Harnessing carbon capture to boost India's methanol energy security and economy

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India has an ambitious goal of adding 450 GW of renewable energy by 2030. According to the Central Electricity Authority, the country has 147 GW of installed capacity as of May 2024. We must add 50 GW per annum in the next 6 years to meet the target set for 2030. Any shortfall is likely to be met by coal, complicating our emission reduction goals. Therefore, the exploration of alternatives that can complement mainstream renewable energy options is not just a choice but a necessity.

Carbon capture, utilisation, and storage (CCUS) is a promising option for hard-to-abate sectors such as coal power, cement, and steel production. According to the NITI Aayog, India has a theoretical CO2 storage potential of 400–600 Gt, but the infrastructure requires a 10-year gestation period. Therefore, immediate attention needs to be directed to carbon utilisation methods. Imagine a future where carbon emissions from hard-to-abate sectors are raw materials for producing essential chemicals.

CO_2 has various applications in industries (enhanced oil recovery in oil fields, chemicals production, and food and beverage), agriculture (fertilisers and increased photosynthesis efficiency), energy (biofuels), materials, medicine, and so on. However, utilising captured CO2 to produce green methanol is a less explored area. The domestic demand for methanol in India is mainly met through imports. It is used as a raw material in manufacturing paints, adhesives, plywood, and acrylic fibres and as a blended fuel in internal combustion engines.

According to the Ministry of Chemicals and Fertilizers, India imported 23.2 million tonnes (MT) of natural gas (48% of its demand) and 2.4 MT of methanol (94% of its demand) in 2021–22, costing INR 1 lakh crore and INR 7,400 crore, respectively. The growing demand for methanol will increase imports and expenses. Alternative production routes are vital to minimise import dependency and increase domestic energy security. Captured CO_2 has the potential to avoid imports by producing green methanol domestically.

Potential sources for CO_2 capture

There are two main CO2 emission sources: point and non-point. Point-source emissions are released from a single source, such as coal power, steel, and cement plants. Non-point-source emissions are released from multiple sources, including transport, residential, and other dispersed sectors. It is difficult to capture CO2 emissions from non-point sources, and the technologies capable of doing it are still evolving. Point sources, on the other hand, except methane and fluorinated gases, provide the flexibility of capturing higher concentrated CO_2, leading to minimal capture investments (INR 0.3–1.0 crore / tonnes per day). According to a recent report, India

emitted a total CO_2 of 3 Gt in 2022. Of these emissions, 60% is from point sources, which can be captured and utilised.

CO_2-based methanol

Hydrogenation is an innovative technology that utilises captured CO_2 and green hydrogen to produce green methanol. For every kilogramme of methanol produced, 1.5–2.4 kg $CO_2$and 0.2–0.4 kg H_2 is required. Capturing 0.25% of emissions from point sources can meet India's methanol demands without importing.

However, commercial methanol production using captured CO_2 and green hydrogen has not yet started in earnest in India. India can take the lead from plants across the globe that are in various stages of operation, construction, and planning. The George Olah plant in Iceland produces 4,000 MT of green methanol annually by recycling 5,500 MT of CO_2 released from an adjacent geothermal power plant. The Cepsa and C2X project in Europe plans to produce 3 lakh MT of methanol using 1 MT of CO_2 by 2025.

Investments in CO2-based methanol

According to our analysis, the total capital expenditure to avoid imports with domestic CO_2-based methanol production is INR 8,980–16,750 crore. The operational expenses, including capture, transport, and manufacturing, amount to INR 19,600–21,000 crore. Seventy-eight percentage of operational expenses include procuring green hydrogen (INR 300–400 per kg), catalysts, energy, and auxiliaries.

The investment required to capture CO_2 varies by plant size and industry type. Capturing 1 tonne of CO2 per day needs an investment cost of INR 0.3–1 crore. Manufacturing 1 tonne of green methanol from this CO2 costs INR 0.7–0.8 crore in investment and INR 2.6–3.0 crore in operational expenses. Conventional methanol production (1 tonne per day) and operation costs INR 1.9 crore and INR 0.9 crore, respectively.

Avoiding the import of 2.4 MT of methanol can reduce the import bill by INR 7,400 crore per year. Developing CO_2-based methanol plants can generate positive revenues (INR 800 crore per year) when methanol is sold at a threshold price of INR 85 per kg. The estimated payback period for these plants is around 11 years.

Conventional methanol is sold at INR 32–40 per kg. However, green methanol needs to be INR 45–50/kg higher to be economically viable. To compete, subsidies for capital investment and lower raw material costs are essential. Producing green methanol at import levels can abate 4 MT of CO_2, resulting in an abatement cost of INR 35/kg. Offering this abatement cost as a subsidy, along with performance incentives, will ensure sustainability and quick payback periods for green methanol plants, thereby promoting the methanol economy through carbon capture initiatives.

Not in the distant past, India’s solar photovoltaic ambitions looked unattainable, but now it is affordable and available in our neighbourhoods. Similarly, if we think ahead and implement CCUS, we can turn it to our advantage and emerge as market leaders.