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With the highest hydrogen-to-carbon ratio of any liquid fuel, methanol is a superior hydrogen carrier that supports the faster development of hydrogen economies by enabling the adoption of hydrogen as a fuel today. Thus, any investments in India's methanol economy would be an investment in the hydrogen economy of the future. Fuel cells power by methanol can extend the range of a battery-electric vehicle from 200 km to over 1,000 km. It acts as a battery range extender that can be refuelled in a very short time, says **Gregory A. Dolan**, CEO, Methanol Institute, in conversation with **Manu Tayal**, Associate Editor, Energetica India. Mr. Dolan also discussed about the benefits of renewable methanol for Indian economy, its availability, utilization areas, competitiveness, demand, etc. Here're the edited excerpts from that interaction:

Q How significant could be the role of renewable methanol for the Indian economy?

Gregory A. Dolan: Methanol, which has been on the government's agenda since 2016, is a strategic product that can help India achieve its 2070 carbon neutrality vision.

Methanol can be produced from a wide variety of conventional (natural gas and coal) and renewable feedstocks including biomass, municipal solid waste, solar and wind power plus captured carbon dioxide. As a low carbon and net carbon-neutral fuel, methanol offers pathways for significant GHG emission reductions. Compared to conventional fuels, renewable methanol can cut carbon dioxide emissions by up to 95% on a carbon lifecycle assessment (LCA) basis, reduce nitrogen oxide emissions by up to 80%, and eliminate sulfur oxide and particulate matter emissions. These climate and local pollution benefits are compounded when methanol is used as a fuel to lower the carbon intensity of applications such as road mobility, inland waterways, power generation,

cookstoves, and fuel cells. Methanol is also highly complementary with hydrogen, as it can be used as a liquid hydrogen carrier with simple logistics and handling. The benefits to India are twofold, it is able to up-cycle waste to produce a green product such as renewable methanol which can be used as a fuel or a hydrogen carrier that can support the government's vision of a future hydrogen economy and support the country's energy transition.

Methanol is strategic to India's efforts to be more self-sustaining as methanol can be produced with indigenous resources allowing the country to bolster energy security while growing a new domestic industry that will create more economic opportunities within the country. As India stands up its own domestic methanol production, increased imports of methanol will still help the country diversify its access to energy feedstocks from a wider range of suppliers. This will also further accelerate India's energy transition as methanol can be utilized as a low-carbon alternative fuel or feedstock for green chemicals when produced sus-

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tainably. A significant share of India's energy requirement can be met with greater renewable methanol utilization that will create significant opportunities for the Indian economy to gear up for the new energy value chains related to renewable methanol and create significant economic benefits for the nation in its pursuit of a low-carbon economy.

Q What is the state of availability of clean methanol within the country?

Gregory A. Dolan: Renewable methanol production capacity in India is at a nascent stage where there are plans for pilot plants to produce small quantities of renewable methanol with the inten-

tion of scaling up as technological and commercial requirements are met. Last year, NTPC set up a CO₂-to-methanol plant at NTPC Vindhyachal to demonstrate an environment-friendly technology for producing green fuels and chemicals. Industries such as steel, cement, and power utilities can reduce their carbon footprint by producing renewable methanol from carbon dioxide flue gas emissions captured at their facilities. Tata Steel India has indicated their intentions to use larger carbon capture units in the future and utilize carbon dioxide to produce green chemicals like methanol. The market for renewable methanol is expected to expand in the coming years as a significant push is given to renewable energy sources.

Q In which sectors renewable methanol fuel can be used?

Gregory A. Dolan: Hard to abate industries including chemicals and shipping have touted renewable methanol as a promising solution for reducing carbon footprint. Recently the Indian government approached Deccan Water Treatment Pvt. Ltd. and its joint partner ScandiNAOS to promote methanol marine engines for the defence and maritime industry as part of a strategy to bolster energy security and improve air quality. Methanol is a viable, affordable alternative transportation fuel due to its efficient combustion, ease of distribution, and wide availability around the globe. India has set standards for M15 (15% methanol with 85% gasoline) for gasoline engines. Last year, ARAI along with automobile companies like Hero MotoCorp Ltd, Bajaj Auto, TVS, Honda Motorcycle and Scooter launched trials of M15 two-wheelers under the Methanol Economy program spearheaded by NITI Aayog. Methanol is an excellent hydrogen carrier and can also be reformed to produce hydrogen that will be utilized in fuel

cells to generate clean electricity for cell phone towers, construction sites, or ocean buoys. Methanol can also be reformed on-site at fuelling stations independent of the grid to provide hydrogen for fuel cell vehicles, and electricity for charging EVs. The Indian Army has a history of utilizing methanol fuel cells for backup power generation in remote regions.

Methanol is also a useful fuel for heating and cooking purposes. It is used as a cooking fuel in both industrial kitchens and residential settings. Industrial boilers providing process steam and those used in heating for residential buildings can be fuelled with methanol.

Q Up to what extent methanol can compete with other sustainable energy sources like Solar, Wind, Hydro, Biofuel, etc?

Gregory A. Dolan: There cannot be a “one size fits all” solution, and it is important to acknowledge that future energy economies will be comprised of different energy vectors all contributing and completing to deliver on the goal to decarbonize. These energy vectors will all play a role as there are many different sectors/technologies/applications to decarbonize. With India being the third-largest consumer of power in the world -- even as the majority of the population remains unconnected to the grid-- it is imperative to have a diverse supply energy basket.

Renewable methanol supports this vision by providing a reliable source for energy storage of renewable electricity. Due to the intermittency of renewable power (solar, wind, and hydro), renewable energy assets may be curtailed when the grid is operating at the base-load. For load balancing, renewable energy assets can be deployed to produce renewable methanol when they are not supplying renewable electricity to the grid. This enhances the utility of re-

newable energy assets while lowering the risk associated with capital injection needed to increase renewable energy production capacity.

Methanol is a complementary energy product to the emerging sustainable energy products such as hydrogen, ethanol, and EVs. With the highest hydrogen-to-carbon ratio of any liquid fuel, methanol is a superior hydrogen carrier that supports the faster development of hydrogen economies by enabling the adoption of hydrogen as a fuel today. Thus, any investments in India’s methanol economy would be an investment in the hydrogen economy of the future. Fuel cells power by methanol can extend the range of a battery-electric vehicle from 200 km to over 1,000 km. It acts as a battery range extender that can be refuelled in a very short time.

The ambitious goal of E20 ethanol blending by 2025 can pose a challenge in terms of the supply of ethanol and pressure on land and food resources. The introduction of gasoline-ethanol-methanol (GEM) blends could support achieving the target by reducing the burden on ethanol producers and fuel retailers to maintain high levels of ethanol production. GEM blends have been tested and trailed by countries like Italy and Australia.

Methanol can work in tandem and draw synergies to support and complement sustainable energy options.

Q How safe and cost-competitive methanol is if we talk about its mass production and usage in the Indian scenario?

Gregory A. Dolan: Over the course of the last century, methanol has been a globally traded commodity with annual trade of over 100 million metric tons or 125 billion litres. This has led to the development of infrastructure that supports the safe and efficient logistics of producing, storing, and transport-

ing methanol. Globally, there are also recognized standards and guidelines on its safe handling. Being a liquid at ambient temperature and pressure, methanol does not require complex equipment or processes for its handling. This contributes to its ease of handling as it can be transported and stored just like other liquid chemicals or petrol.

IMO has approved a regulation on the storage and handling of methanol on-board ships. It is a cost-effective solution that can immediately enable the utilization in different applications like power generation and mobility. With a mature supply chain that extends throughout different markets, methanol will help lower the cost of storage and infrastructure needed to transport, store, and dispense it safely over long distances. It offers India a viable and practical alternative fuel that can be produced with indigenous resources, creating jobs and economic opportunities domestically while reducing the country's energy import reliance.

Q How can India attract investment into this sector?

Gregory A. Dolan: The government can help foster a low carbon fuels ecosystem that will attract investments in methanol. This includes policy interventions in the research and development of technologies for the production of methanol with sustainable feedstocks. Incentives to promote the development of the methanol value chain are a significant step to expand the supply and demand. The Budget 2021-22 recently announced the reduction in import duties in methanol to enhance domestic value addition. This is a welcome move sending a strong signal that the government will support the creation of the methanol value chain to create more economic opportunities in India's energy transition. As methanol can now be imported at a lower cost

it will encourage the uptake of methanol applications to spur local production of methanol in the long run. This enhanced domestic manufacturing will support in creating a robust methanol value chain across the country.

Q What could be the production pathways for methanol in India?

Gregory A. Dolan: Conventionally, methanol is produced from coal and natural gas. India is rich in coal reserves that can support the production of methanol. The National Coal Gasification Mission aims for 100 MT of coal gasification by 2030 to produce utility chemicals including methanol. We acknowledge that it is a resource that India can tap into but also note that carbon capture utilization and storage (CCUS) technology must grow on a parallel track to reduce the emissions generated in the coal-to-methanol production process.

India has diverse sustainable feedstocks— such as captured carbon dioxide, municipal solid waste (MSW), and agricultural residue for the production of renewable methanol which is a carbon-neutral hydrogen carrier that offers a pathway for the energy transition.

Bio-methanol produced from biomass feedstocks holds great potential to meet the growing energy demand and support the rural economy of the country. Indore was adjudged the cleanest city for the fifth year in a row in the Union government's annual survey. The Indore Municipal Corporation earns INR 80 million annually from the plants which convert waste into useful biofuel products. This could be amplified and extended to pan-Indian cities where bio methanol could support efficient waste management systems, provide economic opportunities, and reduce carbon footprints.

Q What kind of challenges and barriers do you see in India to augment renewable methanol?

Gregory A. Dolan: India has a wide availability of feedstock for the production of bio-methanol that can create new economic value in the form of chemicals and fuel, but the production volumes are low. Inaccessibility of these feedstocks exacerbates the situation. Lack of financial incentives and resource allocation to support the infrastructure for handling methanol, and limited ongoing projects are some of the barriers that the country must address. Inadequate policy measures to encourage low-carbon fuels hinder the demand generation for their applications.

Q What will be your recommendations for the Indian policymakers to mitigate the challenges?

Gregory A. Dolan: Policy interventions to encourage the role of low carbon and net carbon-neutral fuels like renewable methanol would strengthen the country's energy security and offer India a viable and practical alternative fuel that can be produced with indigenous resources. Investments in dedicated pilot and demonstration of renewable methanol technologies with the inclusion of the private sector could enhance the scale-up of the renewable methanol. Beyond policies to support production, there should also be a focus on demand creation for renewable methanol in the Indian market. There is a need to develop a supportive policy landscape that creates commercial opportunities for the increased adoption of methanol for different applications such as mobility and power generation. Additionally, India could also look at the scope of expanding its markets internationally positioning itself as an international hub for renewable methanol production with the intention of exploring exporting opportunities.