Role of CCUS in India's energy sector

Final Report-Presentation

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Building a better working world

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Project Scope & Objectives - Status update

	Duration	Module	Objectives	Deliverables
0	1 week	Project Mobilization	▸ Articulation of core outcome expectation ▸ Capture inputs from FIPI ▸ Agree deliverable formats, team and mobilize	Kick off presentation
1	3 weeks	Market assessment for CCUS deployment and its drivers	▸ Define CCS & CCU value chain at a high level **1a. Role of CCUS** ▸ Assessment of CCS's role in reaching net zero targets (Major countries) **1b. CCS project tracker** ▸ Track progress of CCS deployment in major geographies **1c. Monitor CCUS trends** ▸ Highlight the factors determining CCUS deployment in major geographies & risks **1d. India story** ▸ CCS development status ▸ CO_2 capture potential by major sectors ▸ CO_2 demand (utilization)	Study presentation
2	9 weeks	CCUS value chain assessment (Technology, cost trends, maturity & LCA assessment)	**2a. CO_2 capture tech assessment** ▸ Deployable CO_2 technology options, TRLs, major players (Global) **2b. CO_2 transport assessment** ▸ Through pipelines, road, rail, water – existing technologies, options, and ability to set up new CO_2 pipelines ▸ Risk assessment for CO_2 transport (focus on pipeline transport) **2c. CO_2 storage assessment** ▸ Greenfield/ brownfield storage infra development in depleted fields, caverns ▸ Risk mitigation measures for CO_2 leak **2d. CO_2 utilization** ▸ CO_2 monetization end uses assessment ▸ Handling of liquid CO_2 & other op. issues **2e. LCA assessment** ▸ Lifecycle emissions for CCS value chain ▸ CCS site monitoring protocol	Study presentation
3		Regulation assessment and Carbon pricing trends	**3a. Global policy benchmarks** ▸ Policy/incentives (in USA, UK, EU, Canada, Australia) across CCUS value chain with support from Carbon markets ▸ Regulations for laying CO_2 pipes in mature markets ▸ Permits for CO_2 storage **3b. India regulatory & Carbon pricing trends** ▸ CO_2 price forecast in India and global for next 15 year ▸ Analyse the need for other incentives like guarantees, PTC etc. in India ▸ Assessment of green financing opportunities	Study presentation
4		Techno commercial assessment	**4. Tech commercial feasibility** ▸ CCU tech comparison with renewables & other decarb options ▸ Business model assessment ▸ High level economic model for CCUS (base case) ▸ Scenario analysis (for Capture, transport & storage/use options)	Presentation Excel model
5		Recommendation & way forward for CCS deployment in India	**4. Recommendations** ▸ Recommendations on policy support & tax framework, subsidisation / incentivisation mechanisms for CCUS adoptions ▸ Implementation roadmap to scale up CCUS deployment in 10 -15 years ▸ Support with white paper on subsidy support to govt. to encourage investment	Final report with recommendations

Completed

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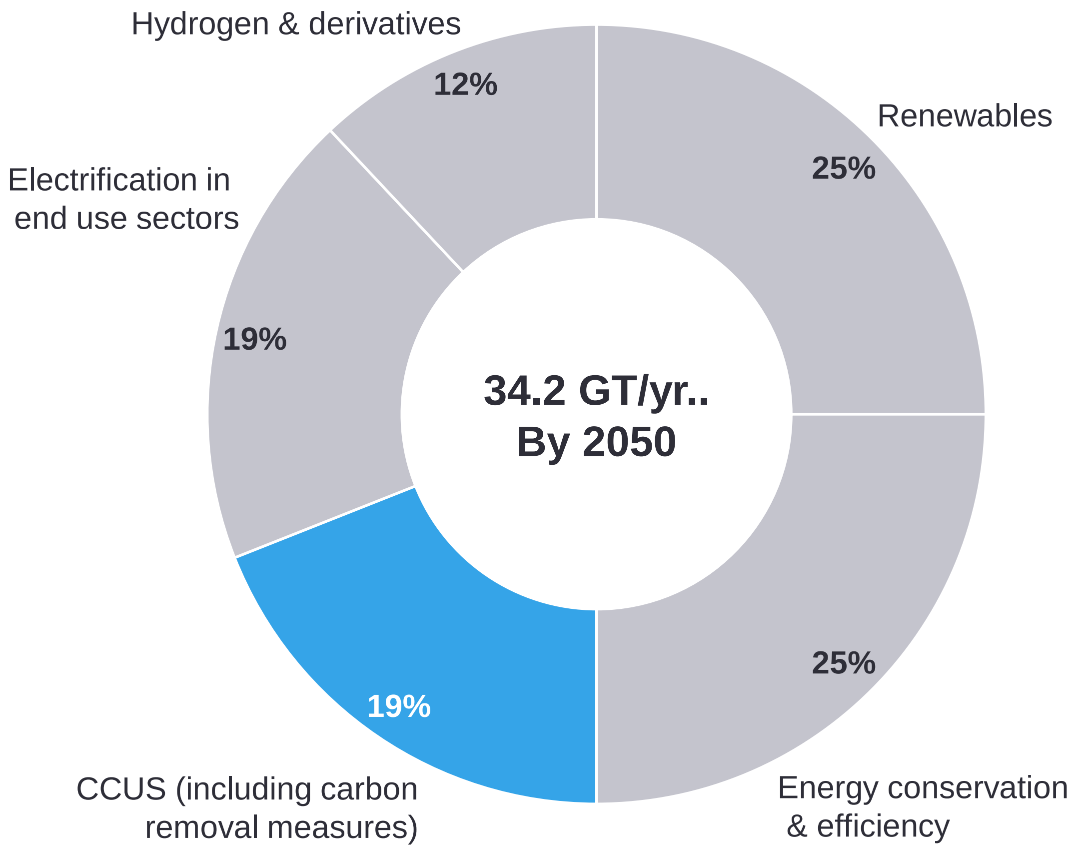
Introduction to CCUS

CCUS is a critical lever to reach the overall CO_2 reduction targets by 2050; with potential for decarbonization in hard to abate industrial sectors

Levers for Carbon emissions abatement under 1.5°C scenario



Role of CCUS to achieve net zero emissions

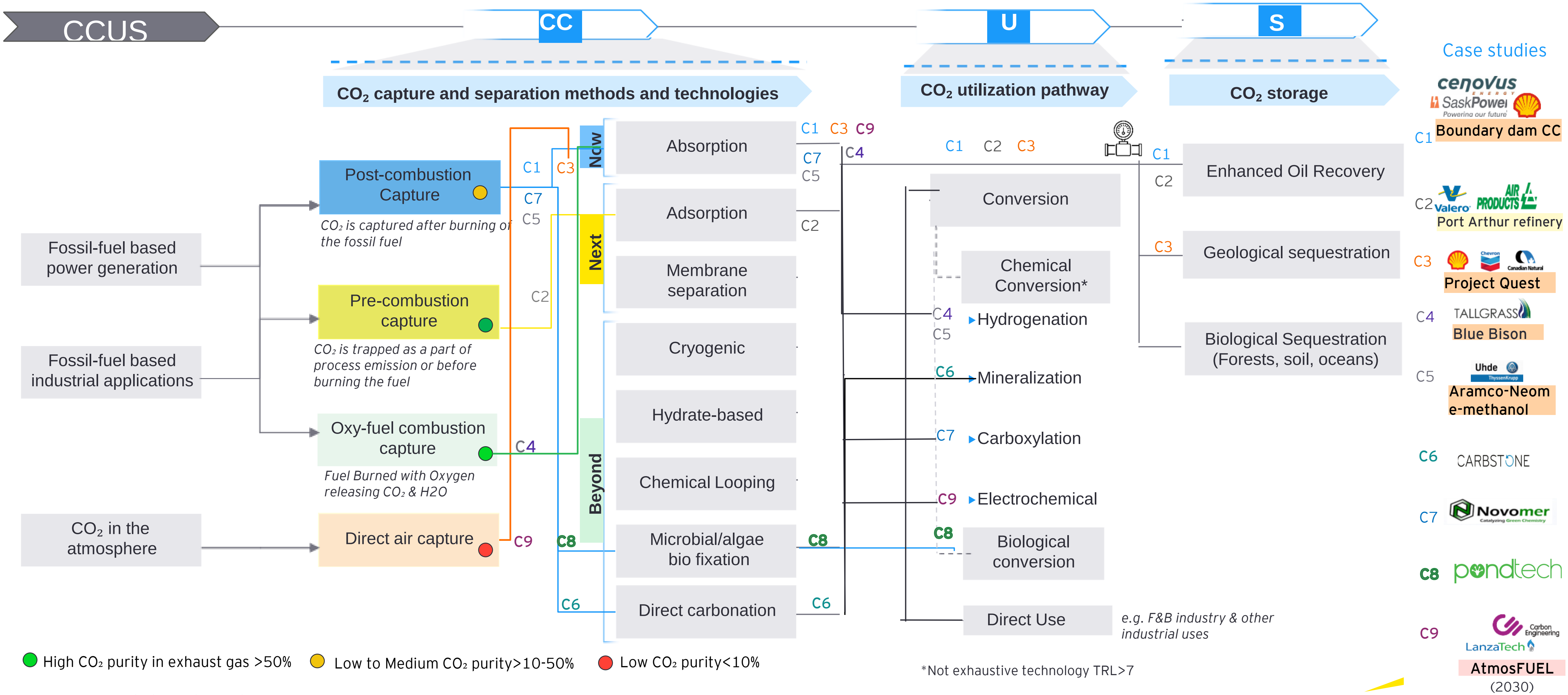
- **Achieve deep decarbonization in hard to abate industrial sectors**
  - The cement, iron and steel, oil & gas and chemical sectors emit Carbon due to the nature of their industrial processes with CCUS being one of the mature and cost effective options for deep decarbonisation of hard to abate industry
- **Enabling the production of low Carbon hydrogen at scale**
  - Coal or natural gas with CCUS is currently the most cost-effective way to produce low-Carbon hydrogen
- **Potential to deliver negative emissions (from atmosphere & bio sources)**
  - Residual emissions in hard-to-abate sectors need to be compensated for CCUS. It provides the foundation for technology-based Carbon dioxide removal, including bioenergy with CCUS (BECCUS) and direct air capture (DAC)
- **Provide low Carbon electricity and improve grid resilience**
  - Decarbonising power generation is crucial to achieve net-zero emissions. CCUS complements renewables, helping make the low-Carbon grid of the future

Source: IRENA Energy transition outlook 2023, Industry reports, EY-P analysis

Value Chain Assessment for CCUS

After being captured during various steps in the production process Carbon can either be utilized in diverse industrial processes or can be sequestered

CCUS Value Chain



🟢 High CO_2 purity in exhaust gas >50% 🟡 Low to Medium CO_2 purity>10-50% 🔴 Low CO_2 purity<10%

*Not exhaustive technology TRL>7

Source: EY-P Strategy Edge Analysis

The separation of CO_2 molecules contained in waste/flue gases can be realized through 4 main technologies

Carbon separation technologies

Absorption (solvents based)*

Chemical: Ethanolamine (MEA), caustic, ammonia solution, etc.

Physical: Selexol™, Rectisol, Fluorinated solvents, N-Methyl-2-Pyrrolidone (Purisol®)etc.

Linde, Axens, Air Liquide, carbon clean, Mitsubishi Heavy Industries

Boundary Dam CCS, USA

Adsorption (sorbents based)*

Physical: alumina, zeolite, activated Carbon, CaO, MgO, Li_2ZrO_3, Li_4SiO_4

Linde, Air Products, Air Liquide, Shell, Svante

Port Arthur Refinery, USA

Membranes

Polymer based: Polyphenylene oxide, Polyethylene oxide, Poly ionic liquid

Inorganic membrane: ceramic based, zeolite based

Linde, JGC, Honeywell, GENERON

CEMEX, USA

Liquid or supercritical CO_2

Dry ice formation at low temperature; separation affected by a series of compression, cooling, and expansion steps

Linde, Air Liquide, Air Products

Novel technologies

Microbial and algal systems

Electrochemical pumps

Chemical looping

Molten carbonate fuel cell

Mineral Carbonation

*Require to be regenerated: pressure swing, temperature swing, moisture swing, or a combination thereof

Source: IEA, AT Kearney, GCC Institute, EY-P analysis

Full report is available to the members on request. Please note the final report has been submitted to the study partners namely- BPCL, GAIL, HPCL, HMEL, IOCL, Nayara, ONGC, and OIL.