

# Methanol Fueling India's Hydrogen Aspirations

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## The Methanol Institute (MI)

The Methanol Institute (MI) is the global trade association for the methanol industry, representing the world's leading producers, distributors, and technology companies. Founded in 1989 in Washington DC, MI now represents its members from five offices around world in Washington DC, Beijing, Brussels, Delhi, and Singapore. MI serves its members as the voice of the methanol industry, representing companies within the membership to governments and businesses around the world to promote the sustainable growth of the industry. MI focuses on advancing the utilization of methanol as a clean fuel in energy-related applications such as land & marine transport, power generation, fuel cells, industrial boilers, and cook stoves. MI also supports sustainable and renewable process to produce methanol as a carbon-neutral chemical and fuel. [www.methanol.org](http://www.methanol.org)

## The Indian Methanol Economy Coalition (IMEC)

The Indian Methanol Economy Coalition (IMEC) is first of its kind in India to support a future where methanol plays a pivotal role in sustainability and energy security in India. It is a platform that brings diverse stakeholders interested to come together with a common goal of augmenting the methanol economy. Through the power of community, it acts as the voice to stimulate a favorable climate for the methanol industry. Through collective advocacy, IMEC works with its members to promote the adoption of methanol as an energy product and serves as a body that will represent the entire value ecosystem the methanol economy.

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## Executive Summary

India is globally ranked third in power consumption and the primary energy demand is set to increase two-fold by 2040. To meet its energy needs, the country is expanding its energy portfolio, in particular the country's share of renewable sources. Renewable energy is expected to form 70% of fresh capacity expansion expected over the next 5 years. There is significant interest in alternative sources to reduce India's dependence on imported fuels, with consideration given to fuels with superior emission scorecards to lower the country's carbon footprint. India has increased its momentum to reduce the carbon footprint and diversify its energy portfolio to introduce hydrogen in the energy system. A number of key developments such as the launch of India's National Hydrogen Energy Mission suggests that hydrogen will play an important role in combating climate change. However, to achieve realistic goals it is important to focus on adopting a progressive roadmap which involves practical solutions that can lead to the ultimate realization of the country's hydrogen aspirations. There are solutions available today that allow for the deployment of hydrogen without the technological and cost challenges associated with storing, transporting, and utilizing hydrogen.

Methanol is a solution which is available today. Methanol's adoption as a hydrogen carrier allows the Indian economy to build the foundation of its future hydrogen economy. Investments in methanol production, utilization, and infrastructure supporting its logistic are investments made for a future hydrogen economy that deliver immediate economic returns today. This report presents the potential of methanol as a hydrogen carrier, addresses policy gaps in the Indian context, and proposes recommendations to promote faster adoption of methanol and hydrogen. Some of the key policy recommendations include:

1. Acknowledge methanol as a hydrogen carrier. Methanol and hydrogen are complementary energy products, and methanol offers roadmap to a future hydrogen economy by enabling hydrogen utilization today.
2. Develop a supportive policy landscape that creates commercial opportunities for the increased adoption of methanol as a hydrogen carrier for different applications such as mobility and power generation.
3. Encourage investments in R&D and pilot activities to promote the adoption of methanol as a hydrogen carrier.
4. Promote the development of methanol supply chains in India to ensure seamless storage and delivery of methanol as a hydrogen carrier to end-users.

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## Introduction- India Energy Mix

As one of the world's fastest-growing economies, India is experiencing rising urbanization and a growing middle class. The country will account for 25% of the rise in global energy use by 2040 and will have record growth in energy demand over the next several decades. India's energy portfolio continues to be heavily dependent on fossil-based sources. Coal accounts for over 57% of India's electricity production.

India's primary consumption is majorly met by coal (45%), followed by petroleum and other liquids (26%), and traditional biomass and waste (20%). Natural gas accounts for 6% of the energy consumption and about 3% from other renewable sources (solar, wind, hydroelectricity and nuclear).<sup>1</sup> By 2040, 42% of this new demand (25% of the rise in global energy use by 2040) will be met by coal, and the country is projected to be among the largest oil consumers. India contributed 2.48 billion tons of carbon dioxide (CO<sub>2</sub>) in 2019, which amounted to 7% of global CO<sub>2</sub> emissions.<sup>2</sup> The country's rising carbon footprint and hefty import bill on oil and gas are causes for concern as energy demand grows.

To address these challenges, the country has been swiftly shifting towards renewable energy technologies. A considerable increase in renewable energy capacity has been observed in the last decade. However, renewable energy will not be the panacea to the challenges of transitioning India's energy landscape. In 2016, methanol was identified as an alternative fuel that can be produced with indigenous resources, decarbonize the transport sector, and even offer a pathway to a future hydrogen economy. More recently, the Government of India announced its ambitious plans for a domestic hydrogen economy. This paper will show how methanol and hydrogen are complementary energy products that will prove strategic in India's roadmap to decarbonization and energy security.

## Regulatory landscape on climate change: Hydrogen Economy

### National Hydrogen Energy Mission

India announced its ambitious and promising National Hydrogen Energy Mission (NHEM) during the Union Budget of 2021. It is indicated that the proposal in the Budget will be followed up with a mission draft and a roadmap for using hydrogen as an energy source. Specific focus would be on green hydrogen dovetailing India's growing renewable capacity with the hydrogen economy. Recognized as one of the most promising sources of energy, having environmental benefits, hydrogen will play a future role in transitioning India's energy consumption towards climate-neutrality and support in reducing associated health hazards due to air pollution.

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## Challenges to the Hydrogen Economy

There are substantial challenges associated with the adoption of hydrogen as a commercially viable energy product. According to a recent report by The Energy and Resources Institute (TERI), all hydrogen currently consumed in India comes from fossil fuels. Fossil-based hydrogen has a significant carbon footprint and will not contribute to the country's goal of reducing its carbon footprint. While the target is to produce nearly 80% of India's hydrogen with renewable electricity by 2050, there are significant gaps to bridge between today's reality and those ambitions:

- **Renewable Energy Supply:** India has made a commendable effort to increase its renewable energy production capacity in the last decade. However, renewable energy capacity in the country will have to increase significantly to accommodate the production of green hydrogen which is targeted to contribute 80% of India's hydrogen supply by 2050. The production of green hydrogen through electrolysis and renewable electricity is an energy-intensive process which requires approximately 50 – 55 kWh of electricity for every kilogram of hydrogen.<sup>3</sup> This challenge is exacerbated by the intermittent nature of renewable energy, and the country will have to significantly increase its renewable energy capacity to be able to reach its 80% target by 2050.

India's target to produce 80% of its hydrogen supply with renewable electricity also presents a competing agenda to its target to generate 40% of its electricity from non-fossil fuel sources by 2030.<sup>4</sup> To achieve both targets, there will be significant pressure to expand the renewable energy capacity in the country. Beyond the significant cost associated with the expansion, these competing policies threaten the realization of both targets.

- **Cost of Production, Storage, and Transport:** Given the current maturity of electrolyzer technologies, the cost of producing green hydrogen is high. These costs are expected to decrease over time, but India's hydrogen economy vision will be constrained by the speed at which these costs diminish.

As a highly volatile gas, hydrogen requires capital-intensive infrastructure and equipment to support its safe handling. This entails a storage and distribution network with either high-pressure or cryogenic capabilities, both will come at a significant cost as they are not widely prevalent in the Indian market. The need for high-pressure or cryogenic technology for hydrogen storage also renders it energy intensive, where it is estimated that 15% of the energy content of the hydrogen stored will be required for its safe storage. Beyond high-pressure and cryogenic technology, the materials and components used to construct hydrogen tanks and pipes are also more expensive with a limited lifetime of 1500 cycles.<sup>5</sup> The lack of durability will result in wear and tear and constant need for maintenance to ensure that storage and transport systems are adequate.

Last mile delivery to end users will also have to be considered as end users currently rely on liquid fuels which are much easier to handle. Underground pipes, storage tanks, and filling stations will have to be constructed across the country to support a wide-scale adoption of hydrogen. Trucks and

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trailers fitted with adequate equipment to transport hydrogen will also be needed to deliver hydrogen to regions without access to pipelines.

These factors combine to present a hefty price tag on the supply chain required to support the delivery of hydrogen to its end user.

- **Safety Concerns:** Hydrogen is a highly volatile gas which requires adequate handling that can be more challenging than other liquid and gaseous fuels. It requires capital-intensive infrastructure and equipment to support its safe production, storage, and transport. Globally, instances of hydrogen leaks and explosions have proven to result in serious consequences. Strict safety protocols and standards will be required in India to ensure that mishaps do not occur. It will also be necessary to locate hydrogen production and storage in regions with low population density or away from residential areas to avoid significant loss of lives or damage to property.

It is expected that the cost of hydrogen will reduce with greater technological maturity and economies of scale achieved when the demand increases. However, these challenges will delay the realization of India's hydrogen economy vision.

## Methanol supporting the hydrogen economy

Methanol is chemical building block for hundreds of products that touch our daily lives. It is used in everyday products such as paints, carpeting, plastics and more. Increasingly, methanol is being employed as an emerging energy product around the world. It is used to fuel cars and trucks, marine vessels, boilers, cookstoves, and kilns. Adding to methanol's growing list of market applications, it is also utilized as a superior hydrogen carrier. As one of the most versatile chemical commodities and energy sources available today, methanol facilitates the energy transition of economies towards a greener and more sustainable future. It also represents a pathway that enables the development of hydrogen economies.

With the highest hydrogen to carbon ratio of any liquid fuel, methanol can be highly instrumental in realizing hydrogen adoption immediately. As a liquid, it circumvents the common challenges associated with the logistics required for hydrogen. It is a globally traded commodity with a global production capacity of 148 MMT to meet a global demand of nearly 100 MMT.<sup>6</sup> There is a mature global supply chain that can be leveraged on to store, transport, and distribute methanol as a hydrogen carrier. These supply chains exist in India today and can readily support the delivery of methanol to end users who will reform it into hydrogen for their necessary applications.

The following section of the report will delve into the methanol production pathways, applications, methanol-to-hydrogen technology, and factors that position methanol as an ideal hydrogen carrier that will support India's hydrogen aspirations.

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## Methanol Production

Globally, 100 million metric tons (MMT) of methanol was produced and consumed in 2020.<sup>7</sup> India has a methanol production capacity of approximately 1MMT. This number is derived from the combined production capacity of methanol plants owned by Assam Petrochemical, Rashtriya Chemicals and Fertilizers, and Gujarat State Fertilizers & Chemicals. The country's methanol demand is projected to grow to 46.75 lakh tonnes by 2030.<sup>8</sup> Methanol can be produced from diverse feedstocks. Conventionally, methanol is produced from coal and natural gas. Increasingly, sustainable feedstocks such as capture carbon dioxide, municipal solid waste, and agricultural waste are also used to produce renewable methanol. The adoption of methanol as a fuel or hydrogen carrier provides the industrial and transport sector with a roadmap to be net carbon neutral.

**Methanol as a hydrogen carrier:** Methanol is an excellent hydrogen carrier, packing more hydrogen in this simple alcohol molecule than can be found in hydrogen that has been compressed (350-700 bar) or liquified (-253°C).<sup>9</sup> The following advantages allow methanol to be a superior hydrogen carrier:

- **Ease of storage and transportation:** A liquid at ambient temperature and pressure, methanol alleviates the cost and challenge of transporting and storing hydrogen. It can rely on existing infrastructure supporting the global methanol trade. This enables a faster adoption of hydrogen as an energy product as capital-intensive infrastructure will not have to be constructed for the storage and transport of hydrogen. This ensures a cost-effective roadmap towards increased hydrogen utilization in India.
- **Higher energy efficiency:** Methanol-to-hydrogen reforming process consumes considerably less energy than production of hydrogen from electrolysis of water. Water electrolysis consumes 50 to 55 kWhr electricity/kg hydrogen whereas methanol reforming consumes <0.04 kWhr electricity/kg hydrogen that yields 84% LHV (Lower Heating Value) high energy efficiency.
- **Easy and safe handling:** Over the course of the last century, methanol has been a globally traded commodity. This has led to the development of infrastructure that supports the safe handling of methanol, but also globally recognized standards and guidelines on its safe handling. This has enabled the negligible occurrence of safety incidents when methanol is produced, stored, and transported. Being a liquid at ambient temperature, methanol does not require complex equipment or processes for its handling. This contributes to its ease of handling as it can be handled similarly to other liquid chemicals. IMO has approved regulation on storage and handling of methanol for bunkering use in marine.
- **Low carbon intensity:** Conventional methanol delivers on immediate emissions reductions. Compared to conventional fuels, methanol reduces nitrogen oxide emissions by up to 60%, and virtually eliminates sulfur oxide and particulate matter emissions. Methanol can also be a product with extremely low carbon intensity when it is produced from renewable feedstocks such as biomass, municipal solid waste (MSW), and captured carbon dioxide. When produced with renewable feedstocks, renewable methanol (green methanol) can be a carbon-neutral or carbon negative energy product. The production of renewable methanol enables the decarbonization of

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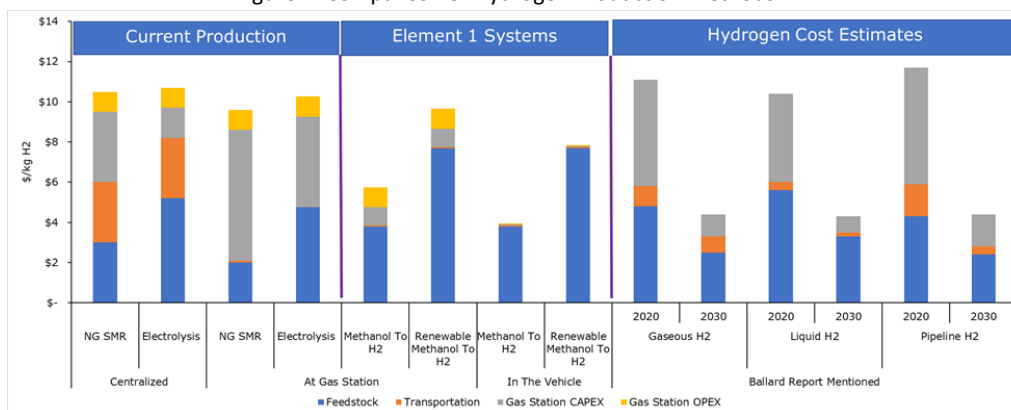
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other industries by off-taking carbon dioxide from industrial emitters. When renewable methanol is produced from waste, it creates circular economies which upcycles waste into a useful chemical and energy product. It also allows for the avoidance of greenhouse gas (GHG) emissions that are produced when waste is dumped in landfills or incinerated. Methanol offers India a double-barreled solution. Firstly, it encourages greater sustainability by offering a pathway for carbon emissions and waste to be upcycled, decarbonizing industries in the process. It also offers India a cost-efficient way of producing hydrogen which can be adopted today. As India is making green hydrogen a priority, the country could leverage green methanol as a carrier that would support in utilizing the large-scale carbon emissions emitted by the power plants.

- **Overcomes the challenge of intermittency of renewable power generation:** High intermittency of renewable energy sources is a challenge when there is a lack of appropriate energy storage technologies particularly for renewable electricity. Power-to-liquid technologies offers a promising solution, where excess supplies of renewable electricity can be stored in the form of methanol. This generates greater economic value in renewable energy assets and de-risks the investments needed to increase the country’s renewable energy capacity.
- **Cost effective:** Methanol can deliver hydrogen at half the cost of producing hydrogen through electrolysis. Although the cost will increase when using renewable methanol at current prices, it is still more cost-effective than other pathways (see below figure).<sup>10</sup> Methanol will help lower the cost of storage and infrastructure needed to transport, store, and dispense hydrogen safely over long distances.

Figure 2: Comparison of Hydrogen Production Methods



**Methanol Technologies:** Methanol fuel cells use hydrogen as a fuel to produce clean and efficient electricity. They can be classified as Direct Methanol Fuel Cells (DMFC) or Reformed Methanol Fuel Cells (RMFCs). DMFCs produces electric power by the direct conversion of the methanol fuel at the fuel cell anode. The RMFCs converts methanol into hydrogen to be reacted in the fuel cell to produce electricity. Methanol can be easily reformed into hydrogen through a catalytic process using a reformer. Methanol is reformed at a temperature of 200-300 °C.<sup>11</sup>

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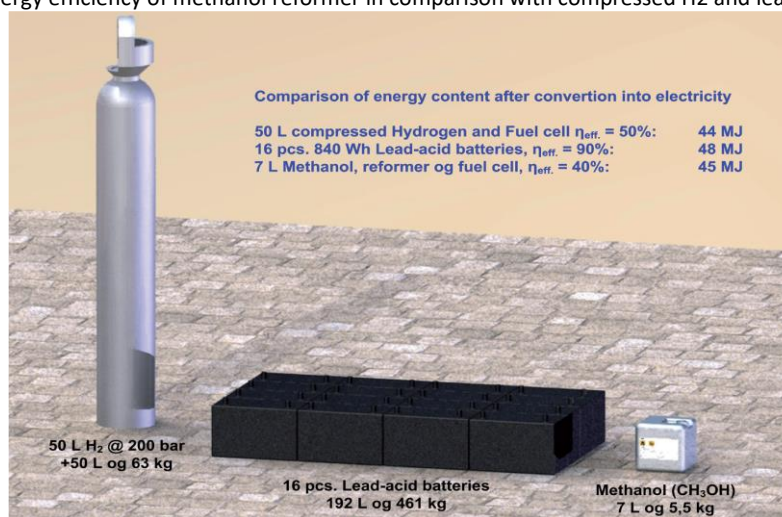
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Methanol reformers range in different sizes. Larger reformers can reform methanol on-site at fueling stations to generate hydrogen for fuel cell cars. Reformers can also be deployed alongside fuel cells to provide clean electricity to telecom towers, construction sites, or ocean buoys. In smaller ranges, they can be integrated with vehicles to produce an onboard supply of hydrogen for mobility applications. Methanol fuel cells can be fueled just as quickly as gasoline or diesel vehicles and can extend the range of a battery electric vehicle from 200 km to over 1,000 km.<sup>12</sup> Unlike water electrolysis, very little electricity is required for methanol reforming to hydrogen.

Figure 3: Energy efficiency of methanol reformer in comparison with compressed H<sub>2</sub> and lead acid battery



**Methanol Fuel Cell Applications:** Methanol today is taking a key role in meeting the growth in energy demands and methanol fuel can support powering the following industry sectors:

- **Transport Sector:** Methanol can be stored in large volumes onboard heavy-duty vehicles providing high vehicle operability, longer driving ranges, and superior drivetrain energy density. In electric vehicles, the fuel cell technology functions as a range extender to achieve greater ranges. This also requires minimal maintenance, occupies smaller space on the vehicle and is a highly scalable solution. The RMFCs are deployed for on-board reforming for heavy duty vehicles like trucks, ships, and trains.
- **Industrial & Residential Sector:** Fuel cells provide reliable off-grid power supply for mobile towers and radio systems. They are also used as a backup power at residential buildings.
- **Military applications:** Military applications of DMFCs are garnering interest since they have low noise and thermal signatures, while emitting no toxic effluent. The fuel cells are reliable as they can work in harsh conditions such as remote areas with limited infrastructure. They can also operate in subzero temperatures, ensuring that variability in climate will not affect military operations. The Indian Army has a long experience of utilizing methanol fuel cell for the basic field electrification of the military posts, battery charging (of surveillance systems, vehicles, communication devices, sensors etc.) and autonomous power for test and training instrumentation.

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➤ **Proven Methanol Technology**

Element 1 Corp., a leading American developer of hydrogen generation technology, has been developing methanol reforming technologies and providing hydrogen on a commercial scale for more than a decade. Blue World Technologies of Denmark and Shanghai-based Palcan has credible experience in producing reliable, affordable reformed methanol fuel cell solutions. Companies like Advent Technologies and RIX Industries have systems that incorporate proven methanol fuel reforming technology to generate hydrogen and are utilizing methanol for the promotion of hydrogen economies. In India, methanol fuel cells are deployed at military bases by German based SFC Energy and their Indian partner FC TecNrgy. Since 2017, the Indian paramilitary force has been using SFC Energy's EMILY 3000 and JENNY 600S fuel cells for powering border protection equipment, electrical equipment, and critical communication systems.

➤ **Methanol policies in India**

The Government of India laid out an ambitious plan to expand the domestic methanol industry in 2016. The methanol economy program was aimed at reducing the country's oil import bill and displacing oil products in the end-use sector. Together with different ministries and government agencies, NITI Aayog, the leading government think tank, is spearheading the methanol economy. They have created the policy agenda, regulatory standards, and implemented projects to support its methanol economy vision. NITI Aayog recently published a paper "Methanol: A Competitive Alternate Fuel" that factors methanol blending is more economically competitive than ethanol blending and supports methanol as a cost-effective alternative fuel for India.<sup>13</sup>

Apart from laying the playing field for the methanol economy to prosper, entities like Coal India Limited (CIL) and National Thermal Power Corporation Limited (NTPC) are taking action to promote and produce methanol domestically. CIL last year announced global bids for their coal block to be utilized for the methanol production from the gasification of surface coal. Approximately 6.76 lakh tonnes of methanol per annum is targeted to be produced from the plant.<sup>14</sup> NTPC has completed a detailed study on green methanol production at Ramagundam and has recently selected Carbon Clean and Green Power International to set up a CO<sub>2</sub> to methanol demonstration plant at NTPC Vindhyachal.<sup>15</sup>

In 2018, methanol manufacturer Assam Petrochemicals Limited (APL) jointly with the government of Assam and NITI Aayog rolled out 300 methanol cookstoves to APL colony residents. The results were positive and the methanol cookstoves were well received according to a program assessment by Project Gaia.

Apart from APL, Gujarat State Fertilizers and Chemicals, one of the few methanol producers in the country, resumed their operations last year to support import substitution and meet the current and anticipated future domestic demand for methanol. Shortly after, the Rashtriya Chemical and Fertilizers (RCF) followed the suit to restart their methanol plant in Trombay.

In February this year, the Department of Science and Technology gave a serious consideration to methanol in its monthly report. Around eight initiatives related to methanol projects are stated under the technology development two of which includes production of ultra-pure hydrogen from methanol for fuel cells and demonstration of Polymer Electrolyte Membrane (PEM) based Electrochemical Methanol Reformer (ECMR) for hydrogen production.<sup>16</sup>

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## Policy Recommendations:

- 1. Acknowledge that methanol and hydrogen are complementary energy products:** 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. As a liquid hydrogen carrier at ambient temperature and pressure, economies can rely on existing infrastructure that supports methanol's global trade to store, transport, and deliver it to hydrogen to end users. Most importantly, it is a cost-effective solution that can immediately enable the utilization of hydrogen in different applications like power generation and mobility. Methanol reformers can generate on-demand hydrogen at the point-of-use to fuel hydrogen applications. Methanol fuel cells can extend the range of a battery electric vehicle from 200 to over 1000 km. Policy frameworks in India should leverage on the country's existing investments and experience in methanol to further develop methanol value chains in the country. These value chains can support and be further integrated in India's future hydrogen economy with minimal investments.
- 2. Develop a Supportive Policy Landscape for Methanol:** Being a vast country, India has a myriad of choices for energy resources. However, the private sector is heavily reliant on the government to send affirmative positions to the Indian market to signal the channeling of investments and resources to develop alternative energy sources. The Government of India has been supportive of methanol, and this support can extend towards methanol's role as the preferred hydrogen carrier in India. Policies that acknowledge the complementary nature of methanol and hydrogen will be welcomed by the Indian market as it offers companies a cost-effective route to realizing the adoption of hydrogen. Primarily, policies should create an enabling technology-neutral environment for the development of India's domestic methanol economy with attention paid to how this could be pivoted to support India's hydrogen aspirations. Particular attention should also be paid to how policies can support the commercialization of methanol as a hydrogen carrier, as companies have indicated their willingness to use methanol as a hydrogen carrier.
- 3. Encourage Investments in R&D and Pilot Projects:** Technologies to produce hydrogen with methanol have been tested and proven around the world. To move from the R&D phase to commercialization, the government should invest in deployment of such technologies and encourage greater public-private partnerships to de-risk the investment and promote effective inclusion and participation from the private sector.
- 4. Promote the Development of Methanol Supply Chains:** Methanol is simple to handle, store, and transport and it does not require dedicated capital-intensive infrastructure like hydrogen. Furthermore, there are already existing logistical supply chains in India which supports the trading of methanol. By developing methanol supply chains, India will be able to take a cost-effective route to deliver methanol as a hydrogen carrier to end users. Every rupee spent on logistical supply chains to deliver methanol, is a rupee invested in India's future hydrogen economy.

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## Conclusion

India's energy transition is continuing at an unprecedented pace and continued industrialization and urbanization will make huge demands of its energy sector and seek rapid policy changes to ensure energy security. Apart from access to energy, affordability are key concerns for India's consumers. To address these challenges, it will require coordinated action from both the public and private sector to adopt new low carbon technologies. The logistical ease that comes with methanol addresses both access to energy and affordability issues. Its ability to be integrated with existing infrastructure will effectively reduce the cost of logistics and simplify the ease of bringing energy to regions that require it. It is widely recognized that methanol is an excellent hydrogen carrier and a viable future proof fuel that will support the transition towards energy security and sustainability.

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