Technology to convert methane and carbon Dioxide into eco-friendly biofuel

The emission of greenhouse gases, such as methane (CH_4) and carbon dioxide (CO_2), has been rising tremendously at an alarming rate. Moreover, the global warming potential of methane is estimated to be 27-30 times higher than CO_2. Therefore, researchers worldwide are striving to combat the issue by exploring ways to convert these greenhouse gases into liquid fuels and other value-added chemicals. Although, there are numerous chemical methods to catalytically convert methane and CO_2 into useful chemicals, these chemical routes are constrained by the requirement of: (i) expensive catalysts; (ii) extreme process conditions such as, temperature and pressure as high as 850 °C and 100 bar, respectively; and (iii) generation of toxic by-products, *e.g.*, carbon monoxide; which make the overall process energy-intensive, as well as economically and environmentally non-sustainable. Hence, it becomes necessary to explore sustainable biological alternative routes for capture and bioconversion of the major greenhouse gases. Similarly, there has been a rise in energy demand, leading to rapid depletion of non-renewable fossil fuel reserves and surge in fuel prices, which is further causing extreme environmental pollution, global warming and climate change. This mandates the need to search for non-petroleum based cleaner and renewable alternative fuels.

Our research team at the Bioprocess Development Laboratory of the Department of Biosciences & Bioengineering has developed a technology for the biological conversion of methane and carbon dioxide into methanol (a potential biofuel) utilizing methanotrophic bacteria (*Methylosinus trichosporium*) as biocatalyst. Based on the ability of the methanotrophic strain to metabolize methane and CO_2, we developed a sequential two-stage integrated process, wherein the first stage involved sequestration of methane to produce methanotrophic biomass, which was utilized as biocatalyst in the second stage to convert CO_2 into methanol. Our patented technology (Sahoo et al. 2023, Indian Patent No. 447607), being a completely biological process overcomes the constraints associated with the conventional chemical processes used for methane and CO_2 sequestration and methanol synthesis. The process requires mild-operating conditions and do not release any toxic by-products. It also addresses the limitations associated with the mass transfer and solubility of methane and CO_2 from gas phase to liquid phase through the application of novel process engineering strategies, leading to improvement in the yield of methanol.

Furthermore, we have demonstrated “bio-methanol” as an alternative transportation fuel (a potential diesel fuel blend) through analysis of physicochemical properties, and characterization of emission and performance in a four-stroke compression ignition engine (diesel engine). Diesel can be blended with different proportions of bio-methanol (5 – 20% volume/volume). Brake specific emissions of carbon monoxide, hydrocarbons and hydrogen sulphide, and smoke opacity are observed to decrease with increase in methanol content in the blend, attaining maximum decrements of 38.8-46.5%, 39.8-60.7%, 85.4-87.8% and 21.0-27.5%, respectively, with 20% methanol-containing blend (M20) under varying engine loads. Additionally, diesel-methanol blends exhibit better performance characteristics relative to pure diesel (D100) with respect to fuel consumption, brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC), brake thermal efficiency (BTE), air to fuel ratio (AFR) and equivalence ratio, while delivering D100-equivalent output in terms of mechanical efficiency in compression ignition (CI) engine. This research has been published in the journal Fuel, Elsevier (https://www.sciencedirect.com/science/article/abs/pii/S0016236124012900). To the best of our knowledge, this is the first study demonstrating the potential of methanotrophic bacteria-derived bio-methanol as a renewable alternative transportation fuel. Bio-methanol production from greenhouse gases overcomes the problem of biomass limitation and the controversial “food vs fuel” crisis, as are suffered in case of first- and second-generation biofuel production processes (*e.g.*, bio-ethanol, biodiesel), which rely on agricultural crops or lignocellulosic biomass as feedstock (*e.g.*, sugarcane, maize and other sugar-rich plant biomass). This technology can be implemented in potential industries for sustainable sequestration of methane and CO_2 present in flare gases and exhaust off-gases, offering an eco-friendly biological route for decarbonization, and value-addition through bio-methanol production.