THE CASE FOR CARBON CAPTURE

Leveraging carbon capture, utilisation and sequestration for emission reduction

IPI SINGAPORE
Innovation Partner for Impact

White Paper

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Harnessing carbon capture, utilisation and sequestration for emission reduction

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EXECUTIVE SUMMARY

Fossil fuels have powered us through the ages since the first Industrial Revolution in the 18th century. From generating electricity to transforming our manufacturing processes, they have spurred industrialisation, developed economies and created new ways to travel. Fossil fuels like crude oil, natural gas and coal are commodities that have shaped the world into the one we know today.

The more we progress, however, the more damage to the environment we have wrought. Burning fossil fuels is the main contributor to the emission of greenhouse gases (GHG), especially carbon dioxide (CO_2), which has resulted in rapidly increasing global temperatures and disruptive climate shifts. Every year, our usage of fossil fuels releases over 30 billion tonnes of CO_2 into the atmosphere.

With fossil fuels still the mainstay of our energy and manufacturing requirements, governments and businesses seek innovation and alternative methods to mitigate the environmental and climate impact of fossil fuels. Many are focused on emissions reduction, adopting promising solutions such as carbon capture, utilisation and sequestration (CCUS), which comprise technologies that trap CO_2 emissions to repurpose them in other applications or keep them permanently in underground storage facilities.

As the United Nations' (UN) goal of achieving net zero by 2050 looms, countries are under pressure to reduce their emissions. The global CCUS market is forecast to hit US$2.84 billion in 2027—a growth trajectory that offers opportunities for innovators and investors alike. By analysing market trends and the patent landscape, this white paper presents a deep dive into CCUS technologies and the latest innovations in the space. We round off our analysis with three tech offers that have the potential to make CCUS more efficient and scalable.

KEY HIGHLIGHTS

01
Market drivers for CCUS technologies

Our climate is changing at an alarming rate. With carbon emissions being the crux of the climate change crisis, the UN strives to achieve net-zero emissions by 2050. This goal has prompted many countries to decarbonise and seek technologies that promote sustainability and address climate change issues like CCUS. The global CCUS market is set for tremendous growth and offers opportunities for investors and innovators.

02
Need for regulatory standardisation and enforcement

The primary push for businesses to be more sustainable lies with the government. Through legislation and investments, governments are showing their commitment to sustainable efforts. However, with different countries implementing their own rules, it can be challenging for businesses to ensure compliance, particularly corporations with global operations.

03
Accurate carbon tracking is essential

Carbon tracking is the first step in understanding emissions and arguably the most crucial to achieve. Businesses should know their emission sources and scopes first to be able to address them effectively. Advancements in carbon tracking are equipping businesses with data-driven findings to manage their emissions.

04
Find niche areas to address

Instead of trying to address the whole value chain, CCUS innovators should find unique opportunities or particular industries to cater to as no one-size-fits-all solution exists. New solutions should be simple and ideally compatible with existing systems—the simpler the solution design, the likelier businesses will adopt it.

05
Work towards simple longer-term solutions

CCUS technologies are the best available solutions to reduce emissions in pursuit of net zero, but simple longer-term solutions are necessary, such as fully transitioning to more sustainable power sources like renewable energy. Because major changes are risky and costly, building the foundation via CCUS for such changes to take place should begin now.

DEFINING EMISSIONS

Regarded as one of the greatest challenges facing humankind, anthropogenic climate change is predominantly attributed to the burning of fossil fuels, which emits almost 90 percent of Earth's most significant GHG—carbon dioxide (CO_2).[1]

More than 30 billion tonnes of CO_2 released into the atmosphere annually are because of our activities.[2] Compared to pre-industrial times, atmospheric CO_2 concentrations have soared by more than 40 percent. In Singapore alone, CO_2 emissions have surged almost 65 percent from 1990 to 2019,[3] as a result of rapid industrialisation and urbanisation.

Injecting more CO_2 into the atmosphere supercharges the natural greenhouse effect, causing global temperatures to rise. Alarmingly, mere changes of one or two degrees in the average temperature of the planet can cause potentially dangerous shifts in climate and weather. From hotter temperatures and more intense storms to increased drought and a warming, rising ocean, the visible effects of climate change are presenting a multitude of challenges to our society and our environment, accelerating the loss of species and posing more health risks than ever.

CONFRONTING THE CLIMATE CRISIS BRINGS WITH IT A UNIQUE SET OF CHALLENGES

The global imperative to curb climate change

Concerted global action is the only answer to escalating global temperatures. With carbon emissions being the crux of the climate change crisis, the UN has laid out a roadmap towards achieving net-zero emissions by 2050, an initiative that more than 70 countries are participating in—covering about 76 percent of global emissions.[4] Singapore has pledged to reduce emissions by 36 percent from 2005 levels by 2030.

The UN Climate Change Conference 2022, or more popularly known as COP27, took place in November to continue addressing global climate issues through three actionable areas: minimising emissions, developing resilience against climate change impact and providing financial support to developing countries. While the summit concluded with the creation of a fund dedicated to helping developing countries manage loss and damage from climate change, it was not able to push world leaders to stop using fossil fuels completely.[5] Nonetheless, this summit and its previous iterations have highlighted the importance of government policy in bringing about meaningful reductions in emissions.

Many governments have implemented carbon pricing mechanisms to monitor and regulate carbon emissions as well as place the onus of mitigating emissions on emitters. Despite progressing at a much slower pace than Western countries, Asia's uptake of carbon pricing mechanisms is gaining steam. For example, China, South Korea and New Zealand have launched emission trading schemes, while Japan, Singapore and Indonesia have begun to impose carbon taxes.

In Southeast Asia, Singapore is leading in the decarbonisation of the power sector, followed by Thailand, Malaysia and Indonesia.[6] Apart from carbon taxes, the city-state has also introduced attractive incentives for solar and is developing green financing to support a more sustainable economy and Asia's transition to a low-carbon economy. To facilitate that transition, many businesses will have to rely on carbon offsetting and carbon capture, utilisation and sequestration (CCUS) techniques.

Conquering the carbon challenge

Confronting the climate crisis brings with it a unique set of challenges. For instance, many businesses either lack deep understanding or are unaware of their carbon footprint. This is further complicated by the majority of them releasing Scope 3 emissions, which are indirect and difficult to track with ineffective carbon accounting practices.

Further, there is no one-size-fits-all formula for decarbonisation. Keen businesses have to consider a whole range of factors, such as the suitability, adaptability and compatibility of various technologies like CCUS, which in itself has different methods to capture carbon—direct air capture, process capture and post-combustion capture. The lack of expertise could very well stymie progress in this area.

Unsurprisingly, financial viability is also a major driver of the energy transition. In Singapore, where the S$5 per tonne carbon tax is much lower than in Europe, businesses might perceive paying penalties as more financially worthwhile than implementing exorbitant carbon-capture processes. Without proper motivations, many are likely to choose less expensive but slower and inefficient decarbonisation methods such as carbon offsetting through tree planting.

Nonetheless, the multifaceted challenge of curbing emissions presents many opportunities for businesses to develop innovative technologies that can improve the efficiency and viability of carbon offsetting and CCUS.

[1] Renewable energy – Powering a safer future. United Nations. Retrieved in October 2022 from https://www.un.org/en/climatechange/raising-ambition/renewable-energy
[2] Cause of climate change. (2022). US Environmental Protection Agency (EPA). Retrieved in October 2022 from https://www.epa.gov/climatechange-science/causes-climate-change
[3] Singapore. International Energy Agency (IEA). Retrieved in October 2022 from https://www.iea.org/countries/singapore
[4] Addendum to the Emissions Gap Report 2021. United Nations. Retrieved in October 2022 from https://wedocs.unep.org/bitstream/handle/20.500.11822/37350/AddEGR21.pdf
[5] COP27 climate talks: What succeeded, what failed and what's next. (2022). Nature. Retrieved in November 2022 from https://www.nature.com/articles/d41586-022-03807-0
[6] Which ASEAN countries will be the front-runners to decarbonize their power sectors? (2022). IHS Markit. Retrieved in October 2022 from https://ihsmarkit.com/research-analysis/which-asean-countries-will-be-the-frontrunners-to-decarbonize.html

TRENDS IN THE MARKET

Global climate targets and investment initiatives are injecting much-needed momentum into our battle against climate change. Notwithstanding the economic uncertainty ensuing from the COVID-19 pandemic, there is a rising demand for advanced technologies such as CCUS. However, clear and strategic policymaking remains to be seen.

CCUS technologies see demand surge

The potential of CCUS to mitigate climate change has been recognised for decades, but because deployment has been lagging, it has had only a limited impact on global carbon emissions. Yet, there are clear signs that CCUS is gaining traction, with the market forecast to reach US$9.43 billion by 2027 from US$2.84 billion in 2022, at a compound annual growth rate (CAGR) of 27.1 percent.[7]

Driving this growth are net-zero targets announced by many countries. While the CCUS market is expanding at a quickening pace, it is concentrated mainly within five countries, namely the US, the UK, Canada, Russia and the Netherlands, all of which have shown a disposition to adopt and invest in green technologies via infrastructure investments.

Going forward, Southeast Asia and China are projected to have the largest demand for CCUS in the 2040s.[8] Since 2000, almost 90 percent of Southeast Asia's energy appetite has been satisfied by fossil fuels.[9] CCUS technologies can be a key pillar for supporting clean energy transitions in the region. For China, the world's largest CO_2 emitter, the nation stands to benefit tremendously from large-scale CCUS projects that can help keep its pledge to become carbon neutral by 2060.

The central role of government and policy

Standardised legal and regulatory frameworks are needed to underpin the safe and effective development and implementation of decarbonisation technologies. Currently, there is a lack of strong, consistent carbon-related policies or enforcement, which thwarts the compliance of organisations. In Singapore, the National Environment Agency (NEA) outsources carbon tracking and accreditation to third-party providers, with minimal government oversight.

The biggest investors in CCUS generally originate from industries with massive carbon footprints, such as manufacturing, oil and gas (O&G) and building and infrastructure. While consumers worldwide are increasingly eco-conscious, they remain mostly cost-oriented. In that regard, governments are still the primary driving force in influencing sustainability actions through campaigns or effective climate policies and ambitions.

[7] Global carbon capture, utilization, and storage (CCUS) market (2022–2027) by service, technology, end-use industry, geography, competitive analysis, and the impact of COVID-19 with Ansoff analysis. (2022). Research and Markets. Received in October 2022 from https://www.researchandmarkets.com/reports/5601480/global-carbon-capture-utilization-and-storage#src-pos-4
[8] CCUS planned capacity nearing 1 billion tonnes per annum. (2022). Wood Mackenzie. Retrieved in October 2022 from https://www.woodmac.com/press-releases/ccus-planned-capacity-nearing-1-billion-tonnes-per-annum/
[9] Carbon capture, utilisation and storage: The opportunity in Southeast Asia. (2021). IEA. Retrieved in October 2022 from https://www.iea.org/reports/carbon-capture-utilisation-and-storage-the-opportunity-in-southeast-asia

Staunch commitment by governments can also provide more certainty for investors, who play a valuable role in encouraging businesses to accelerate spending on transitioning the global economy to a lower-carbon model.

COVID-19 hamstrings progress

If there was a silver lining in the COVID-19 pandemic cloud, it was the resulting emissions reduction. Global emissions reportedly plunged almost 5 percent in 2020 as lockdowns and restrictions halted economic and social activities worldwide.[10]

However, the pandemic has severely crippled global supply chains, including those for renewable energy and decarbonisation projects. While CCUS applications had gained considerable momentum before the pandemic hit, many businesses have paused investment plans. As a result, the adoption of cutting-edge CCUS technologies has since struggled to keep up. Even as economies and individual organisations recover from the pandemic, business survival is still expected to take precedence over innovation in the next several years.

THE POTENTIAL OF CCUS TO MITIGATE CLIMATE CHANGE HAS BEEN RECOGNISED FOR DECADES

[10] Greenhouse gas emissions rise to record, erasing drop during pandemic. (2022). International Monetary Fund. Retrieved in October 2022 from https://www.imf.org/en/Blogs/Articles/2022/06/30/greenhouse-emissions-rise-to-record-erasing-drop-during-pandemic

STATE OF THE ART & EMERGING TECHNOLOGIES

CCUS technologies typically involve three main pillars: (1) tracking and offsetting carbon, (2) capturing carbon and (3) utilising and sequestrating carbon.

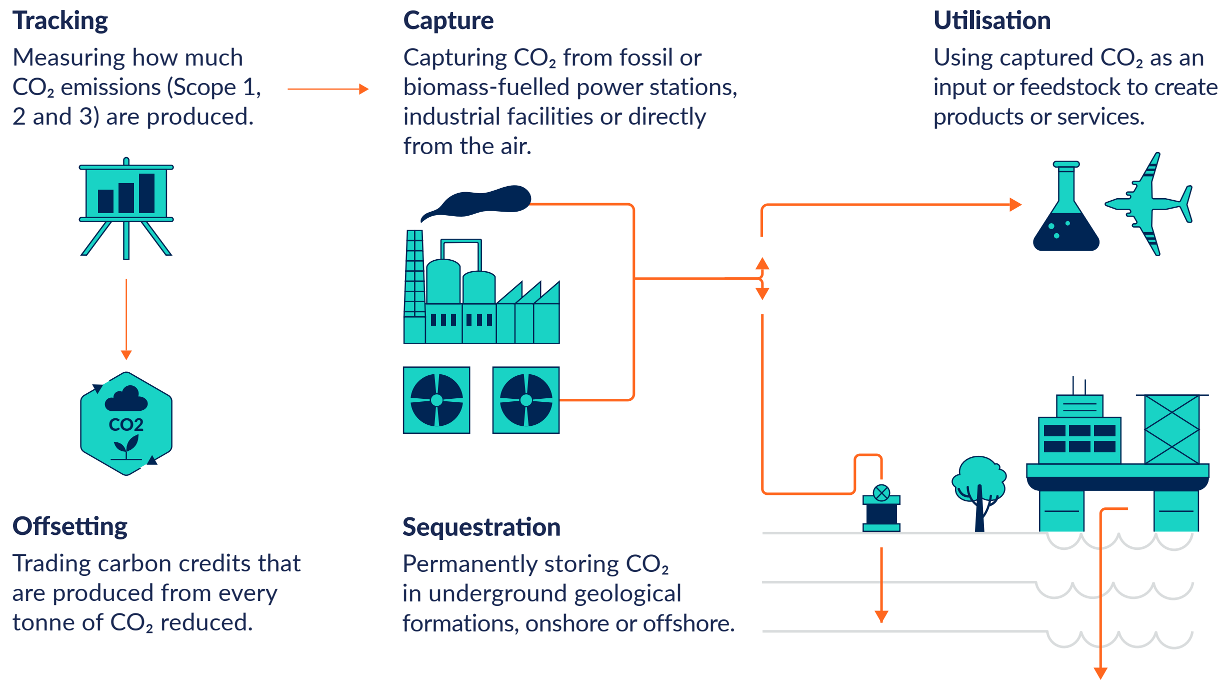

Figure 1 *The three pillars of CCUS technologies. Adapted from IEA 2021 (CC BY 4.0). This is a work derived by IPI from IEA material and IPI is solely liable and responsible for this derived work. The derived work is not endorsed by the IEA in any manner.*

Carbon tracking provides businesses with a better estimate of their carbon footprint and helps them determine areas in their direct operations or supply chain that can be improved with more sustainable approaches. The Greenhouse Gas Protocol categorises emissions as direct and indirect, and requires organisations to track and report all scope 1 and 2 emissions:

- Scope 1 – direct emissions within an organisation's control
- Scope 2 – indirect emissions generated from an organisation's energy sources or utilities, such as electricity and heating
- Scope 3 – indirect emissions occurring throughout the value chain that are beyond an organisation's control

For businesses largely reliant on carbon-heavy processes, a common and possibly the easiest solution to counter emissions is to offset them. Organisations could sell their carbon credits, particularly if they are carbon negative, to other businesses. In industries where governments have imposed a limit on emissions, businesses must purchase carbon credits to cover additional emissions and ensure compliance. Other forms of carbon offsetting involve participating and investing in programs that curb emissions, such as tree planting and clean energy projects.

On the other hand, carbon capture is the process of absorbing CO_2 from the air or flue gas for usage or sequestration. There are several methods to capture carbon, including direct air capture (DAC)—which captures CO_2 directly from ambient air—and processes that capture CO_2 at the source, such as post-combustion capture.

The final pillar of CCUS involves transporting captured CO_2 to be stored deep underground (sequestration) or to facilities where it can be turned into useful products. For example, Canada-based Carbon Engineering, one of the biggest names in CCUS, combines captured CO_2 with hydrogen (H_2) to create carbon-neutral synthetic fuel.

Innovations to counter current challenges

Technologies for carbon tracking are mature and enable the CCUS process, of which carbon capture is the most complicated to implement at scale. For example, pressure swing adsorption (PSA) is often used to capture CO_2 resulting from steam methane reforming (SMR), a commonly used H_2 production process. However, PSA is expensive and can only capture CO_2 concentrations of a certain amount.

Captured CO_2 that is not directly repurposed on-site is either stored permanently underground or used in various applications. Technologies are being developed to make carbon tracking and CCUS, particularly carbon capture and utilisation, more efficient.

Companies are also looking at novel ways to improve carbon offsetting, such as generating carbon credits through the hydrometallurgical recycling of metals and graphite from lithium-ion batteries. By recycling critical metals, the need to mine new ones—a process that takes a much heavier toll on the environment—is reduced. Compared to other recycling methods, hydrometallurgy is an eco-friendlier process of extracting metals that uses less energy and emits lower carbon.

	Current Scenario	Emerging Technologies
Tracking	• It is costly because it is often outsourced to a third party • It is inaccurate because current methods rely on historical data to measure carbon footprint	Using AI, ML and blockchain to enable: • Real-time monitoring of emissions • Automated recommendations to reduce carbon footprint
Capture	• DAC is energy-intensive because the CO_2 level in the atmosphere is less concentrated	• Advanced HVAC systems can filter and capture CO_2 from ambient air more efficiently
	• PSA is costly, energy-intensive and does not capture low CO_2 concentrations typically found in flue gas • Recirculating CO_2 to increase its concentration has high energy requirements	• A more simplistic membrane system can simultaneously purify H_2 and pre-concentrate CO_2 during SMR • Using aqueous ammonia at ambient temperatures can capture low CO_2 concentrations without recirculation
Utilisation	• Carbon conversion is not thermodynamically viable because CO_2 requires high energy to break it down	• Leveraging solar power to convert CO_2 molecules • Mineralisation, or turning CO_2 into carbonated aggregates for reuse

Key: AI – Artificial intelligence; ML – Machine learning; HVAC – Heating, ventilation and air conditioning

PATENT LANDSCAPE

The patent landscape is used as a proxy for investment opportunities as filing patents demonstrates an organisation's commitment to a cause. According to BDO, global interest in the CCUS space is growing, as evidenced by the increasing number of patents registered each year.[11] Between 2020 and 2021, the total number of registered patents was 203, a huge jump from 62 patents between 2015 and 2016. Working toward its goal to be carbon neutral by 2060, China holds the majority of global patents between 2020 and 2021 with 164 patents, followed by the US.

Historically, China and the US are the most dominant countries in terms of CCUS patent activities.[12] China produces the most CO_2 emissions worldwide, contributing 33 percent to total emissions in 2021.[13] The country's rise in emissions is mainly due to its increasing demand for electricity, which was 1.6 percent higher than its economic growth in the same year. The country primarily uses coal power to cater to its electricity demand. Nonetheless, the country is working toward reaching peak emission levels by 2030 and generating 80 percent of its energy from non-fossil fuel sources by 2060.

Number of Patents Filed by Key Companies

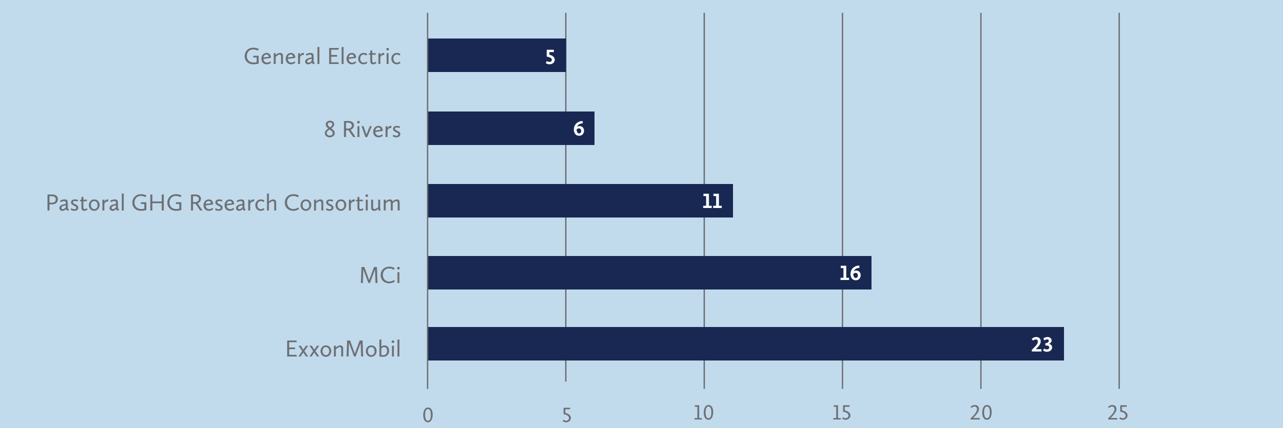

Figure 2 *Patent analysis by IPI of key companies investing in CCUS and related technologies from 2017 to 2022.*

Multinational companies in the O&G industry are the largest investors in CCUS. This is unsurprising as the industry is also among the biggest emitters—carbon emissions from natural gas rose to about 7.5 billion tonnes in 2021. Our patent analysis covering the period from 2017 to 2022 revealed that the US-headquartered ExxonMobil, one of the biggest O&G companies in the world, has 23 patents related to CCUS. ExxonMobil

[11] Carbon capture patents rise for fifth year running as companies race to address climate crisis. (2021). BDO. Retrieved in November 2022 from https://www.bdo.co.uk/en-gb/news/2021/carbon-capture-patents-rise-for-fifth-year-running-as-companies-race-to-address-climate-crisis

[12] Carbon capture, usage and storage: A worldwide overview of patenting related to the UK's ten point plan for a Green Industrial Revolution. (2021). Intellectual Property Office. Retrieved in November 2022 from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1031165/Carbon-capture-usage-and-storage.pdf

[13] Global CO2 emissions rebounded to their highest level in history in 2021. (2022). IEA. Retrieved in November 2022 from https://www.iea.org/news/global-co2-emissions-rebounded-to-their-highest-level-in-history-in-2021

projects that low-carbon solutions will make up the majority of its cash flow in 2050,[14] in line with its goal to achieve net-zero emissions in its operations by the same year.

Aside from the big names in the O&G industry, pioneers in clean energy, such as Australia-based clean technology group Mineral Carbonation International (MCi), are also pushing for new CCUS technologies. According to our patent analysis, MCi has filed a total of 16 patents, putting them close behind ExxonMobil. The start-up aims to create a mineral carbonation technology that mimics the natural process of CO_2 reacting to basic minerals to form solid carbonates like chalk and baking soda. To increase the technology's viability, MCi aims to make solid materials produced from carbonation into ones that could be sold and used in low-carbon products.

The Pastoral GHG Research Consortium is a New Zealand-based organisation researching technologies and practices to reduce methane emissions using microbiome. It collaborates with the New Zealand government to mitigate emissions in the agricultural sector. In a similar vein, the US-headquartered 8 Rivers offers a range of net-zero solutions, including robustly and cheaply capturing CO_2 as well as a more efficient and cleaner H_2 production method.

As countries and businesses continue to find the best ways to reach their respective carbon targets, CCUS remains the popular choice. The World Economic Forum opines that the CCUS market is promising due to the push from governments, the adoption of technologies in heavy industries and the development of new, more scalable technologies arising from industrial collaborations. According to the Center for Climate and Energy Solutions, carbon capture has the potential to reduce 14 percent of global GHG emissions needed to satisfy the Paris Agreement. In order to keep global warming below 1.5°C, emissions need to reach net zero by 2050.

Along with the focus on reducing emissions, our patent analysis also revealed that companies in the CCUS space have been filing patents for technologies related to fuel cells. These cells operate similarly to traditional batteries, but instead of storing electricity, a fuel cell generates electricity through chemical reactions. The most common chemical used to power fuel cells today is H_2, as it only produces water, electricity and heat when used in a fuel cell. Based on our patent analysis, ExxonMobil and General Electric are among the companies exploring this area.

Research and innovation in addressing climate change issues and maximising the potential of emissions-reducing solutions are increasing worldwide and across industries. New CCUS technologies are being introduced, with many having technology readiness levels ranging from four to nine.

[14] Looking at climate change through the eyes of ExxonMobil. (2022). Forbes. Retrieved in November 2022 from https://www.forbes.com/sites/bobeccles/2022/08/10/looking-at-climate-change-through-the-eyes-of-exxonmobil/

OUR INSIGHTS

Market drivers for CCUS technologies

Globally, many countries are decarbonising to align themselves with the UN's climate change stance and achieve net zero by 2050. With the effects of climate change spreading, technologies that promote sustainability and address climate change issues are high in demand. Western countries such as the US and Europe lead the way in adopting CCUS technologies, while countries in Asia are catching up, albeit at a slower pace. Despite the COVID-19 pandemic disrupting the supply chain and shifting the business focus from innovation to survival, the global CCUS market is set for tremendous growth.

Need for regulatory standardisation and enforcement

Although consumer awareness about the advantages of reduced emissions has risen, the government remains the primary force driving businesses to be more sustainable. Through legislation and investments, governments are showing their commitment to sustainable efforts. However, with different countries implementing their own rules, it can be challenging for businesses to ensure compliance, particularly corporations with global operations. Governments should standardise regulations as well as impose stricter ones, for example, higher carbon tax, and offer other incentives like green financing that can ease the compliance process and further motivate businesses to go green.

Accurate carbon tracking is essential

Carbon tracking is the first step in understanding emissions and arguably the most crucial to achieve. Businesses should know their emission sources and scopes first to be able to address them effectively.

Tracking & Offsetting

Why	How
With data-driven findings, businesses will be better equipped to manage their emissions.	Advancements in carbon tracking are resulting in technologies that can automate and track carbon in real-time, providing businesses with a more accurate picture of the size of their carbon footprint.
As carbon taxes rise, businesses can leverage carbon offsetting to remain profitable without overhauling processes.	Other than investing in green businesses and tree-planting, new technologies like hydrometallurgy can recycle much-needed commodities such as lithium-ion batteries for a more sustainable supply chain.
As countries adjust policies to reduce carbon emissions, businesses must comply with stricter carbon regulation.	Blockchain-enabled tracking can provide reliable data across each step of the supply chain. Businesses can make informed-decisions and ensure they are aligned with existing regulation.

Find niche areas to address

Instead of trying to address the whole value chain, CCUS innovators should find unique opportunities or particular industries to cater to as no one-size-fits-all solution exists. For example, they can develop new technologies or adapt current solutions to deal with specific pain points. They could also consider supporting large corporations in areas where they might lack capabilities, such as offering a more energy-efficient technology to capture carbon. A key point to note is that new solutions should be simple and ideally compatible with existing systems—the simpler the solution design, the likelier businesses will adopt it.

Work towards simple longer-term solutions

CCUS technologies are the best available solutions to reduce emissions in pursuit of net zero, but simple longer-term solutions are necessary. An ideal scenario involves governments, industries and businesses adopting CCUS technologies while creating a roadmap towards overhauling industrial processes or fully transitioning to more sustainable power sources like renewable energy. Because major changes are risky and costly, building the foundation via CCUS for such changes to take place should begin now.

TECH OFFERS: TRACKING, TRAPPING, TRANSFORMING

Currently, technology at each step across the entire CCUS process exists at a different phase of development. While companies have found ways to refine tracking technology, capturing technology has room to grow and utilisation remains the most nascent. Find out more about three tech offers that encompass the next generation of efficient CCUS technology.

Carbon Tracking
AI for End-to-End Carbon Accounting and Management

Today, most organisations rely on manually updating spreadsheets to track their carbon footprint. Organisations without internal experts turn to consultants to help accurately measure and interpret their carbon data.

With the help of AI, and capable of being integrated with common platforms and enterprise systems, this technology will allow organisations to track carbon emissions independently and receive reports up to 90 percent more quickly.

Currently a software-as-a-service (SaaS) platform, the technology's carbon accounting methods are in line with Greenhouse Gas Protocol.

While existing methods typically make use of year-old data, this system works with live data and offers users a real-time dashboard—allowing organisations to be aware of their footprint at all times and make changes based on current information.

The system also offers automated recommendations unique to each organisation's situation. This can help streamline ESG compliance, reporting and emission reduction.

The technology owner, Zuno Carbon, is looking to work with partners in the energy, O&G, manufacturing and logistics industries to conduct pilot projects and refine industry specific requirements of the software.

Carbon Capture
Enabling Carbon Capture via Hydrogen Separation Membrane

Carbon capture traps and stores excess carbon, preventing it from entering the atmosphere and causing damage. It is considered one of the most effective solutions in the effort to achieve global net-zero CO_2 emissions.

This tech offer, developed by DiviGas, is a H_2 separation membrane that reduces the cost of H_2 purification and carbon capture.

Because membrane-based technology must be adopted into pre-existing processes, it can be difficult to implement. By capturing carbon in the post-combustion phase, this tech offer circumvents the problem.

Simple, temperature-resistant and corrosion-resistant, the membrane splits syngas into H_2 and CO_2-rich streams. At the same time, it purifies the H_2 and pre-concentrates the CO_2 for easier capture, transport and potential sequestration. Waste H_2 can then be recovered to improve overall efficiency.

The technology is simple and affordable, allows organisations to gain carbon credits from carbon capture and enhances process and cost recovery by recycling H_2. It converts grey H_2 (commonly produced without capturing carbon in the process) into blue H_2 (often considered as low-carbon H_2 as CO_2 is captured in the process).

DiviGas is looking for collaborators in O&G refineries or other H_2-intensive industries to implement pilot trials of the technology.

Carbon Utilisation and Sequestration
Liquid-phase Electro-conversion of Carbon Dioxide to Syngas

Carbon utilisation and sequestration transforms CO_2 into a valuable material that can be used again like sand or stone. It remains the most nascent pillar of CCUS technologies and requires more development before it can be fully commercialised.

This tech offer uses a natural, low-temperature, liquid-phase process to convert CO_2 into syngas. A highly desired product, syngas is a mixture of H_2 and carbon monoxide (CO)—it can be turned into a variety of useful materials like plastics, ammonia and methanol. Syngas is typically made from fossil fuel and using recycled CO_2 would greatly benefit the environment.

The technology, developed by 3G&S Technologies, relies on a proprietary catalyst for the electrochemical conversion of CO_2.

The process also allows for the easy and cheap transportation of CO_2 in a carbonised electrolyte form.

On top of successfully eliminating carbon emissions and creating useful products, the technology is also easy to integrate into existing plants and systems to improve overall efficiency.

The technology owner is looking to work with companies in CO_2-emitting industries to further co-develop and testbed the solution.

CONCLUSION

As countries move steadily towards individual deadlines to reach net-zero emissions, the CCUS market is expected to keep growing and become a major driver of sustainability goals. Despite overall growth, innovation and investment remains concentrated within five countries—the US, the UK, Canada, Russia and the Netherlands.

Currently, carbon offsetting is a popular solution but can be a slow process. CCUS technologies are set to speed up the returns of sustainable investment by generating greater carbon credits across industries.

As the market grows and companies look to CCUS, it is important for innovators to focus their efforts on simple and specific solutions. By identifying niche pockets where they can address global concerns, rather than attempting to solve the multifaceted problem of carbon emissions, innovators will be more likely to find success.

If you would like more details and to learn about the opportunities outlined in this report, please contact: techscout@ipi-singapore.org.

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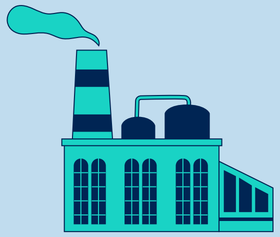
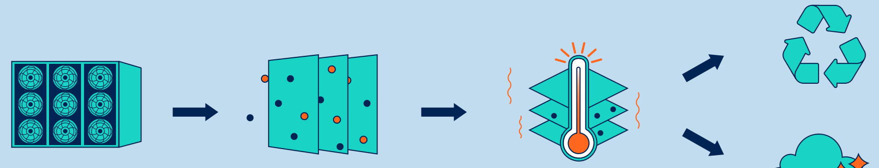
THE CARBON CAPTURE PROCESS



Industrial Processes
Fossil fuel combustion for industries like manufacturing and transportation is the most significant producer of carbon

Direct Air Capture

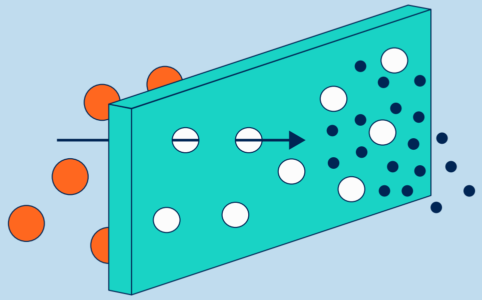
This method requires a significant amount of energy, and the benefits of capturing carbon already present in the air may not be obvious to many companies.



Emerging tech
Carbon capture in HVAC systems for improved energy efficiency

Process Capture

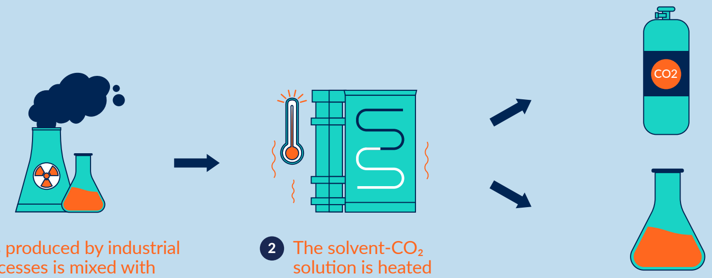
Carbon can be captured during industrial processes, but it can be difficult for companies to retrofit new capture technology into existing systems.



Emerging tech
Carbon capture via hydrogen separation membrane

Post-Process/Combustion Capture

This technology can be easily included in existing plants and applied to most facilities.



Emerging tech
Carbon capture from dilute flue gases using aqueous ammonia

Innovation
Partner for
Impact

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