® membranes are based on a cheap and abundant, but more importantly, alkaline stable polystyrene backbone.

• Sustainion® XA additives in the catalyst layer lowers the overpotential of the reaction, raising the reaction selectivity to greater than 95%, allowing the electrolyzers to operate at commercial current densities of 200 mA/cm2 and higher.

By way of background, the technology was developed at Dioxide Materials, a start-up company originating in 2010 by Rich Masel, retired professor from the University of Illinois (Urbana-Champaign). To really make a significant impact on reducing greenhouse emissions at that scale, one has to step back and consider what sources are emitting large concentrations of CO2 into the atmosphere and what can be done to curtail it?

More importantly, how can we reuse that waste carbon and convert it into a renewable fuel or chemical that can be used every day through products we use and wear, thereby closing the carbon loop/cycle. That's where the breakthrough began.

Back in 2011, the team at Dioxide Materials (DM) discovered that CO2 could be converted to a more reactive carbon species using half the amount of electricity/energy. Professor Masel has published experimental work on CO2 conversion and related electrochemical technologies back in 2011 when the discovery was first published in Science and noted as “One of the most important scientific papers of the year”.

Dioxide Materials has developed an economically viable process by creating a series of new membrane catalysts that raise the selectivity of CO2 conversion to CO to over 95% and increase the overall energy efficiency to over 80%. This lowers the amount of electricity needed to produce a ton of product by a factor of 2-3.

So, whereas recycling one of the world’s biggest waste gases into renewable fuels and chemicals required too much energy in the past to be cost effective and economical, the Dioxide Materials team has now developed electrochemical opportunities, so one can economically convert CO2, “a waste gas” into key chemical feedstocks.

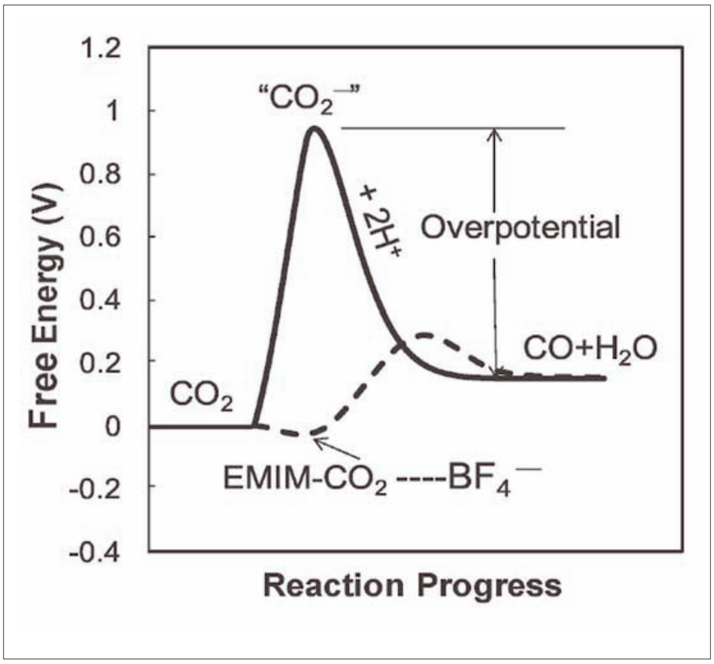
“Another key advantage of our technology is that it is easy to scale-up, making modular units that can be interconnected to achieve the desired output, while enabling low-capex production of carbon-neutral chemicals and fuels,” says Jerry Kaczur, senior engineer at Dioxide Materials.

Dioxide Materials’ electrolyzers can also enable industries to reduce their CO2 emissions, to comply with carbon regulations or to establish their “green” credibility, while addressing big environmental concerns such as emissions from fossil fuels and associated climate change costs, as evident in the air quality issues found in India, China, and throughout the world.

Electrolyzers can also help lower the cost of renewable energy. There is a critical need to harvest and leverage the volume energy produced by intermittent renewable energy sources, such as wind and solar, and store that excess renewable energy, but unfortunately the cost is high.

If renewable energy sources produce more energy than can be used by the grid, the grid operator needs to limit (i.e. curtail) the amount of renewable energy that is accepted by the grid or it will become unstable. Some renewable energy suppliers need to shut down their solar or wind farms, or even worse, pay someone to take the energy when there is excess renewable energy available. That raises the cost of renewable energy.

While batteries may provide short-duration energy storage at reasonable costs, they do not provide long term storage capacities. One alternative is power-to-gas (or liquid) technologies, such as water electrolyzers that convert electricity to chemical energy in hydrogen (H2), which can then be stored in pressurized tanks or underground caverns. While these systems do allow for longer-term storage at a lower cost, roundtrip efficiencies are reduced.



Dioxide Materials’ patented catalysts make the process economic by reducing the overpotential of CO2 reduction. The schematic shows how the free energy of the system changes during the reaction $CO_2 + 2H^+ + 2e^- \neq CO + H_2O$ in water or acetonitrile (solid line) or EMIM-BF4 (dashed line). EMIM-CO_2 is a complex between the solvent and the CO_2^-

The DM team has been highly focused on developing an alkaline water electrolyzer for an improved power-to-gas system. The electrochemical cells are composed of an anode, a cathode, and a membrane that allows charged ions (anions in this case) to pass through, while being electrically insulating. High-conductivity anion exchange membranes are rare and often do not have the chemical or mechanical stability to withstand H2 production at elevated pressures.

We have developed an anion exchange membrane that has sufficient conductivity, chemical stability and mechanical strength, is low-cost, and manufacturable in a scaleable process. Moreover, by operating at alkaline instead of acidic conditions, the electrochemical cells do not need to use expensive precious metal catalysts, which most systems require to prevent corrosion.

Dioxide Materials estimates that operating under alkaline conditions could lead to a significantly lower electrolyzer stack cost due to higher current densities and lower material costs (i.e. non-precious metals such as knickel and iron vs. platinum, etc.). The system will be compatible with intermittent energy sources because it can operate at lower temperatures than competing technologies, thus allowing startup times on the order of seconds.

“When scaled, Dioxide Materials’ electrolyzers will be able to use hundreds of MW of electricity at one time and because they can be turned on/off depending on when renewable energy sources produce more energy than the grid can use, they can help offset some of the renewable energy that would otherwise be curtailed,” stated Rich Masel.

The technology has been successfully tested by a number of Fortune 500 companies, fermenters and universities. Research grade AEM electrolyzers, membranes, and catalyst materials are now sold by the company.

More information

Dioxide Materials, headquartered in Boca Raton, Florida in the Research Park of Florida Atlantic University, is highly focused on empowering the world to enable a low carbon future. Rich Masel, CEO, is one of the most highly cited chemical engineers in the country with over 250 publications, 400 talks, 25 issued and allowed patents.

dioxidematerials.com

Chemical-looping: the answer to the cost and energy penalties of CCS?

With the first generation of CO2 capture now being well established, and with the pressure to decarbonize the economy building up, the time may have come to look for the 2nd generation of CO2 capture.

By Professor Anders Lyngfelt, Chalmers University of Technology, Sweden

The key obstacle for CCS is well known; the large cost and energy penalty of CO2 capture. For every tonne of fuel burned, infinitely small CO2 molecules must be removed from 10,000 cubic meter, or 350,000 cubic feet, of flue gas. This is not even in theory possible without energy and equipment for capture.

However, there is a way around this problem. In normal combustion you mix air and fuel, and therefore your combustion products inevitably become diluted in nitrogen, the major constituent of air. But, if you could transfer the oxygen needed for the combustion from the air to the fuel without mixing air and fuel, the problem would be solved. And this is exactly what Chemical-Looping Combustion (CLC) does.

CLC is a novel principle of combustion, where the combustion air is kept separate from the fuel. Instead, the oxygen is transferred from air to fuel by means of the oxygen carrier, i.e. metal oxide particles which circulate between two fluidized beds, the air reactor and the fuel reactor, Fig. 1. The gas leaving the fuel reactor is ideally pure CO2 and H2O, the latter easily removed by condensation.

A key question is of course if this process really works in practice, but more than 11,000 h of operation in 45 pilots with more than 100 different oxygen carrier materials gives a clear answer.[1] In particular the results for solid fuels, including more than 3000 h of operation in more than 20 pilots, are important because of the potentially very low costs for CO2 capture.

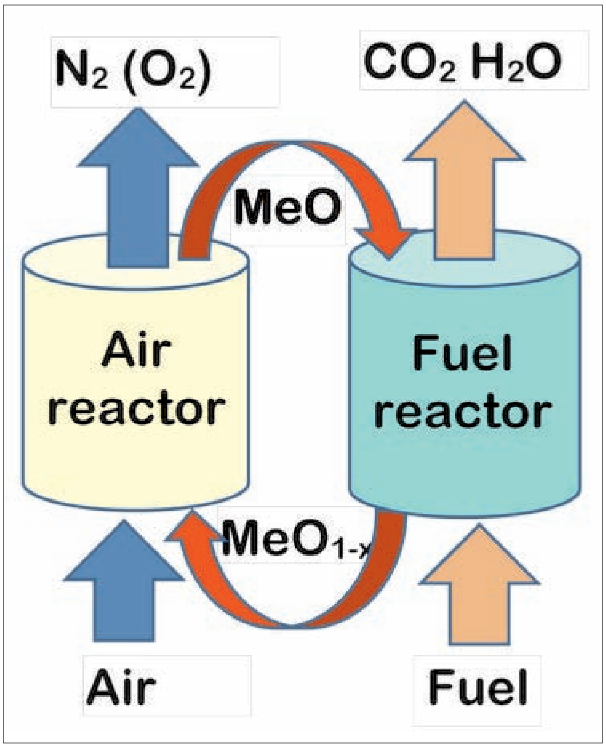


Figure 1. CLC principle. MeO is the metal oxide circulated

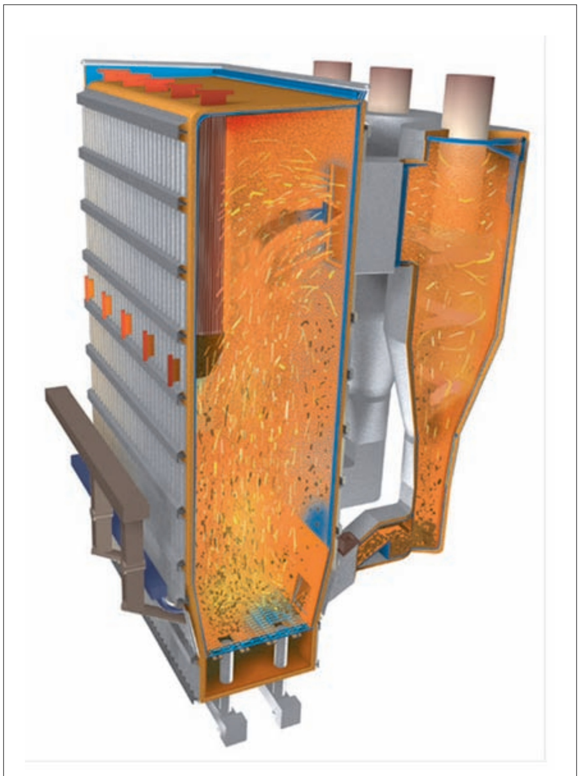


Figure 2. Circulating fluidized-bed boiler

The reactor system used involves two interconnected fluidised beds, a fuel reactor where the fuel reacts with the oxygen-carrier to form CO2 and steam, and an air reactor where the oxygen carrier is regenerated. The oxygen carrier is used as bed material. After condensation of the steam a flow of essentially pure CO2 is obtained – without any active gas separation.

The CLC process has important similarities to combustion of solid fuels in Circulating Fluidized Bed (CFB) boilers, cf. Figs. 2 and 3.

Thus, CFB combustion is an integral part of the state of art for CLC. A techno-economical comparison between a 1000 MWth CFB boiler and a 1000 MWth CLC boiler highlights important differences and similarities.

The two boilers are outlined in Fig. 4. The most important differences and similarities are:

i) The horizontal cross-section area is similar, because of similar gas flows and gas velocities.

ii) In the case of CLC the combustion chamber is divided in three parts, with one fuel reactor in the middle surrounded by two air reactors.

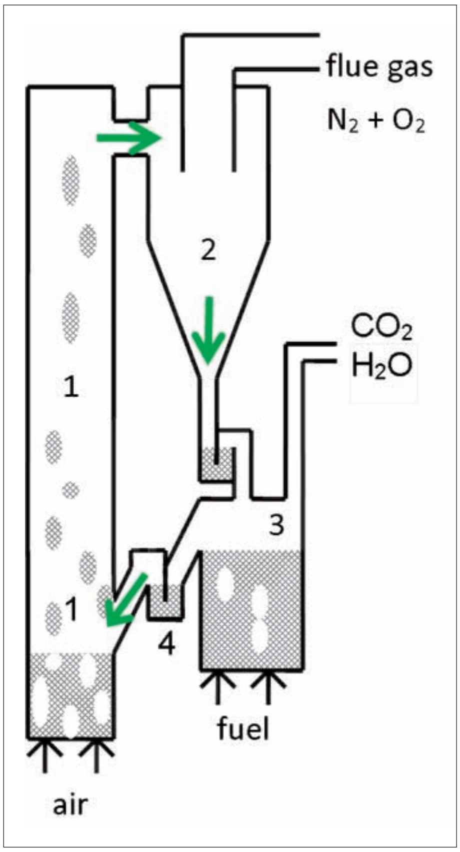


Figure 3. CLC reactor system for gas, 1) air reactor, 2) cyclone, 3) fuel reactor 4) loop seals

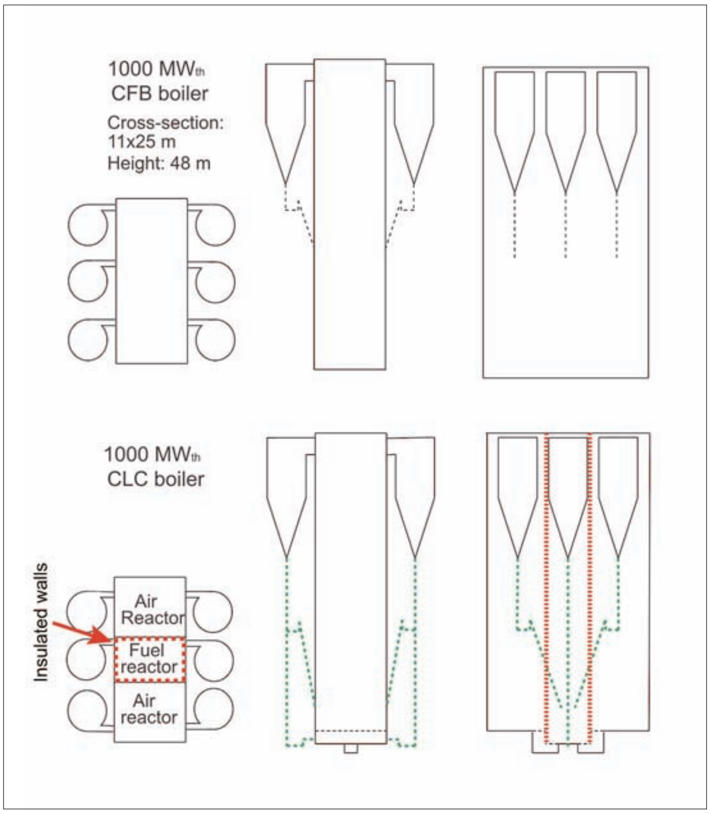


Figure 4. Top: layout of 1000 MWth FBC boiler, Bottom: Layout of 1000 MWth CLC boiler

iii) Because no heat is generated in the fuel reactor, it is adiabatic, i.e. not cooled. iv) There are ducts for transferring material from air reactor cyclones, to fuel reactor, as well as a fluidized connection below the reactors for returning the material.

The important cost of a boiler is related to the large heat-transfer surfaces needed to take the combustion heat to the steam generated. Because CLC operates at higher temperatures, this area is expected to decrease. However, the adiabatic fuel reactor will give added costs for insulated walls that are not used for steam generation.

Based on the cost of insulated boiler wall, 1500 €/m2, and the total wall needed, 2500 m2, the added investment cost of the fuel reactor should be around 4 M€. If this corresponds to a yearly cost of 0.4 M€, and 2 million ton CO2 is captured yearly the corresponding CO2 capture cost is only 0.2 €/ton.[2]

The major added costs of CLC are not associated with the boiler. The largest cost is CO2 compression, around 10 €/ton, which is inevitable and common to all CO2 capture technologies. The second largest cost, 4-9 €/ton, is air separation for production of oxygen. This assumes a gas conversion of 85-95% meaning that the need for oxygen is in the range 5-15% of that of oxyfuel CO2 capture. Other added costs are related to oxygen carrier, steam fluidization of fuel reactor and fuel grinding. The total cost of CO2 capture for CLC with coal is estimated to be 20 €/tonne CO2 and within the range of 16-26 €/tonne.[2]

Operation with coal in a 100 kW pilot clearly demonstrates that the process works well, although a full conversion of the gas is not attained leading to the need of adding oxygen to the exhaust stream.

Pilot experiences indicate that gas conversion typically ranges from 75-95% depending on fuel and operating conditions. This is when using low-cost oxygen-carrier materials such as natural ores.

Further, pilot operation shows that essentially complete CO2 capture, >99, can be reached. However, the pilot operation shows a loss of unburned fuel char, corresponding to 10% of total carbon. Significant improvement of this number is expected in the full scale, where a 10 times higher riser and an efficient cyclone will add important residence time for char conversion.

In addition to a radical reduction of CO2 capture cost, CLC also has potential to eliminate SO2 and NOx emissions, as these are concentrated in the small CO2 stream and may addressed there at reduced cost. A critical feature is also the potential of 100% CO2 capture – in a world now starting to aim for carbon neutrality, is 90% CO2 capture enough?

So why is not everyone building CLC boilers? Today, no-one is prepared to take the cost and risk of scaling up this technology, when there is known and proven technology available, albeit at high cost and energy penalty. But this should change when the CO2 capture market takes off.

References

1. Lyngfelt, A.; Brink, A.; Langørgen, Ø.; Mattisson, T.; Rydén, M.; Linderholm, C., 11,000 h of Chemical-Looping Combustion Operation – Where Are We and Where Do We Want to Go? International Journal of Greenhouse Gas Control 2019, 88, 38-56.

2. Lyngfelt, A.; Leckner, B., A 1000 MWth Boiler for Chemical-Looping Combustion of Solid Fuels – Discussion of Design and Costs. Applied Energy 2015, 157, 475-487.

More information

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Siemens and Evonik CO2 to chemicals Rheticus research project Phase 2

The project aims to produce high-value speciality chemicals from CO2 and water using electricity from renewable sources and bacteria. www.siemens.com / www.evonik.com

Evonik and Siemens have launched a joint research project Rheticus II which aims to develop an efficient and powerful test plant that will use carbon dioxide (CO2) and water as well as electricity from renewable sources and bacteria to produce specialty chemicals.

In the Rheticus I project, the two companies worked for two years to develop the technically feasible basis for artificial photosynthesis using a bioreactor and electrolyzers. Evonik and Siemens are now combining these two, previously separate, plants in a test facility at Evonik's site in Marl (Germany). Rheticus II will run until 2021 and will receive funding of around €3.5 million from Germany's Federal Ministry of Education and Research (BMBF).

“The innovative technology used for Rheticus has the potential to contribute to the success of Germany's energy transition,” says Thomas Haas, who is responsible for the Rheticus project at Evonik. “In the future, this platform could be installed anywhere CO2 is available—for example, at power plants or biogas plants. We use available CO2 as the raw material for the production of high-value chemicals using artificial photosynthesis.”

Siemens is contributing the world's first CO2 electrolyzer to the Rheticus project. “We are developing a flexible system that can provide answers to various questions raised by the energy transition,” says Karl-Josef Kuhn, who is in charge of Power2X research at Siemens. “We are making it possible to store renewable energy by converting it into useful substances such as specialty chemicals or fuel. We are also contributing to the stability of the grid because production is so flexible that we can respond to fluctuations in power supply.”

The test facility is scheduled to start operating in early 2020. It comprises electrolyzers and a bioreactor. In a first step, carbon dioxide and water are converted into carbon monoxide (CO) and hydrogen in electrolyzers with the aid of electricity. Special microorganisms then convert the CO in the gases synthesized in this way into chemicals. Siemens and Evonik are each contributing their core competencies—electrolysis and biotechnology—to this artificial photosynthesis process.

The world's first fully automated CO2 electrolyzer from Siemens generates carbon monoxide. Together with hydrogen, it delivers the main nutrients for the bacteria in the bioreactor. (Image: Siemens)

Artificial photosynthesis means combining chemical and biological steps so that energy can be used to produce viable chemicals from CO2 and water. Plants use natural photosynthesis in a similar way: chlorophyll, enzymes and sunlight are used to synthesize glucose—a vital, energy-rich nutrient. An other advantage of Rheticus is, that the technology platform also contributes to the reduction of carbon dioxide levels in the atmosphere, as it uses CO2 as a raw material. Three tons of carbon dioxide would be needed to produce one tonne of butanol, for example.

The synthesis module came on stream at Evonik in spring 2019. At its heart is an 8-meter high stainless steel bioreactor with capacity of 2,000 liters. Microorganisms work continuously in the reactor. Their main nutrients are hydrogen and carbon monoxide. Siemens has developed a fully automated CO2 electrolyzer which was integrated into a container in summer 2019. The world's first CO2 electrolyzer comprises 10 cells and the total surface area of the electrodes is 3,000 cm2. The electrolyzer and the bioreactor will be combined in the coming months. In addition, a unit to process the liquid from the bioreactor is being built to obtain pure chemicals.

In the test facility, bacteria will produce butanol and hexanol for research purposes. These substances are used as starting products, for example, for specialty plastics and food supplements. However other specialty chemicals are conceivable, depending on the bacterial strain and conditions.

Following successful completion of Rheticus II, Evonik and Siemens will have a unique technology platform allowing production of useful, energy-rich substances such as specialty chemicals and artificial fuels from CO2 in a flexible, modular process.

Sydney researchers copy leaves to convert CO2 to hydrocarbons

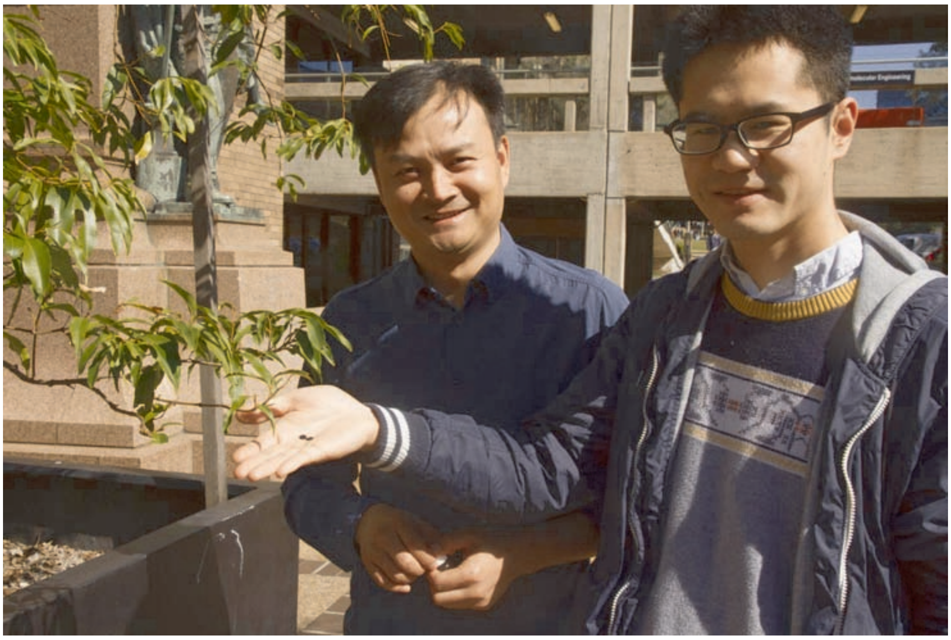
University of Sydney researchers are drawing inspiration from leaves to reduce carbon emissions, using nanotechnology to develop a method for 'carbon photosynthesis' that they hope will one day be adopted on an industrial-scale.

Professor Jun Huang from the University of Sydney's School of Chemical and Biomolecular Engineering is developing a carbon capture method that aims to go one step beyond storage, instead converting and recycling carbon dioxide (CO2) into raw materials that can be used to create fuels and chemicals.

"Drawing inspiration from leaves and plants, we have developed an artificial photosynthesis method," said Professor Huang.

"To simulate photosynthesis, we have built microplates of carbon layered with carbon quantum dots with tiny pores that absorb CO2 and water.

"Once carbon dioxide and water are absorbed, a chemical process occurs that combines both compounds and turns them into hydrocarbon, an organic compound that can be used for fuels, pharmaceuticals, agrichemicals, clothing, and construction.



Professor Huang has developed small plates that capture and convert CO2 (pictured in his hand). Photo: Luisa Low/University of Sydney

"Following our most recent findings, the next phase of our research will focus on large-scale catalyst synthesis and the design of a reactor for large scale conversion," he said.

While the research has been conducted on a nanoscale, Professor Huang hopes the technology will be used by power stations to capture emissions from burning fossil fuels.

"Our CO2 absorbent plates may be small, but our goal is to now create large panels, similar to solar panels, that would be used by industry to absorb and convert large volumes of CO2 ," said Professor Huang.

CO2 emissions from the burning of fossil fuels and transport are the main cause of global warming, contributing up to 65 percent of the total global greenhouse gas emissions.

While plants 'breathe' in CO2 , a process called photosynthesis, deforestation and development has decreased their overall capacity to restore oxygen levels.

As nations attempt to curb emissions and divest from fossil fuels, Dr Huang feels there should also be an increased focus on carbon capture and re-use to minimise the harmful impact of increased atmospheric CO2.

"The current global commitment to cut carbon emissions by 30 percent by 2030 is an enormous challenge, and one that will be difficult to achieve given that energy needs are accelerating," said Professor Huang.

Carbon capture technologies have been around for over 10 years. However, they rely on carbon being stored in deep underground chambers.

"Carbon conversion could be a financially viable alternative as it would allow for the generation of industrial quantities of materials, such as methanol, which is a useful material for production of fuels and other chemicals," he concluded.

Professor Jun Huang's research is supported by the Australian Research Council (DP180104010, the Sydney Research Accelerator Prizes (SOAR) and the University of Sydney Nano Institute Grand Challenge program.

The paper was authored by Dr Haitao Li, Dr Yadan Deng, Dr Youdi Liu, Dr Xin Zeng, Professor Dianne Wiley and Professor Jun Huang.

More information

sydney.edu.au/nano

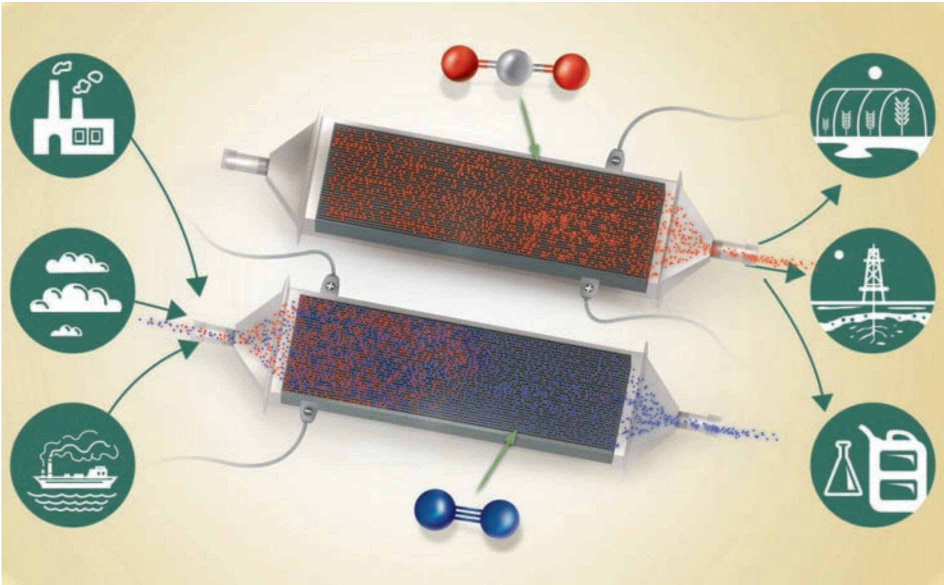
MIT engineers develop a new way to remove CO2 at any concentration

The process, based on passing air through a stack of charged electrochemical plates, could work on the gas at any concentrations, from power plant emissions to open air.

Most methods of removing carbon dioxide from a stream of gas require higher concentrations, such as those found in the flue emissions from fossil fuel-based power plants. A few variations have been developed that can work with the low concentrations found in air, but the new method is significantly less energy-intensive and expensive, the researchers say.

The technique, based on passing air through a stack of charged electrochemical plates, is described in a new paper in the journal Energy and Environmental Science, by MIT postdoc Sahag Voskian, who developed the work during his PhD, and T. Alan Hatton, the Ralph Landau Professor of Chemical Engineering.

The device is essentially a large, specialized battery that absorbs carbon dioxide from the air (or other gas stream) passing over its electrodes as it is being charged up, and then releases the gas as it is being discharged. In operation, the device would simply alternate between charging and discharging, with fresh air or feed gas being blown through the system during the charging cycle, and then the pure, concentrated carbon dioxide being blown out during the discharging.



A flow of air or flue gas (blue) containing carbon dioxide (red) enters the system from the left. As it passes between the thin battery electrode plates, carbon dioxide attaches to the charged plates while the cleaned airstream passes on through and exits at right. Image ©MIT

As the battery charges, an electrochemical reaction takes place at the surface of each of a stack of electrodes. These are coated with a compound called polyanthraquinone, which is composited with carbon nanotubes. The electrodes have a natural affinity for carbon dioxide and readily react with its molecules in the airstream or feed gas, even when it is present at very low concentrations. The reverse reaction takes place when the battery is discharged — during which the device can provide part of the power needed for the whole system — and in the process ejects a stream of pure carbon dioxide. The whole system operates at room temperature and normal air pressure.

"The greatest advantage of this technology over most other carbon capture or carbon absorbing technologies is the binary nature of the adsorbent's affinity to carbon dioxide," explains Voskian. In other words, the electrode material, by its nature, "has either a high affinity or no affinity whatsoever," depending on the battery's state of charging or discharging. Other reactions used for carbon capture require intermediate chemical processing steps or the input of significant energy such as heat, or pressure differences.

"This binary affinity allows capture of carbon dioxide from any concentration, including 400 parts per million, and allows its release into any carrier stream, including 100 percent CO2," Voskian says. That is, as any gas flows through the stack of these flat electrochemical cells, during the release step the captured CO2 will be carried along with it. For example, if the desired end-product is pure carbon dioxide to be used in the carbonation of beverages, then a stream of the pure gas can be blown through the plates. The captured gas is then released from the plates and joins the stream.

In some soft-drink bottling plants, fossil fuel is burned to generate the carbon dioxide needed to give the drinks their fizz. Similarly, some farmers burn natural gas to produce carbon dioxide to feed their plants in greenhouses. The new system could eliminate that need for fossil fuels in these applications, and in the process actually be taking CO2 right out of the air, Voskian says. Alternatively, the pure carbon dioxide stream could be compressed and injected underground for long-term disposal, or even made into fuel through a series of chemical and electrochemical processes.

The process this system uses for capturing and releasing carbon dioxide "is revolutionary" he says. "All of this is at ambient conditions — there's no need for thermal, pressure, or chemical input. It's just these very thin sheets, with both surfaces active, that can be stacked in a box and connected to a source of electricity."

More information

chemistry.mit.edu

Tanks of algae 'future' of carbon capture

To advance this science, biotech startup Helios-NRG is testing technologies for algae cultivation and carbon capture in a greenhouse at University at Buffalo.

On a recent summer morning, three tanks of microalgae in the building shined a bright, jewel green as sunlight beamed through the water. In just a few days, however, the contents of the containers had darkened as the number of microorganisms inside exploded.

And that's what Helios-NRG wants to see: Its algal research, largely funded by the U.S. Department of Energy (DOE), strives to grow dense populations of algae quickly.

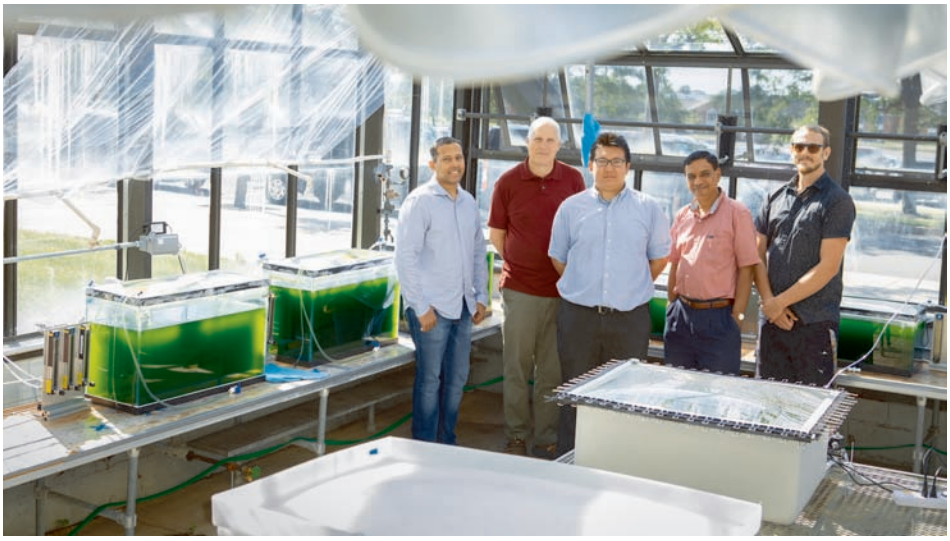
The objective is to produce 35 grams of algae per square meter of area per day and to capture more than 70 percent of carbon dioxide emissions from a concentrated source. The company has made significant progress toward those goals, using special photobioreactors and inventing new processes to achieve high algal growth and CO2 capture rates simultaneously.

Once the technology has been refined, Helios-NRG will have the chance to pilot it at the National Carbon Capture Center, a DOE-sponsored research facility in Alabama.

"Fossil fuel power plants are dominant sources of carbon dioxide production," says Ravi Prasad, president of Helios-NRG. "This is a global problem with severe effects, and more and more people are realizing that we need to do something about it. By developing a sustainable biotechnology approach for carbon capture, our company is working to address the challenge of climate change."

"We are committed to the environment," says Benjamin Lam, Helios-NRG senior research engineer, who received his master's degree in chemical and biological engineering from UB. "We produce algae strains with desirable traits through breeding. We don't use genetic modification to add genes that you would not normally find in algae because it's so difficult to predict what could happen if genetically modified algae gets into the environment."

Helios-NRG was a client of the UB Technology Incubator for seven years, receiving mentoring and support from UB's Business and Entrepreneur Partnerships office.



The Helios-NRG team with tanks that act as photobioreactors holding microalgae grown by Helios-NRG in the Dorsheimer Greenhouse on the North Campus at University at Buffalo. Image: Douglas Levere / University at Buffalo

The startup graduated from the incubator in July 2019, but continues to be located at UB, with labs and offices on the South Campus. In addition, Helios-NRG has been leasing space in the Dorsheimer Laboratory/Greenhouse on the North Campus since April, and James Berry, professor of biological sciences, College of Arts and Sciences, has been a valuable resource in answering questions about the facility as the startup has set up operations. (Berry has an office and laboratory in the greenhouse complex.)

Helios-NRG also has strong relationships with other members of the UB community. The company has hired alumni, provided internships to several chemical and biological engineering students, and funded collaborative research.

In one project, Haiqing Lin, associate professor of chemical and biological engineering, School of Engineering and Applied Sciences, is helping Helios-NRG develop efficient, long-lasting membranes for inexpensively separating algae and water.

Once harvested, microalgae can be used in biofuel, feed for animals and nutraceuticals for humans, says scientist Derek Koscinski, who leads Helios-NRG's dewatering efforts.

"Our goal is to not just carbon capture, but to also take our algae and turn it into something that people want," says Fred Harrington, Helios-NRG chief scientist. "By producing commercial products, we will create revenue, which will bring down the cost of carbon capture. This is important because large-scale implementation of carbon capture technology will require it to be economically feasible."

Converting carbon-consuming algae into commercial products also has environmental benefits, Prasad says. He notes that many carbon capture technologies are designed to simply separate carbon dioxide from flue gas, creating a new problem to solve: what to do with all that CO2. Burying captured carbon dioxide underground is one solution, but sequestration is expensive and carries unknown risks, he says.

More information

www.buffalo.edu

Capture and utilisation news

Sunfire partners with Total for CO2 to fuel technology

www.sunfire.de

Sunfire will provide a megawatt-scale high temperature electrolyser for use in industrial environments as part of the E-CO2MET research and development project.

The company will also be responsible for the integration at the site as well as the operation and maintenance of the electrolyser, which will be the first step for the industrial-scale production of synthetic methanol from renewables and industrial concentrated CO2 from the Total Raffinerie Mitteldeutschland.. Total Carbon Neutrality Ventures, the venture capital arm of Total SA, has been a minority equity shareholder in Sunfire since 2014.

The production of green methanol and hydrogen from renewable energies offers great opportunities for the global energy and transport transition. "Total is delighted to develop efficient technologies to re-use CO2 to chemicals, materials and fuels. Carbon capture, utilisation and storage is going to play an essential role in achieving carbon neutrality without curbing economic and social growth," said Marie-Noelle Semeria, Senior Vice President, Group Chief Technology Officer at Total.

The advantage of the high-temperature electrolyser is its ability to directly use economically produced steam or waste heat from industrial and synthesis processes. With this method, the use of valuable green electricity can be reduced. It is the most efficient process on the market for converting electricity into hydrogen. The high efficiency of over 80% also significantly reduces the overall cost of the integrated process.

The cooperation heralds a new era for the industrial use of renewable hydrogen and methanol in refineries. "The use of our high-temperature electrolyser at one of the largest oil companies in the world confirms our years of hard work driving decarbonisation in large-scale industries," says Nils Aldag, Managing Director of Sunfire.

"This technology can become the core building block for energy sectors that cannot source electricity directly from renewables. With the transformation into renewable gases and fuels and the use of existing infrastructures, we can make the transport sector and the chemical industry climate-neutral."

During the collaboration with Total, Sunfire's electrolyser will be involved in various research and development projects. Various operative studies will be carried out at its location in Leuna to evaluate the performance of the system, as well as in relation to volatile renewable energy supply.

The evaluation of the results will be undertaken by Total according to quality and qualification guidelines for new technologies.

Transport and storage news

London Protocol to allow transboundary CO2 export

www.imo.org

www.zeroemissionsplatform.eu

Transboundary export of carbon dioxide for the purpose of carbon capture and storage can now be provisionally allowed under certain circumstances, Parties to the London Protocol have agreed.

The London Protocol provides the basis in international environmental law for Governments to allow carbon capture and storage under the seabed - which is recognized as one tool in climate change mitigation, whilst ensuring protection of the marine environment.

London Protocol Parties, meeting in London for their annual meeting with Parties to the London Convention (7-11 October), adopted a resolution to allow provisional application of an amendment to article 6 of the Protocol to allow sub-seabed geological formations for sequestration projects to be shared across national boundaries.

The London Protocol has, since 2006 provided a basis in international environmental law to allow CO2 storage beneath the seabed when it is safe to do so, and to regulate the injection of CO2 waste streams into sub-seabed geological formations for permanent isolation.

The 2009 amendment adopted by Parties to the London Protocol allows for sub-seabed geological formations for sequestration projects to be shared across national boundaries – effectively allowing CO2 streams to be exported for CCS purposes (provided that the protection standards of all other London Protocol requirements have been met). However, the 2009 amendment has yet to enter into force.

The resolution to allow provisional application of the 2009 amendment as an interim solution, pending sufficient acceptance by Contracting Parties, enables countries who wish to do so, to implement the provisions of the amendment in advance of entry into force.

To do this, the Parties concerned will need to deposit a declaration of provisional application and provide notification of any agreements or arrangements with the Secretary-General of the International Maritime Organization (IMO).

"The adoption of the resolution will remove a barrier for countries who wish to make use of carbon capture and storage - but which do not have ready access to offshore storage sites within their national boundaries," said Fredrik Haag, Head, Office for the London Convention and Protocol and Ocean Affairs, IMO.

"An important point to note is that reduction of CO2 emissions at source should be the primary focus, and provisional application of the amendment should not be seen as a substitute for other measures to reduce CO2 emissions"

"Carbon sequestration can be considered as one of a portfolio of options to reduce levels of atmospheric carbon dioxide and can be an important interim solution in the fight against climate change."

The Zero Emissions Platform developed a position paper in support of this amendment.

Drilling complete at Otway low cost CO2 monitoring project

A 59-day drilling program has been successfully completed at CO2CRC's Otway National CCS Research Centre, located at Nirranda South in south-west Victoria.

On 18 September the last of four new 1600-metre-deep monitoring wells was drilled and cased with each well equipped with the latest technologies in fibre optics sensing and subsurface gauges. Pressure communication between wells has been confirmed and the seismic imaging system is functioning on all wells as designed.

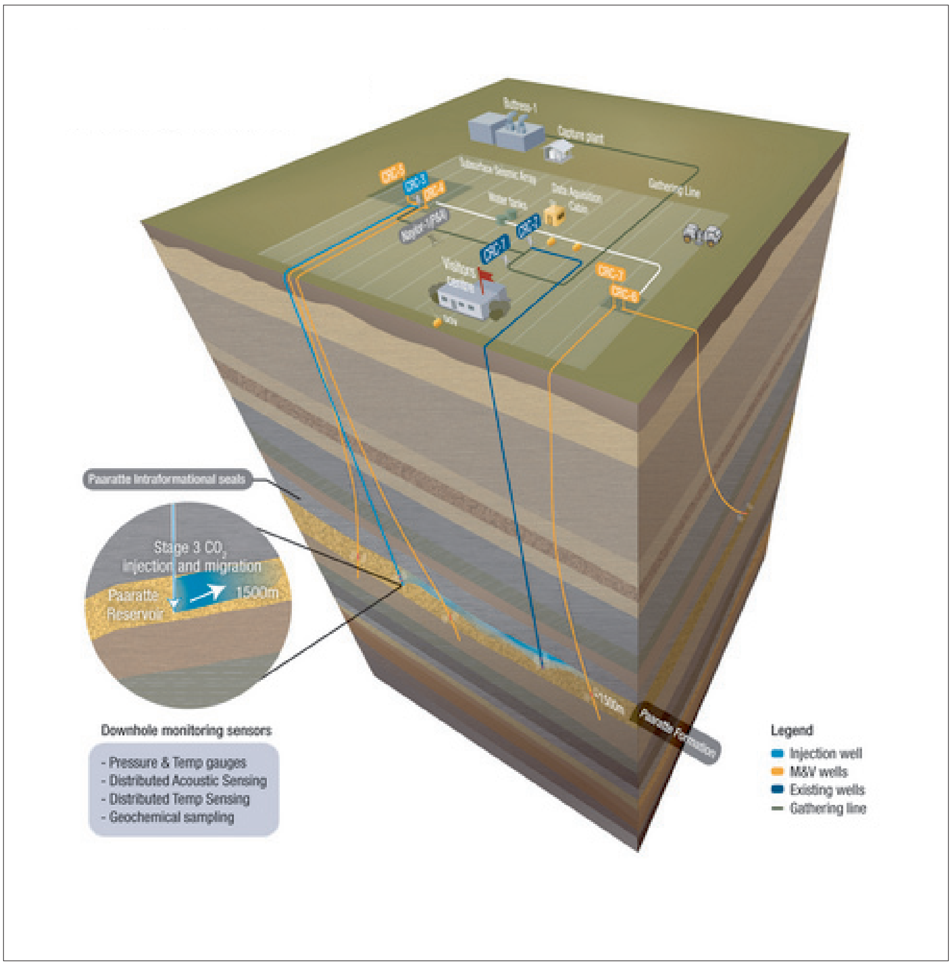
The wells are part of CO2CRC's biggest project to date, known as Otway Stage 3. The project is proving up technologies which provide data on demand, as well as reducing the cost and impact of long-term CO2 storage monitoring for carbon capture and storage (CCS) projects.

The next six months will see teams from CSIRO and Curtin University calibrating the pressure tomography monitoring system and performing baseline seismic acquisitions using fibre optics cables and permanently deployed surface orbital vibrators.

"These new technologies provide data quicker, are much less invasive and cost significantly less than the seismic surveys currently used. Initial estimates show cost savings of up to 75 percent," said David Byers, CEO of CO2CRC.

"Our hope is that the research will lead to more CCS projects around the world, allowing CCS to play a vital role in reducing emissions across all major industry sectors. As the International Energy Agency points out, without CCS as part of the solution, meeting global climate goals will be practically impossible," he said.

With the support of its drilling management team, InGauge Energy, the drilling company, Easternwell Drilling and with multiple specialist service providers, the CO2CRC team drilled almost 7km of directional wells, ran 11km of steel casing, 13km of fibre optic cable and pumped 458 tonnes of cement.



Layout of CO2 injection and monitoring wells for CO2CRC'sOtway Stage 3 Project

This represents the largest single project undertaken by CO2CRC in support of testing new and innovative techniques that will support current and future CCS projects both within Australia and globally.

The $45 million project is jointly funded by the Commonwealth Government's Education Investment Fund (EIF), COAL21 through ANLEC R&D, BHP and the Victorian State Government.

Technical and scientific work programs are being carried out in partnership with Curtin University and CSIRO and are expected to be complete by June 2022.

More information

www.co2crc.com.au

Shell, OGCI, IGOP, Pale Blue Dot, Equinor, discuss carbon capture at Offshore Europe

EY and DNV GL on the future of energy

Total's CEO Patrick Pouyanné on carbon

Image courtesy of SPE Offshore Europe