Council of Enviro Excellence

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DECARBONIZATION IS THE WAY FORWARD TO ACHIEVE NET- ZERO EMISSION
&
Role of Carbon Capture, Utilization and Storage (CCUS)

SPEAKER

PURUSHOTTAM UNIYAL,
SENIOR MANAGER, ENERGY & POWER, MARKETSANDMARKETS.
PHD SCHOLAR, DOON UNIVERSITY, DEHRADUN
(Areas of Expertise - Energy Transition, Decarbonization, Hydrogen Economy, CCS/CCUS)
(Mentor: Dr. Sudhanshu Joshi)

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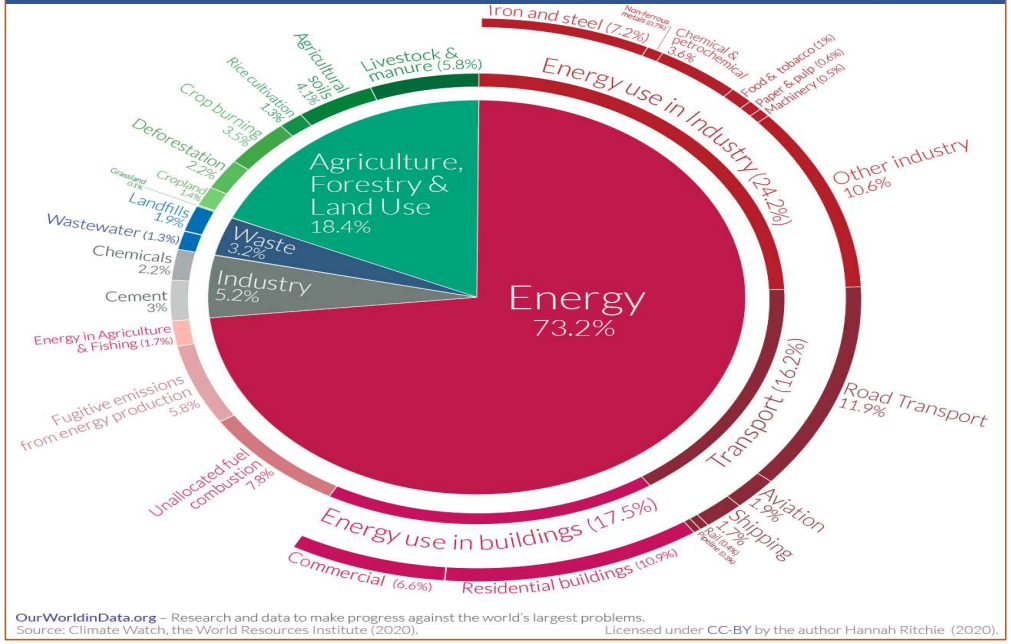
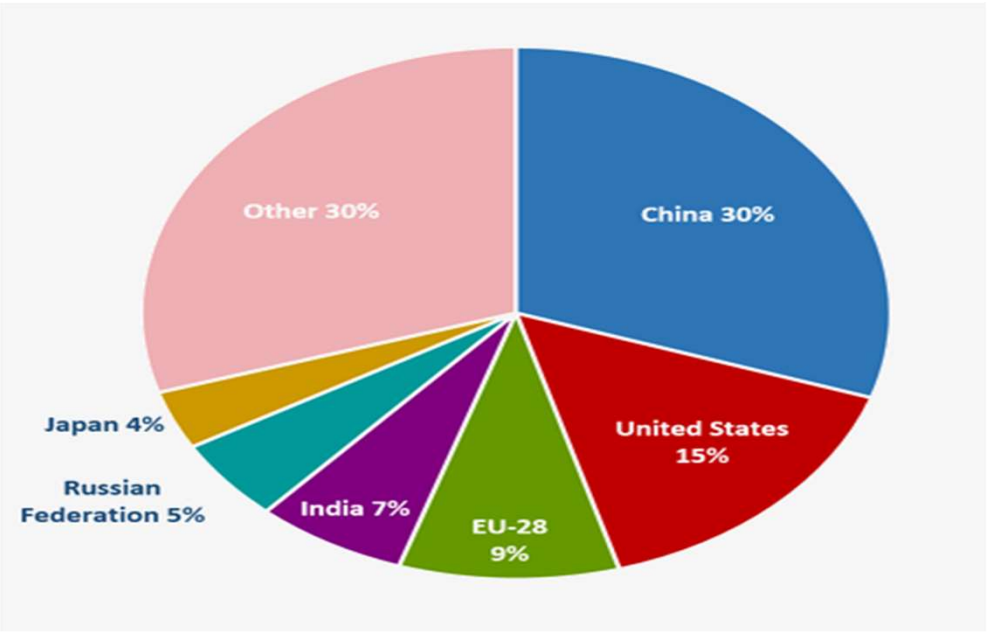
WHAT IS DECARBONIZATION- DEFINITION

In context of a country, the decarbonization could be referred to the phasing out/lowering of atmospheric greenhouse gas (GHG) emissions from all aspects of economic activities without compromising the development and national economic competitiveness and prosperity.

GLOBAL GHG BY SECTORS



GLOBAL GHG BY GEOGRAPHIES



WHAT IS DECARBONIZATION – SOURCE OF GHG EMISSION - WHY DECARBONIZATION/KEY DRIVERS ……2/2

WHY DECARBONIZATION/KEY DRIVERS

- **To prevent severe climate change** - global greenhouse gas emissions need to rapidly reduce
  - The climate pledges made at the 2021 United Nations Climate Change Conference or the COP26 summit in Glasgow will limit the global average increase in temperatures to **under 2 degrees Celsius** relative to pre-industrial levels.
- **Environmental sustainability**
- **Consumer/customer awareness and stakeholder/Investors pressure**
- **Technological development**
- **Government regulations and policy support**
  - **International organization (United Nations/IPCC) and geopolitics**
- **Energy (electricity, heat and transport) use accounts for significant GHG emission** –
  - Energy use is should be first target area for the decarbonization.

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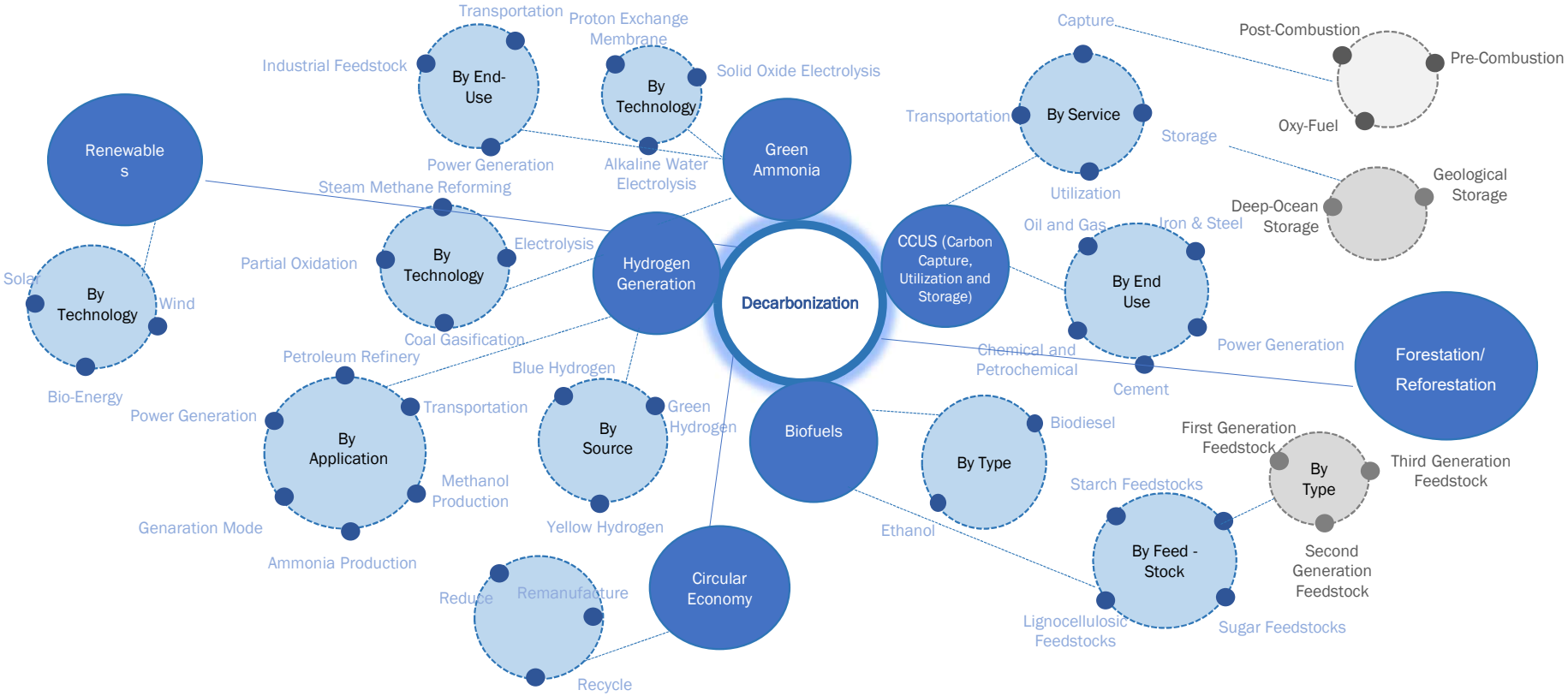
KEY METHODS/OPTIONS AND STRATGIES TO DECARBONIZE THE ECONOMIC ACTIVITIES

- **Carbon Capture and Storage (CCS)/ Carbon capture utilization and storage (CCUS)** – Technology is there but deployment at nascent stage due to associated cost
- **Green hydrogen economy/Green Ammonia** – Technology is evolving, cost is a barrier at the moment
- **Carbon pricing and taxes/Cap-and-trade** – Well in place, a mechanism which could trigger hydrogen and CCS/CCUS
- **Circular economy –** Evolving
- **Energy-efficiency -** Well in place, and have contributed significantly in the efforts so far, more potential to explore
- **Renewable energy (RE) deployment and fuel switching (new addition, coal to gas, nuclear power)*** - This has maximum focus at the moment, to play a dominant role in decarbonization and net-zero targets.
- **Forestation/Reforestation** – it's important, but has limited focus so far**.**

In the last one decade, almost all the business leaders acknowledged decarbonization in their key strategic agenda and emphasized that their business sustainability is linked to environmental sustainability of their business.

‘DECARBONIZATION’ ECOSYSTEM



identified explicit and latent opportunities, markets, technologies, products, and use cases in decarbonization space
Source: MarketsAndMarkets

BUSINESS GIANTS - CORPORATE STRATEGIC PLAN OF ACTION ANNOUNCED TO ACHIEVE THE NET-ZERO GOALS

COMPANY	TARGETS BY YEAR			STRATEGY ADOPTED	RELEASE YEAR OF STRATEGIC PLAN
	ON OR BEFORE 2025	BY 2030	BY 2050		
Google	Significant	100%	100%	· Operating on 24/7 Carbon-Free Energy	2021
Netflix	100% (2022)		100%	· Restoring grasslands and mangroves · Carbon capture and storage	2021
Facebook	75% (2020)	100%	100%	· Switching to RE sources · Reforestation · Carbon capture and storage	2018
Apple		100%	100%	· Circular economy · Switching to RE sources · Forestation/reforestation	2020
Nestle		50%	100%	· Switching to RE sources · Forestation/reforestation	2020
Coca-Cola		30%	100% (2040)	· Switching to RE sources · Circular economy · Green fleet program	2021
Reliance Industries		100% (2035)	100%	· Use of digital tech - IoT, AI / ML · Switching to RE sources · Circular economy	2021
TCS	70% (2025)	100%		· Use of digital tech - IoT, AI / ML · Switching to RE sources	2021
Indian Railways		100%	100%	· Switching to Solar PV	2021
Amazon		Switching to RE	100% (2040)	· Detailed plan yet to come out in 2022	2021
Microsoft		50%	100%	· Forestation/reforestation · Carbon capture and storage	2020

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WHAT IS CCUS AND HOW IT WORKS

DEFINITION

CCUS technologies involve the capture of carbon dioxide (CO2) from fuel combustion or industrial processes, the transport of this CO2 via ship or pipeline, and either its use as a resource to create valuable products or services or its permanent storage deep underground in geological formations.

Let's watch the video to understand the technology.

Source: Council on Energy, Environment and Water

WHAT IS CCUS AND HOW IT WORKS – VALUE CHAIN

CARBON CAPTURE

BY TECHNOLOGY TYPE

Table 1 Mapping of Carbon Capture System and Technology

CO2 Capture System	CO2 capture technology
Post Combustion	Absorption Membranes Adsorption Cryogenic / Microbial / Algal
Pre-Combustion	Absorption Membranes Adsorption Cryogenic / Microbial / Algal
Oxy-combustion	Separation is not required. Instead, purification is required to remove SOx, NOx, H2O.
Direct Air Capture (DAC)	Absorption Membranes Adsorption Cryogenic / Microbial / Algal

Source: Council on Energy, Environment and Water

CO_2 Compression

To make it ready for transportation

Transportation

- Pipeline
- Ship
- Other Modes

Utilization

Storage /Sequestration

WHAT IS CCUS AND HOW IT WORKS – WHY IT IS IMPORTANT

WHY CCUS

- Uniquely important option in global efforts to control anthropogenic greenhouse-gas (GHG) emissions.
- Offers significant strategic value in the transition to net-zero. C enabler of least-cost low-carbon hydrogen production.
- Delivering low carbon heat and power, decarbonising industry and, more recently,

  - ability to facilitate the net removal of CO2 from the atmosphere through DAC

- CCUS can tackle emissions in sectors where other technology options are limited, such as in the production of cement, iron and steel or chemicals, and to produce synthetic fuels for long-distance transport (notably aviation).
- Under net-zero 1/6 to come from CCUS
- CCUS can capture 90% to 95% of an industrial facility's emissions. According to IEA, this method could reduce greenhouse gas emissions worldwide by up to 14% by 2050.

CCUS – STATUS OF TECHNOLOGY-BY-TECHNOLOGY TYPE

POST COMBUTION - ABSORPTION

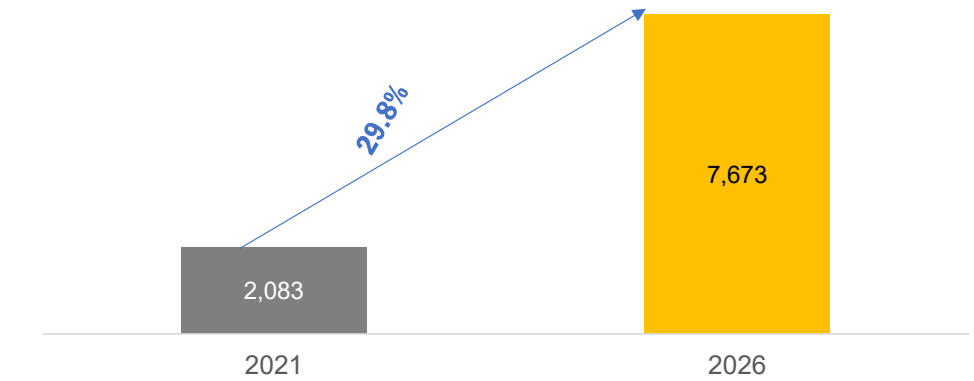
- The most cost-effective approach today is absorption of CO2 by Chemicals (amine-based solvents) that are regenerated by heating, which liberates the absorbed CO2 to be compressed for transport.
- To avoid contamination of the solvent, the flue gas needs first to undergo flue gas desulphurisation (FGD).
- Chemical solvent-based is preferred when dealing with gas streams that are lean in CO2 and have relatively lower pressures, such as flue gases.

NON- POST COMBUTION ARE PICKING UP, BUT COSTLIER

- Pre-combustion, oxy-combustion and DAC are either at the nascent stage, and are more costlier.
- Oxy-combustion require pure oxygen – with the development of hydrogen economy, oxy-combustion could ne more cost effective when oxygen is produced as a by products at a large volume.
- 19 DAC plants are currently operational in Europe, the US and Canada. Most of these are small and sell the captured CO_2 for carbonating drinks.
- The first large-scale DAC plant is now being developed in the United States through a Carbon Engineering and Occidental Petroleum partnership. The plant will capture up to 1 Mt CO_2 each year and could become operational as early as 2024.

CCUS MARKET SIZE AND GROWTH TREND

MARKET POTENTIAL (USD MILLION)



Source: MarketsadnMarkets

END-USE INDUSTRIES

- Oil & Gas
- Iron & Steel
- Power Generation
- Cement
- Chemical & Petrochemical
- Others
  - Pulp and paper
  - Fertilizer
  - Food & Beverage

Key Development

- ExxonMobil continues its agreement (worth up-to $60 million) with FuelCell Energy and Global Thermostat to venture Direct Air Capture technology
- Hydrogen (H_2), as a low-carbon energy carrier, has received a great deal of attention recently. Low-carbon H2 from natural gas with CCS has cost and scale advantages compared to H_2 from electrolysis in the near and medium term. This is expected to drive the CCUS market to a great extent.
- Shell plans to have access to additional 25 million tons per annum of storage capacity by 2035.

KEY CHALLENGES FOR CCUS

CHALLENGES	DESCRIPTION
High deployment cost and dependency on oil price	Low oil prices can undermine the commercial viability of projects that couple CCUS with EOR. Costs and commercial viability of CCS are harder to predict because of the complex nature of the carbon transport and storage infrastructure needed for the technology to work.
Parasitic load on power plants	CCS imposes relatively large parasitic load on a power plant, the majority of which is due to capture, especially the energy needed to regenerate the solvent. The deployment of a carbon capture system at a power plant results in a parasitic load of 20-30% for CO2 capture and compression, with net plant efficiency dropping from 38% to 27%, thus presenting a challenge to its deployment. Source
Doubt about the success of CCUS	Stakeholders have largely remained sceptical of the CCS technology because of the **negligible progress on the deployment of this technology in the last two decades**, the perverse incentive it presents to postpone mitigation actions, and the potential increase in the cost of power generation if this technology is deployed
Source: MarketsAndMarkets, ADB, CEEW	

GLOBAL INVESTMENT IN CCUS PROJECTS

- Since 2010, around USD 15 billion in capital has been invested in the **15** large-scale CCUS projects.
- Plans for more integrated CCUS facilities have been announced since 2017, mostly in the US and Europe, although projects are also planned in Australia, China, Korea, the Middle East and New Zealand.
- Projects at advanced stages of planning represent a total estimated investment of more than USD 27 billion, almost double the investment in projects commissioned since 2010.

Region	Initiative	Budget	Scope
UK	CCS Infrastructure Fund	USD 1.37 billion	The fund aims to develop four carbon capture and storage hubs and cluster projects across UK by end of decade with vision to reach net-zero by 2050. Additional USD 0.2 Billion has been announced for CCUS under UK 10-point plan.
Norway	CCS Infrastructure and Support Fund [Longship CCS project]	USD 1.83 billion	The fund aims to support CCS infrastructure and create a whole new value chain that is needed to deliver on the Paris Agreement.
European Commission	ETS Innovation Fund	Total fund: USD 11.9 billion (part of which will be allocated to CCUS)	The fund aims to support low-carbon technologies including CCUS, renewables, and energy storage to achieve carbon neutrality in Europe.
United States	Federal funding to support the development and advancement of carbon capture technologies	USD 72 million	The support aims to support research and development of coal and natural gas power plants' projects and remove CO_2 from the atmosphere. Out of the total federal funds pledged, USD 51 million has been awarded to nine projects in power plants and rest is for 'direct air capture'.
	Section 45Q Tax credit	---	Section 45Q tax credit is one of the most aggressive CCS-specific incentives providing break-even cost estimate ranges from 5 USD/t-CO_2 to 60 USD/t-CO_2
India	DBT-DST-ACT support for R&D in CCS	USD 1.19 million (INR 8 crore)	DST participated in multilateral ACT (Accelerating CCS Technologies) programme that is focused on accelerating CCUS technologies. Current plan is to support four projects, with each receiving around USD 0.3 million (~INR 2 crores).
Australia	Support fund for CCUS [part of larger new energy technology package (USD 1.5 billion)]	USD 39 million	The fund will provide targeted support to a wide array of carbon capture, use and storage opportunities, including carbon recycling, etc.
Canada	Tax incentives for CCUS adoption	---	As a part of green programs in the budget, 50 per cent reduction in income tax rates is announced for businesses that manufacture zero-emission technologies as well as tax incentives to adopt carbon capture, utilisation and storage (CCUS).

Sources: IEA, Global CCS Institute (2020b,c); Reuters (2020); USA DoE (2020); European Commission (2019); DST-ACT (2020); The Guardian (2020); UpStream (2020a); UpStream (2021); IHS Markit (2021), CEEW.

GLOBAL STATUS OF CCUS IN THE THERMAL POWER SECTOR

CCUS ACROSS THE GEOGRAPHIES AND IN THE THERMAL POWER SECTOR

- In general limited research, finance and policy support until recently. However, financial incentives have been growing across the globe to support the exploration and adoption of CCUS**.** Concern for climate change and policy support - momentum for CCUS has grown substantially now
- Currently, already 14 countries have declared CCS to be part of their NDC Nationally Determined Contribution (NDC).
- Boosted by sustainable recovery plans and net zero goals, governments and industry have committed more than USD 18 billion to CCUS-specific projects and programmes since early 2020.
- Combining bioenergy with CCUS - potential to deliver negative emissions, offsetting emissions in harder-to-abate sectors.
- Only one commercial power plant equipped with CCUS in operation today

Source: IEA, Economics Times. CEEW

During January 2020 and August 2021 - Close to 30 new CCUS-equipped power plants (totalling a capture capacity of just over 30 Mt CO2 per year) were announced in the US - driven by incentives announced. Close to 40 power plants with CCUS globally.

STATUS OF CCUS IN INDIA AND RELEVANCE FOR INDIAN POWER SECTOR

CCUS STATUS IN INDIA

No concrete policy and regulation at the moment. Although, The Ministry of Petroleum and Natural Gas (MoPNG) has issued Draft 2030 Roadmap for Carbon Capture Utilization and Storage (CCUS) for Upstream E&P Companies.

ONGC has identified an EOR project at its Gandhar field in Gujarat, which will use CO2 captured at and shipped from Indian Oil's Koyali refinery in the state. The draft has identified several reservoirs in Gujarat, Assam and other places for carbon storage.

CCUS is far from becoming mainstream in next 5-10 years, the GoI and the Indian industry are trying to understand the technology's techno-economic feasibility and scalability.

As per the draft recommendation - CCS/CCUS may be included in the National Climate Action Plan (NAC) as part of long-term strategy of mitigating climate change. This could driver the focus on CCUS.

CCUS RELEVANCE FOR INDIAN POWER SECTOR

- The power sector in India accounts for 49 per cent of total CO2 emissions. The electricity demand in India is expected to grow at a compound annual growth rate (CAGR) of 5 per cent during 2018-40.
- Coal based generation to remain a dominant source till 30-40 years in India. Although GOI is currently focusing decarbonization through rapid RE capacity expansion.
- CCUS can be retrofitted to existing power and industrial plants, which could otherwise still emit 8 billion tonnes (Gt) of carbon dioxide (CO2) in 2050.
- All the units where CCS need to be installed – first need to be upgraded with FGD systems for SOX/NOX treatment.

Source: MarketsAndMarkets, MoPNG. CEEW

CASE STUDIES OF EXISTING THERMAL POWER PLANTS WITH CCUS

RETROFIT AT BOUNDARY DAM PROJECT

- **The retrofit at Boundary Dam** involved adding an amine-based CO2 capture plant to remove 90% of the CO2 in the flue gas, compress it and inject it into a pipeline to an oil production operation. Most of the CO2 is used for enhanced oil recovery (EOR)* and the power plant operator is paid for the CO2 it supplies.
- Boiler modifications were also made: the old steam turbine was replaced with a new state-of-the-art turbine.
- An FGD system was added to remove virtually all of the SO2 from the flue gas.
- Energy requirements have been minimised by using a combined SO2/CO2 capture system and with selective heat integration.

- After allowing for the energy requirements of the capture plant, the net generating capacity of the retrofitted Unit 3 was reduced to 120 MW from 140 MW, and the refurbishment extended its life by at least 30 years.

PETRA NOVA FACILITY

- **The Petra Nova facility**, which operated from January 2017 to May 2020, had the largest post-combustion carbon capture system installed (240 MW) on a coal-fired power plant. It could capture up to 1.4 Mt CO2 annually, and the captured CO2 was used in enhanced oil recovery, a process in which CO2 is injected to extract oil that is otherwise non-recoverable. However, low oil prices associated with Covid--19 economic impacts resulted in capture operations being suspended in May 2020.
- The captured CO2 was compressed and transported via a 130-km pipeline to the West Ranch oil field, for injection for EOR at a depth of 1-2 km.
- A key difference between the Boundary Dam and Petra Nova facilities is that steam and power for the capture unit at Petra Nova are provided by a 75-MW gas-fired co-generation unit that came online in 2013. As a result, the retrofit did not result in a de-rating of the existing asset because steam and power from the base plant was not redirected for CO2 capture.

* CO2-EOR is a proven technology for rejuvenating the production of oil at mature oilfields but can also provide a means of storing CO2 permanently. For a CO2-EOR/CCUS project to be considered a genuine climate mitigation measure, the CO2 has to come from an anthropogenic source, such as a power station or natural gas processing plant.

Source: IEA

CONCLUSION AND WAY FORWARD....

- Decarbonization is inevitable if climate change to be restricted below 2 degrees of warming relative to pre-industrial levels.
- Hydrogen and CCUS both are most promising decarbonation options, but both are nascent stage of deployment but offering the a multi-trillion-dollar opportunity of investment while playing a vital role in achieving net-zero target and creating a low carbon economy.
- Coal thermal-based generation is not easily replaceable and retrofitting it with CCUS make its comparable to clean sources of energy.
- High cost of capital and generation (nearly 63–75 per cent increase in the base cost of generation) (Rao and Kumar 2014) has been a significant barrier to adopting CCUS technology d so far. However, with
  - With increasing government support to reduce CO2 emissions from industrial and power plants is creating opportunities for investors and bolstering the growth of carbon capture, utilization, and storage market.
    - GoI has also issued a draft policy roadmap - 2030 for E&P companies
    - India has voluntarily committed to reducing GHG intensity of its GDP by 33-35% below 2005 levels by 2030
- There is a need of a roadmap to retrofitting coal based thermal power generation with CCUS for India. The ecosystem should be built and strengthened around the essential pillars - R&D, policy, finance, and governance. Hope, GoI may be working on this to achieve the set goals around Net-Zero in long term.

.....AND HOW MARKETSANDMARKETS CAN HELP YOU IN CCUS MARKET

- What is the current state of carbon capture and utilisation (CCU) technologies, and commercialisation roadmap?
- What is the current state of adoption of CCU across sectors?
- Who constitutes the carbon capture value chain?
- Who, where and how many industry participants (customers) have adopted CCU technologies in their plants?
- Which criteria are most likely to drive the selection of a specific CCU/CCUS process? What specific geographic variances may influence the selection of specific CCU processes?
- Customers' perception of the need, willingness to invest and criticality of adopting CCU/CCUSs?
- What kind of policies and regulations should be adopted to make CCUS as success?
- What is Right-to-Win for CCUS adopted by different competitors?

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