Carbon Capture and Storage (CCS)

What about it?

Introduction

The need to adhere to the Paris climate agreement, which aims to keep global warming well below 2.0°C, preferably to 1.5°C, has led nations and companies around the world to take more aggressive steps to cut carbon emissions and reduce their overall carbon footprint.

Staying within 1.5°C limit means that global emissions need to reduce at about 3% per year from now (37 Gt CO_2 per year) to a net balance of zero around 2050. This push for lower carbon emissions has been dubbed, "transition to net zero". Transition to net zero carbon emissions will require innovation in technology as well as a diverse energy mix that will include greener energy solutions.

Fossil fuels provide cheap and reliable energy compared to renewable energy sources. However, burning fossil fuels like coal, crude oil and natural gas emits greenhouse gases like CO_2 into the atmosphere. This is where carbon capture and storage (CCS) come in. Since fossil fuels will still provide a huge chunk of energy in the foreseeable future, how about we just capture and safely store CO_2 emissions rather than leaving it free to destroy the climate?

Definition

CCS or CCUS, 'U' for utilization, is a group of technologies, that extracts CO_2 from carbon emitting processes like combustion for electricity generation thus preventing CO_2 from entering the atmosphere. This provides a means whereby widespread, accessible, portable, and dense energy storage fuels may be used with minimal impact to the climate.

There are three aspects of CCS which are capture, transport and storage. Captured carbon can also be utilized for other purposes. Capture technologies that can be used in industrial power plants includes post-combustion capture, pre-combustion and oxyfuel combustion. CO_2 can also be captured directly from air; this is known as direct air capture (DAC).

After CO_2 is captured, it is transported through pipelines to a storage location. CO_2 can be stored in depleted oil reservoirs, saline aquifers or in form of mineral carbonates. Carbfix, a company in Hengill, Iceland developed a method to turn CO_2 into calcite rock by injecting the CO_2, mixed with water, into underground basaltic formations. Under intense underground pressure and chemical reactions, the CO_2 is transformed into a rock within two short years. Storing CO_2 this way is a more permanent and safe approach.

Apart from storage, captured CO_2 can also be utilized for enhanced oil recovery (EOR), as a feedstock for production of clean hydrogen, concrete building materials, fertilizer, soda ash, etc. There is a growing market for CO_2 which will encourage carbon capture, thus leading to lower carbon concentration in the atmosphere. McKinsey & Company estimates that by 2030, CO_2 based products could be worth between $800 billion and $1 trillion, and the use of CO_2 for producing fuel, enriching concrete and generating power alone could reduce greenhouse gas emissions by a billion metric tons yearly. This shows a positive correlation between the demand for CO_2 and reduction in global warming.

Brief history and contribution

Although discussions about CCS have ramped within the past decade, the idea of capturing and storing CO_2 is not new. The basic idea of capturing CO_2 and preventing it from being released into the atmosphere was first suggested in 1977. However, CO_2 capture technology has been used since 1920s to separate CO_2 found in natural gas reservoirs from methane gas.

One notable project that brought CCS to light is the Sleipner gas field CCS project in offshore Norway. Operated by Statoil, the Sleipner project is the world's first industrial scale CCS project that started in 1996. It is the first to demonstrate the feasibility of safe long-term storage of CO_2 in deep underground formation. Every year about 1million tonnes of CO_2 from natural gas is captured and stored at Sleipner.

Contributors: Tekena Jim-George and Favour Obiomah

According to the Global Carbon Capture and Storage Institute (GCCSI), there are currently 23 large scale CCS facilities in operation or under construction capturing almost 40 million tonnes per annum (mtpa) of CO_2. According to Statista, the top 20 largest CCS projects in the world have a combined capacity of 34.4mtpa. Century plant in Texas USA, with a storage capacity of 8.4mtpa, is currently the largest operational CCS facility in the world accounting for almost 25% of the combined capacity.

With all these carbon capture and storage capacity, the question that comes to mind however is; by how much is CCS projected to contribute to net zero emissions? Is it worth the investment?

CCS contribution to reducing global warming.

There is international consensus that CCUS will play a critical role as part of an economically sustainable route to the emissions cuts needed to limit global warming to 2°C. According to the International Energy Agency (IEA) models, CCUS will need to contribute about 14% of the cumulative CO_2 emissions reductions between 2015 and 2050 and 17% of global CO_2 emissions reduction from 2050 onwards to meet the Paris agreement.

Industrial and power sector applications of CCUS would need to contribute a greenhouse gas reduction of 7 gigatonnes per year by 2050. This means that current capture and storage rates will have to be increased by a factor of 175 to achieve the 2°C goal.

The primary role of CCS is to delay the shift from fossil fuels, thereby reducing cost associated with the energy transition. According to the US department of energy (DOE), CCUS technology is necessary to meet climate change mitigation goals at the lowest possible cost to society. The Intergovernmental Panel on Climate Change (IPCC) has concluded that without CCS, meeting the Paris goals may be impossible. Also, that the cost of climate change mitigation will increase by 138% without CCUS. In the absence of CCUS, the additional investment required for climate change mitigation in the electricity sector is a whopping $2trillion in the next 40 years.

CO_2-based product industry is also projected to utilize about 7 billion metric tons of CO_2 each year, by 2030, with the right incentives. This presents a huge market that will encourage large scale adoption of CCUS technology and in effect reduce CO_2 emissions by 15%.

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Challenges and enablers

High cost of CO_2 capture, a lack of infrastructure, relative absence of policy incentives and lack of public acceptance is cited by professionals as some of the significant challenges to deploying CCUS in a large enough scale. The IEA has confirmed that for every successful CCUS project, there is at least two large scale projects that have been cancelled.

In addition, companies are not willing to invest premium dollars for what would yield little to no return on investments. However, if there is a significant increase in demand for CO_2-based products such as varieties of chemicals, concrete and fuels, the market value of CO_2 will rise. Then, companies will be more willing to invest in CCUS technology. Note that the high energy cost associated with using CO_2 to manufacture products will have to be overcome first.

Some enablers of CCUS includes tax credits for companies, adequate carbon pricing (carbon tax), government regulations and policies, public sensitization to build confidence and acceptance.

Game Changers

Allam cycle technology: Traditionally, burning of natural gas produces steam and CO_2. The steam is used to turn turbines for electricity generation while the CO2 is emitted. The Allam cycle technology uses a working fluid which consists of steam and CO2 to turn turbines for electricity generation. Here, rather than emitting the CO2 into the atmosphere, it is used along with the steam to turn the turbine. This is achieved by using pure oxygen instead of air to burn the fuel. A company in Texas, Net Power demonstrated this technology with their 50-MW natural gas power plant. It is hoped that it could eventually make zero emissions coal and natural gas power generation competitive with existing power generation technologies.

Fuel cell energy technology: By using molten carbon fuel cells (MCFC), CO_2 can effectively be captured from the exhaust stream of a power plant. The benefits of this technology are that, for one, it does not require onerous changes to existing plants. Also, electricity is generated during the process which will help save costs on power. Overall, this technology developed by the Fuel Cell Energy Company has the potential to dramatically reduce production costs while keeping the CO_2 away from our atmosphere.