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Carbon Capture, Utilization, and Storage

WHITEPAPER
DECEMBER 2022

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As much of the world continues a transition toward a goal of net zero emissions by 2050, many of the technologies that are anticipated to be part of the long-term solution, such as green hydrogen, next generation batteries, and modular nuclear power, will take significant time to reach scale. However, technologies have emerged that should help reach interim climate goals. One such technology is Carbon Capture, Utilization, and Storage ("CCUS"), which captures carbon dioxide ("CO_2") at the source of emissions, preventing its release into the atmosphere. The captured CO_2 can then be transported for use in a variety of applications or stored in underground formations.

Traditional energy sources will continue to be needed for the foreseeable future. The burning of coal, oil, and natural gas emits CO_2. However, there are opportunities to equip natural gas and coal power plants with CCUS systems. Additionally, the industrial and petrochemical sectors (i.e., the makers of plastics and chemicals) are large contributors to global emissions, and many of these industries cannot cost effectively transition to significantly cleaner processes. CCUS systems may be appropriate for them as well.

In addition to focusing on what industries are viable options for CCUS opportunities, consideration must be given to the transportation, uses, and storage of CO_2. The current dominant industrial use of captured CO_2 is in Enhanced Oil Recovery ("EOR"), where CO_2 is injected into a mature oilfield to extract oil. However, there is the potential to increase the use of captured CO_2, for example, in building materials (e.g., cement) and fuels. Permanent storage also has potential to be a long-term solution based on the large-scale availability of reservoir formations that can permanently store the CO_2 in liquid form.

Global energy demand

The US Energy Information Administration ("EIA") predicts that global energy demand will continue to increase with world consumption growing by nearly 50% in the next three decades. Traditional and alternative power generation sources will be required to meet this demand, including fossil fuels, renewables, and nuclear.

Figure 1 depicts how the EIA think that demand could be met. While renewables are expected to experience the largest growth, coal and natural gas are still expected to be needed to meet more than 40% of energy demand in 2050.

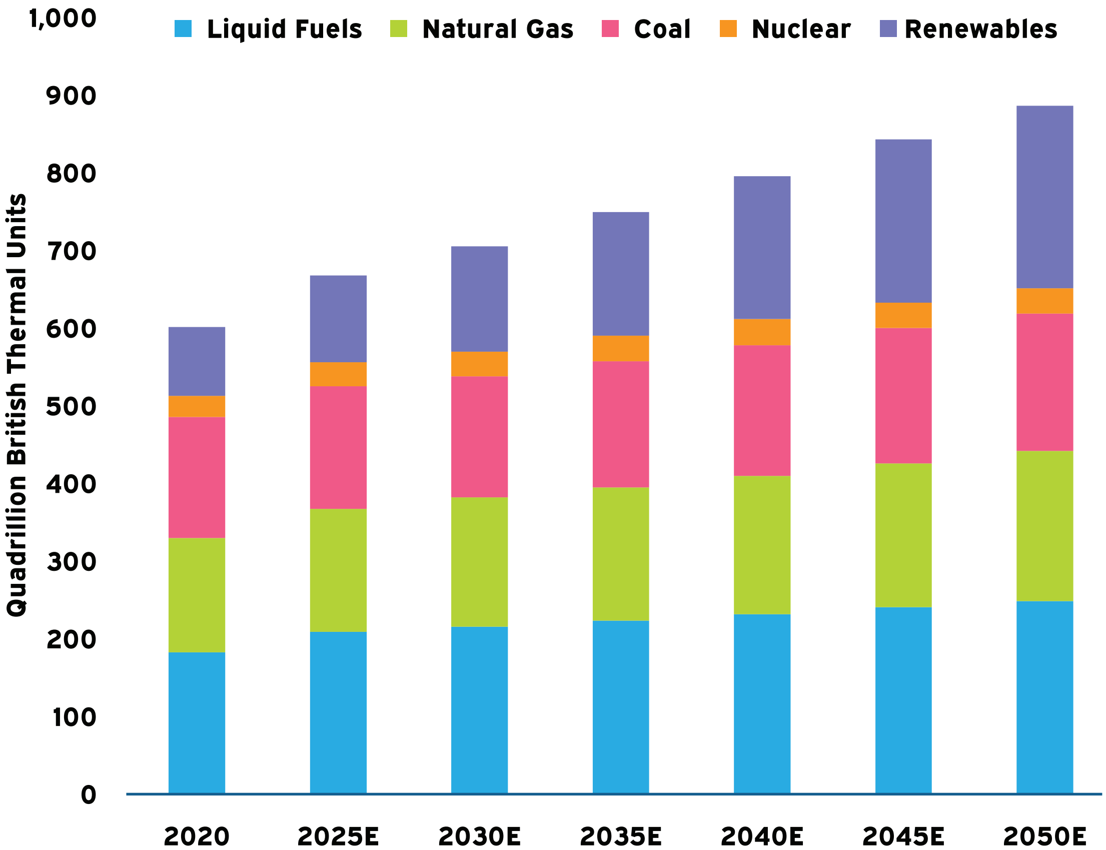

FIGURE 1
Global Energy Consumption by Source

Source: US Energy Information Administration (EIA), World Energy Projection System (2021)

Carbon capture potential

CO_2 emissions come from multiple sectors and have different costs associated with implementation. Power generation from natural gas and coal plants can have capture systems implemented that physically separate the CO_2 to prevent its release into the atmosphere. The power sector has been the primary focus of carbon capture systems to date, but industrial sectors such as cement, iron and steel, and ethanol, are beginning to gain attention. This is because their production involves energy intensive processes that emit CO_2 and, currently, there are no commercially viable alternative processes to create these essential materials. There has been less attention on these sectors, which have costs to capture CO_2 at approximately $40 to $100 per ton, which is relatively expensive in comparison to the $25 to $35 per ton for the processing of ethanol and the $15 to $25 per ton for the processing of natural gas. However, CCUS technologies continue to see cost reductions due to the build-out of related infrastructure, improved processes, and government credits creating additional opportunities within industrial sectors.

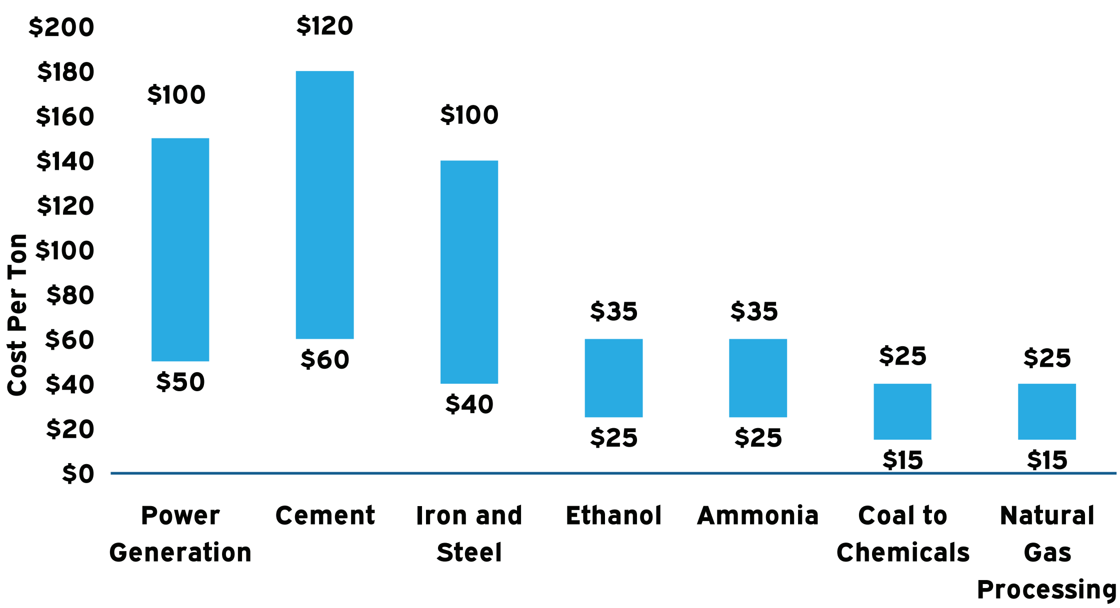

FIGURE 2

CO_2 Capture by Industrial Processes

Source: International Energy Agency. https://www.iea.org/commentaries/is-carbon-capture-too-expensive

Carbon capture varies in extraction cost primarily due to the concentration of CO_2 in the material or process. Cement, iron, and steel production have a relatively low CO_2 concentration, which increases the cost to separate and extract it. Ethanol and natural gas create higher levels of CO_2 emissions, which lowers the cost to extract and has created a larger investable opportunity to date.

Uses for the captured CO_2

The largest use of CO_2 is currently for fertilizers with urea manufacturing[1]. This is the process of reacting CO_2 and ammonia at high temperatures and pressures. Second, the EOR technique has been used for decades in the US and consists of injecting CO_2 into rock formations that contain oil. The CO_2, in liquid form, displaces the oil, allowing for recovery of a greater percentage of the oil than would otherwise be possible. While much of captured CO_2 has been used for oil recovery, a significant portion is also used in fuels, chemicals, and building materials. Other potential uses of CO_2 are in various stages of development and could become significant areas of investment going forward.

Cement | The process of making cement is a large contributor to CO_2 emissions due to the baking of limestone, which releases the gas during calcination. Technologies are being developed that may potentially reduce CO_2 emissions during the process and possibly store and sequester CO_2 within the mixture by reducing the limestone content of the cement.

Fuels | Synthetic gasoline, jet fuels, and diesel can all be created by using CO_2. The current challenge is obtaining the level of hydrogen required to create the fuels. The advancement of low carbon hydrogens is increasing, but it remains in the early stages of commercial development.

[1] Source: International Energy Agency. https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage.

Storage

Captured CO_2 can also be permanently stored in deep underground reservoirs located underneath impermeable layers of rock. The CO_2 can be transported to these locations by high pressure pipelines or truck. When injected into the reservoir, CO_2 is converted into a liquid due to the pressure of the formation. The two types of rock formations that are best suited for CO_2 storage are deep saline formations and depleted oil and gas reservoirs. Geological storage capacity in major oil and gas fields is estimated to be more than 300 billion tons. Saline formations, which have similar rock formations to oil and gas fields but are filled with brine, are estimated to offer 100 times more potential storage capacity than oil and gas fields. However, saline formations currently offer low economic value, so oil and gas formations have been the initial focus of CCUS systems. The number of potential US oil and gas reservoirs is significant[2] with nearly two-thirds of the reserve capacity located in the United States. It is estimated that known geological structures could store 500 years of today's US CO_2 emissions. Globally, the known reservoirs could store 300 years of global emissions[3]. The key hurdle is getting carbon capture and transportation to an economically feasible level in order to begin using the natural storage reservoirs.

[2] Source: Global CCS Institute, Global Status of CCS 2020.

[3] Source: McKinsey, Driving CO2 emissions to zero (and beyond) with carbon capture, use, and storage.

Regulation

CCUS projects are costly, given the major infrastructure that is needed at facilities to capture, transport, and store/use CO_2. To incentivize industries or private investors to initiate projects, the US government created a tax credit for carbon sequestration that rewards a level of CO_2 capture. This was originally created under section 45Q of the Energy Improvement and Extension Act of 2008. The credit accounts for the end use of the captured carbon between transporting to a facility for utilization or EOR processes and permanent storage as described earlier. The credit was revised as part of The Bipartisan Budget Act of 2018, updating the size of the tax credits as shown in Figure 3. These credits have been instrumental in making CCUS economical within the ethanol and natural gas generation industries.

The Inflation Reduction Act of 2022 provided further incentive for CCUS projects. The deadline to qualify for 45Q tax credit was pushed from projects beginning construction before 2027 to 2033. The credit amount was also increased as shown in Figure 3. As mentioned earlier, some of the other high emissions sectors such as cement and iron & steel are more expensive due to the lower concentration of CO_2, so the tax credits are helpful, but not yet enough, to make most of the projects profitable.

($/ton CO_2)	2008	2018	2022
Usage or Enhanced Oil Recovery	$10	$35	$60
Permanent Storage	$20	$50	$85

FIGURE 3
CCUS Tax Credit

Source: Global CCS Institute, https://www.globalccsinstitute.com/wp-content/uploads/2021/05/U.S.-Policy-Landscape_03.05.21_FINAL-2.pdf and https://www.globalccsinstitute.com/news-media/latest-news/ira2022/

Summary

Natural gas and coal power generation is still required to meet growing energy demands, complement the intermittent nature of wind and solar power, and provide affordable and reliable power. However, CCUS can be part of a solution to achieving interim goals in moving toward net zero emissions. There are also industrial sectors for which alternative processes either do not exist or are not economical such as cement production. Because of this, private capital has been focused on the lower cost capturing industries such as ethanol and natural gas production. The investment of private capital into CCUS continues to accelerate as new technologies emerge and tax incentives increase.

There are not yet many funds focused on CCUS, as it remains a narrow segment of the energy opportunity set for investors. Rather, there are likely to be energy, infrastructure, or natural resources partnerships that incorporate one or more CCUS projects in their funds. As investors focus on the energy transition, CCUS is likely to become more prevalent in these funds.

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