Methanol as an Alternative Fuel for India

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Introduction

Methanol is highly sought after by the chemical industry (Schiffer & Manthiram, 2017) to produce formaldehyde, acetic acid and other important solvents, thereby accounting for India's current demand of 1.8 million tonnes (Mt). More than 90% of this is presently imported and the demand for methanol is likely to grow to about 2.5 Mt by 2022 (Saraswat & Bansal, 2017). Methanol is a clean-burning fuel with a high octane rating, making it an ideal blending component for gasoline in the existing internal combustion engines used in all types of vehicles. It can also be converted to dimethyl ether (DME), which is blended with diesel, due to its high cetane rating, as well as with LPG for cooking needs.

Highlights

- **Methanol and DME can significantly reduce India's fossil fuel dependency.**
- **Coal-based methanol production is a well-established technology but has twice the carbon footprint as gasoline production and use.**
- **Methanol synthesised from torrefied biomass is a promising and upcoming low-carbon technology.**
- **Starting with coal and transitioning to biomass would be a logical way forward for India's Methanol Economy dreams.**

The Government of India, advised by the NITI Aayog, has expressed interest in exploring the possibility of a Methanol Economy for India, which essentially means using methanol as an alternative fuel to replace all fossil-based fuels in the country (Methanol Economy for India, 2017). The NITI Aayog also plans to set up a Methanol Economy Fund worth INR 4000–5000 crore to encourage the production and use of methanol.

Given this backdrop, the key motivation for working towards a Methanol Economy in India is two-fold:

1. India aims to reduce its crude oil import dependency by 10% by 2022, and indigenous methanol production could help achieve this goal.
2. As part of its NDCs (Nationally Determined Contributions), India targets to lower the emissions intensity of its GDP by 33–35% from 2005 levels, by 2030; methanol and DME have the potential to contribute towards achieving this target, depending on the production route.

Figure 1 represents the total LPG, gasoline and diesel demand in India, as of 2017, and a projection for 2022, as per the Petroleum Planning and Analysis Cell of the Ministry of Petroleum and Natural Gas. It also shows a 4% and 8% increase in the total cumulative demand if a 10% and 20% penetration respectively, of methanol-based fuels (methanol in gasoline and DME in diesel and LPG) were to materialise by 2022. This increase will occur because methanol and DME's calorific values, 22MJ/kg and 29 MJ/kg respectively, are lower than that of LPG, gasoline and diesel (46, 45 and 45.5 MJ/kg, respectively). This means that burning almost twice the amount of methanol or DME will provide the same amount of energy, as compared to its petroleum-based counterparts. However, despite the increase in total demand, the fossil fuel-based component reduces by 5% and 12% for the 10% and 20% penetration levels, respectively, by 2022.

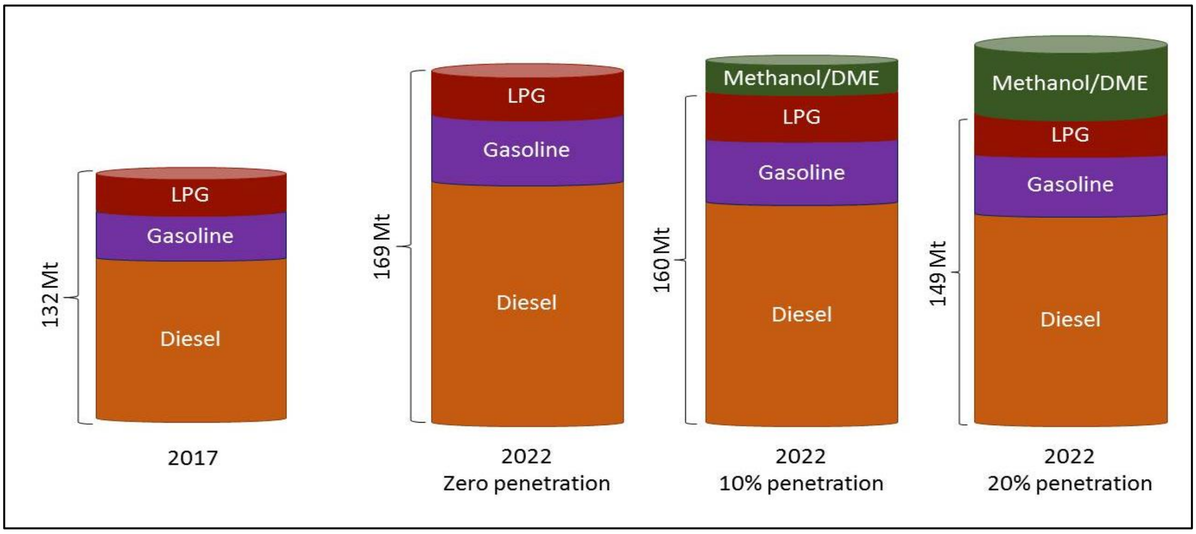

Figure 1: LPG, Gasoline and Diesel demand projections for 2022, with and without methanol (and DME) blending, in million tonnes (Mt)

The total demand for methanol in 2022, including the needs of the chemical industry, will be 24 Mt, if a 10% methanol and DME penetration materialises; and 47 Mt for a 20% penetration. These demands and national targets beget the following question: *What are India's options for methanol production in terms of indigenous resource and technology availability, and their subsequent environmental impacts, to achieve a 10% and 20% penetration of methanol-based fuels by 2022?*

Production Strategies

Methanol is prepared from syngas (a mixture of H_2 and CO) via catalytic synthesis, a well-known and commercially mature technology. Syngas is produced via natural gas reforming, coal gasification or biomass gasification. Emerging technologies like carbon dioxide hydrogenation directly produce methanol, without syngas as an intermediate. India has 21 billion tonnes of *extractable* coal reserves (TERI Policy Brief, 2011), around 200 Mt of surplus biomass residues annually and enough carbon dioxide for hydrogenation. However, due to the lack of sufficient indigenous natural gas and technology availability constraints for carbon dioxide hydrogenation, the onus of acting as raw material for methanol production falls on coal and biomass, in the immediate future.

Table 1 shows our initial estimates on the amount of coal or biomass required to meet India's total methanol demands, calculated based on yields reported in literature (Ptasinski, 2015) (Renó, M. L. G. et al., 2011) (Xiao, Shen, Zhang, & Gu, 2009).

The raw biomass available in India can potentially fulfil the 20% penetration level requirement, but is fraught with other issues like its unwieldy nature, low energy density, inconsistent quality, transportation challenges and lack of a reliable supply chain system. Typically, biomass is not compatible with the efficient and easily scalable Entrained Flow (EF) gasifiers because they strictly require completely pulverised feedstock, and raw biomass cannot directly be pulverised. Only the smaller scale Fluidised Bed or Fixed Bed gasifiers can handle biomass, owing to their higher tolerance for feedstock variability. However, torrefaction can be an alternative pre-treatment step as it converts biomass into an energy-dense coal-like product with increased grindability and hydrophobicity. Torrefied biomass can easily be transported and pulverised for use in the efficient EF gasifiers (Trop et al, 2014).

Table 1: Amount of resources required to meet India's methanol demand

Fuel penetration	Methanol demand (Mt)	Indian coal (Mt)	Raw biomass (Mt)	Torrefied biomass (Mt)
10%	24	48	96	36
20%	47	94	188	70.5

Based on the estimates provided in Table 1, India has enough coal reserves, in theory, to produce methanol for both 10% and 20% penetration levels for at least another decade. However, coal is also required in power generation, industrial heating and various other sectors, which will affect its availability for methanol production. Coal gasification is a well-known, commercially viable process that typically uses EF gasifiers, enjoying their easy scalability, high efficiency, short residence times and good quality of syngas. EF gasifiers can accommodate Indian coal, with a slight reduction in efficiency, due to the high ash content. Alternatively, technologies like Lurgi's Fixed Bed Dry Bottom (FBDB) gasifiers and Fluidised Bed gasifiers like i-MILENA, specifically designed for high-ash coal are also viable options. Table 2 summarises the benefits and challenges of the various technology choices for methanol production in India.

Figure 2 compares the carbon footprint of the choice of raw materials and production processes for methanol, based on published data (Yao et al, 2017) (Ptasinski, 2015) (Renó, M. L. G. et al., 2011). On a life cycle well-to-wheel greenhouse gas (GHG) emissions basis, coal-based methanol production, and its use, is twice as bad as natural gas based methanol and conventional gasoline. If coal is used to produce methanol to meet the 10% and 20% penetration levels by 2022, approximately 106 Mt and 207 Mt of CO_2e will be emitted, respectively. Biomass-based methanol, on the other hand, has a much lower carbon footprint.

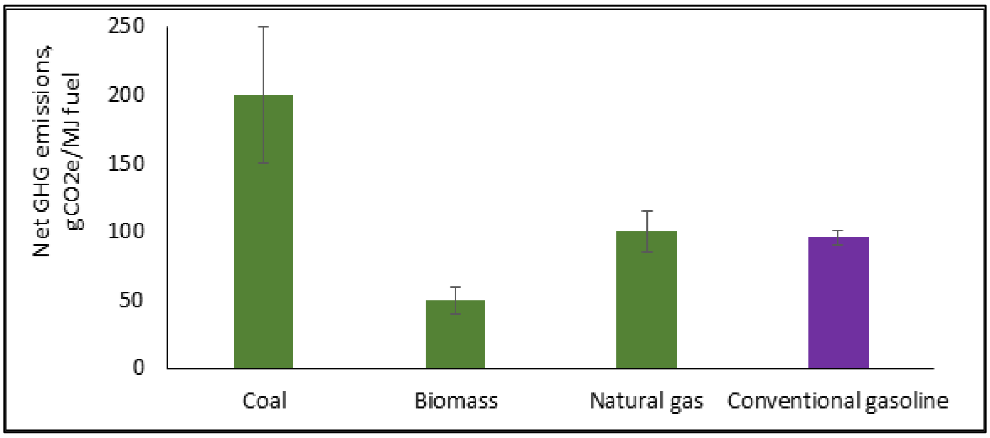

Figure 2: Well-to-wheel lifecycle GHG emissions of coal-based, biomass-based and natural gas based methanol, as compared to conventional gasoline

Torrefaction reduces the energy required (and the associated emissions) for biomass grinding by 10-fold (Thrän, D. et al, 2016), making it a more attractive and sustainable option from an emissions reduction point of view (Tsalidis et al, 2014).

Way Forward

If India's main priority is to reduce import dependency, coal-based methanol production seems to be the logical way forward. This is because it is a well-established technology and the coal mined in India can be used for the process. However, the heavy carbon footprint would be the main challenge in this route, which would hinder India's GHG emissions reduction goals.

On the other hand, to prioritise its GHG emissions reduction target, India could look into developing a biomass-based methanol industry. Since biomass gasification is typically a small-scale process today, the government could consider promoting torrefaction as a technology option to make it suitable for EF gasifiers. Decentralised torrefaction units will help standardise the biomass supply chain in India and produce a high quality coal-like product for methanol production, as well as thermal power plants. Providing accelerated depreciation, tax credits and other incentives to set up torrefaction demonstration plants will not only help developers, but also give investors the confidence to support similar endeavours in the future. Creating a mandate and standard for torrefied biomass should be the next step, to boost supply. When the demand rises, farmers will be encouraged to sell their biomass to torrefaction units and enhance their income.

For detailed insights on both coal- and biomass-based approaches, pilot-scale blending programmes could be implemented. This, along with a techno-economic viability study, will determine the best way forward for India.

Table 2: Summary of options for methanol production in India

Resource	Technology	Benefits	Challenges
Coal	Gasification (Lurgi's FBDB, i-MILENA or EF gasifiers)	Sufficient coal availability Commercially successful technologies	High carbon footprint Coal is currently used for various other needs too
Biomass	Gasification (Fluidised Bed gasifiers)	Low carbon footprint Renewable resource Sufficient availability	Practised only at small scales No stable biomass supply chain and no standard for quality of biomass
Torrefied biomass	Torrefaction followed by EF gasifier	Renewable resource Lowest carbon footprint Potential to resolve biomass supply chain issues	Yet to achieve large-scale commercialisation

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