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14th March 2023

For the kind attention of the Policy Makers & Project Promoters

Respected Sir / Madam,

Sub: Green Methanol Prospects & Fuel Policy

Greetings from Avant-Garde!

We are pleased to share our White paper on Green Hydrogen Prospects based on our assessment of various sectors in India.

Climate change will ultimately force countries to move towards the green hydrogen economy. With the host of incentives by the Government of India for the production of green hydrogen, it is time for the organizations with the potential to generate green power, to look at hydrogen production seriously. With the issues relating to the storage and transportation of hydrogen yet to be fully resolved, the most promising way forward is the distributed production of green hydrogen. With FCV's (Fuel Cell Vehicles) wide availability and popularity a few more years away, what looks more attractive is to use the green hydrogen for the production of methanol and ammonia. Mainly due to its high hydrogen capacity, Ammonia, has the potential for use as a carrier of hydrogen delivery and distribution. While methanol has a lower hydrogen density at 12.5% compared to ammonia at 17.6%, methanol has a higher energy density. The higher energy density and it being less toxic and less corrosive than Ammonia, methanol stands as a better option for usage as a fuel.

While the immediate use for this green hydrogen could be the replacement of hydrogen and ammonia derived from blue hydrogen in refineries and fertilizer plants, respectively, the methanol derived from green hydrogen promises to play a significant role in blending with gasoline and diesel.

A few countries, specifically China has started using methanol as a transportation fuel and they use both gasoline blends and stand-alone M100 as transportation fuels. Approximately China used about 7 million tonnes of methanol last year and has mandated to use about 15 million tonnes (about 1875 Cr liters) by 2025. Our NITI Aayog has also identified methanol as a competitive alternate fuel. The use of methanol as a transportation fuel in blends of MD95, M100 & M15 has already been notified by the Ministry of Road & Transports. An Inland Water Cruise with MD15 fuel (15% methanol in Diesel) has been inaugurated recently. Field trial runs of City buses with MD15 fuel have also been initiated, at Bengaluru. With 20% ethanol blending planned by end 2025, methanol in different blends with diesel or E20 gasoline, or even as stand-alone fuel would pave way for the immediate use of the methanol generated in these distributed power/cogeneration plants.

With the sale of power, generated in the bagasse-based Cogeneration plants, facing tariff issues, the Cogeneration plants can look at the favorable scenario of green hydrogen and green methanol production, using the surplus power generated. With many sugar mills going for ethanol production, the Carbon-di-oxide generated in the fermentors is readily available for the production of methanol, with the green hydrogen generated in the Cogeneration plants. The Government's policies also enable the power producer to sell his power anywhere in the country to green hydrogen producers. It is a national waste not to harness the full potential of power generation using bagasse in the sugar mills, under the developing scenarios related to green hydrogen, methanol and ammonia. The existing Cogeneration plants as well as the potential ones should take up feasibility studies to look at the economics of going through the green hydrogen and methanol/ammonia route.

With the Sugar Industry's bagasse-based Cogeneration plants and the ethanol plants, the country would be able to set up 5.5 GW electrolyzers amounting to the generation of 0.8

million tonnes of green hydrogen and the production of 500 Crore Liters of methanol per annum. A typical sugar plant with a 30 MW Cogeneration plant with a 120 KLPD ethanol plant will be able to produce about 50 kLPD of methanol, by making use of the surplus power of about 20 MW and 60 TPD of carbon-di-oxide from the ethanol plant. Uttar Pradesh Government has incentivized the green hydrogen production with a subsidy upto 60% of the cost of the electrolyzers with the capacity of the electrolyzers above 50 MW.

Avant-Garde, with its vast experience & strong positioning in the conceptualization, design, engineering, and consultancy in various segments like thermal power plants, sugar cogeneration units, ethanol plants, solar plants, chemical plants, FGD plants, CBG plants, steel/cement/fertilizer (on energy aspects) segments, and green hydrogen projects, perceives the need of connecting the technologies with a pragmatic approach for reducing energy imports as well as net emissions, by identifying the potential & opportunities in various sectors to adopt Green Hydrogen. Avant-Garde will be able to take up a feasibility study to look at the potential and the viability of the green hydrogen and methanol production and carry further for project implementation.

It is heartening to note Nation Hydrogen Mission, January-2023 (https://mnre.gov.in/img/documents/uploads/file_f-1673581748609.pdf) has a series of plans for Green Hydrogen project promotional activities, including the formulation of Empowered Group (EG) with the involvement of all concerned ministries & departments. We would request all stakeholders (policy makers & the project promoters) to initiate framing the policy guidelines for procuring 'Green Methanol' from the ethanol plants in the first phase and then extend to other industries / thermal power plants along with CO2 purification.

With Best Regards,

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A WHITE PAPER ON GREEN HYDROGEN PROSPECTS IN VARIOUS SEGMENTS IN INDIA

'GREEN METHANOL – NO LESS THAN A GOLDMINE'

THE SEARCH FOR AN IDEAL HYDROGEN CARRIER ENDS HERE!

MARCH, 2023

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C O N T E N T S

1.0 Abstract

1.1 Direct usage of green hydrogen in the refinery segment is the priority area, while the other major use will be in the transportation segment through Fuel Cell Vehicles (FCVs), but it is expected to happen along with infrastructural changes in the future. Indirect usage of hydrogen (through carriers like ammonia) in the segments like marine transportation, exports & fertilizer are the potential areas. Implementation of newer nano urea plants (a game-changing concept in the fertilizer segment) by next year is likely to bring down local ammonia demand substantially in the fertilizer units. Hence, any plan to use hydrogen for green ammonia for meeting urea requirements would require very careful consideration.

1.2 Production of Green methanol using green hydrogen in Ethanol plants, where pure CO2 is readily available, and the use of this transportation fuel (blends of MD95, M100 & M15 have already been notified by the Ministry of Road & Transports and MD15 blend was adopted in the recently launched Inland Water Cruise at Mahababu, Brahmaputra) opens up a good opportunity for the sugar & ethanol segments, that are already contributing towards the highly successful Ethanol Blending Program (EBP). With a few plants already on a commercial scale, outside India, through hydrogenation of CO2, and the recognition of methanol blends by the Ministry of Transportation, there is no technological barrier whatsoever; but this requires Government's Policy to recognize 'Green Methanol' with a preferential tariff (like preferential tariff was offered for the initial cogeneration & solar power plants).

1.3 Since the CO2 from ethanol plants is Green CO2 (part of the photosynthesis cycle) and the Hydrogen from Electrolysers powered by renewable sources (like bagasse-based cogen plants and solar/wind) will be used for synthesis, this methanol can even be recognized as 'Double Green Methanol' or '2G Methanol' or 'G Square Methanol'. Hence, usage of about one million tonnes of hydrogen,

out of the 5 million tonne target by 2030, could be employed straightaway in the ethanol plants.

1.4 Utilization of green methanol, for adopting green hydrogen in the transportation segment, would give huge comfort to the industry, which extensively uses IC engines. Minor modifications in the IC engines (like the changes being done for E20 & flex engines) would be adequate to accommodate Green Methanol (in different blends), as major fuel. Like the Ethanol blending program, the Green Methanol Blending program has great potential to succeed, with different blending combinations with diesel, gasoline, ethanol, or gasoline-ethanol; and this can be extended up to 100%, given that Methanol is a very versatile fuel for IC engines (SI & CI) and it is even adoptable for the FCVs (Direct Methanol Fuel Cell Vehicles) in future. Blending with diesel at lower proportions (as MD15) in the initial phase & extend it for M100 or MD95 in the subsequent phases would possibly be a worthy option for synergizing with EPB.

1.5 Green DME (Di Methyl Ether), which can be produced from methanol, can also become another Hydrogen Carrier, by using it as a blend with LPG.

1.6 With some additional facilities for the purification of flue gas from power plants (mainly from the plants with FGD), and steel & cement plants, green methanol could become a great tool for reducing energy imports and also GHG emissions. There are a few plants commercialized in recent years, for extraction of CO2 from flue gas as well as methanol production (including the trial plant by NTPC at Vindhyachal) hence again, there is no technological risk, in this route.

1.7 Indigenous coal would continue to remain the prime energy source for the next 3-4 decades in India, particularly for key sectors like power, steel & cement. India's exponential growth in renewable energy would synergize with the elimination of imports (like crude, LNG, and imported coal), in the first step. 100% coal elimination would become a reality, when the worldwide grid (one

Sun, one World, and one Grid vision of our PM) is established and the energy storage systems (either through battery storage consequent to the recent findings of lithium reserves in Reasi district, J&K or hydrogen & its carriers) become affordable. Hence, Green Methanol production from CO2 captured from flue gas in thermal, steel & cement plants can be implemented subsequently. When green methanol production from renewable power with captured CO2 in the power/steel/cement plants is commercialized, it would make the country energy import free!

1.8 The Green Hydrogen program, with the already available encouragement from Power Ministry through wheeling & banking concessions, is looking for a suitable Carrier. By absorbing CO2 from ethanol/power/steel/cement plants, Green Methanol is ready to give hand to Fuel Demand thereby reducing fuel imports & GHG emissions; and this requires a policy guideline from the Empowered Group (EG) formulated through 'Nation Green Hydrgogen Mission'.

1.9 A Swift Policy in a way would be a game changer like Nano Urea Innovation & Ethanol Blending Program, when the price & policy guidelines are framed for 'Green Methanol' based on the project cost & renewable power cost, by delinking from conventional methanol, that is mostly imported in the country. Conventional methanol production releases substantial emissions (between 1T & 5T of CO2 per tonne of feedstock), while Green Methanol absorbs CO2 from the other processes. Hence, no correlation for tariff fixation should be drawn with conventional methanol.

1.10 Self-Reliant India (Aatmanirbar Bharat Abhiyan) target of achieving by 2047 in transportation can get fulfilled through Green Methanol (the right Carrier for Hydrogen), given the abundant availability of resources (like coal, agro feed & solar climate) and the conducive conditions in India, than any other nation globally. Augmentation of local production of renewable energy propellants like solar cells & electrolyzers is crucial, in achieving this Dream through Green

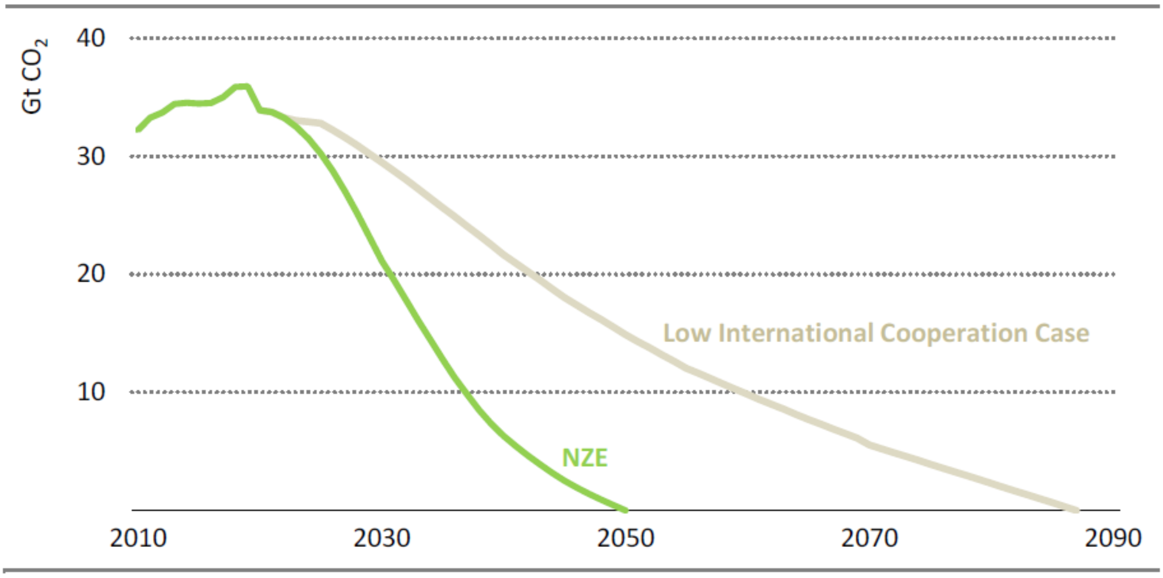
Methanol. Even the export of green methanol in the next few decades is a possibility! The automobile industry's robust positioning with IC technology can be fully fuelled by Green Methanol, to mutually support the renewable segment toward exponential growth & also help in marching towards NZE goals. Hence, Green Methanol is a true Goldmine-in-waiting to be explored!

2.0 Energy demand and Emissions in India

2.1 The COP26 summit at Glasgow, in 2021 had the agenda of meeting the Net-Zero Emission (NZE) goal by 2050. While the US and EU have aimed to attain the NZE goal by 2050, China and India have pledged to achieve by 2060 & 2070, respectively. COP27 summit at Sharm El Sheikh, Egypt in 2022 created a pathway to align the broader finance flows towards low emissions and climate-resilient development, for limiting global temperature to 1.5 Deg above the pre-industrialization Era.

2.2 Based on the various emission reduction measures, International Energy Agency has projected NZE targets for this century, as below:

Global energy-related CO_2 emissions in the net zero pathway and Low International Co-operation Case



Note: Gt = gigatonnes.

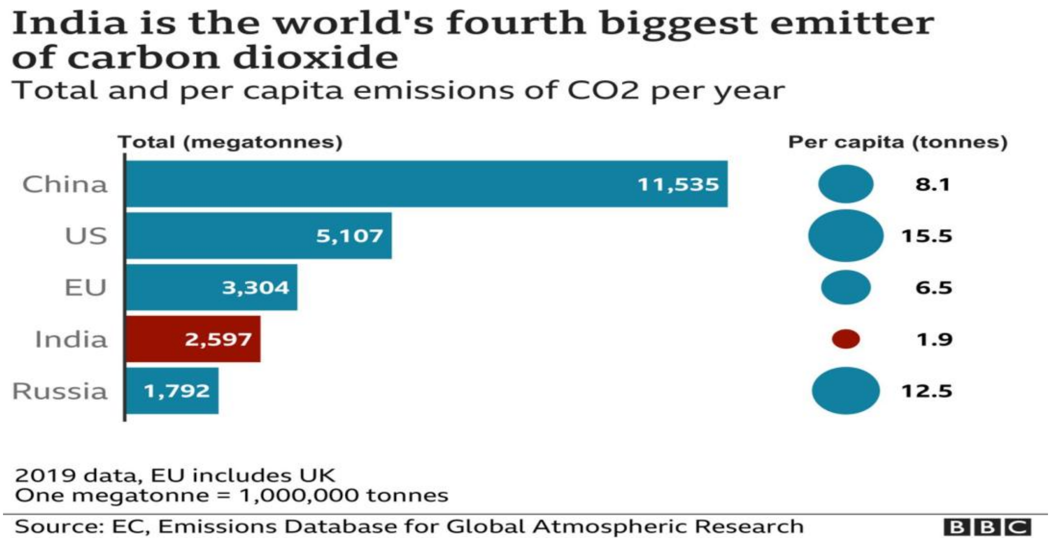
2.3 The 22[nd] Century has the potential to look greener, as the entire demand could be met through renewable energy without depending on fossil fuels, since

- About 1% of the land area will be good enough for meeting the entire global energy demand (power, transportation & industrial) from direct energy generation from Solar Energy, while there will be other renewable sources like hydel, biofuels (ethanol, biomass, biogas, biodiesel, etc) & wind to supplement solar energy generation.

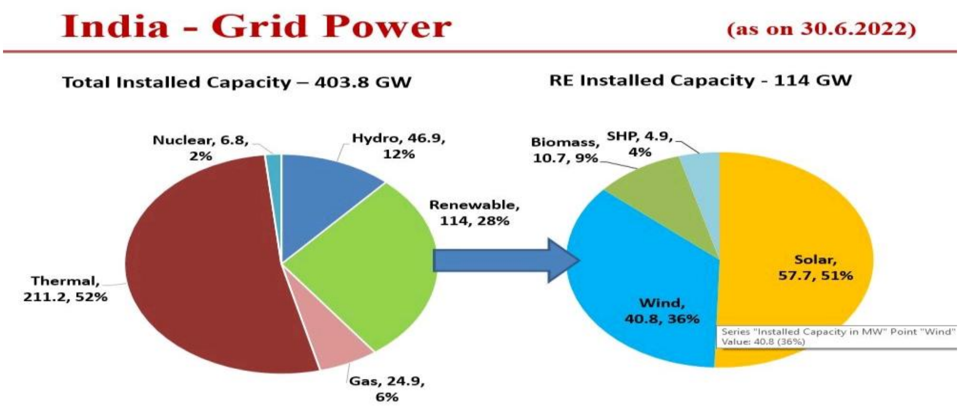
- Energy storage & usage in the form of batteries or hydrogen (as imagined by Joule Verne 150 years back) or its carriers will fulfill all sorts of demands & applications.

This is the reason, why there is not much of a cry over fossil fuel depletion!

2.4 Present CO2 levels:



2.5 India's present installed capacity is about 400GW which includes about 150GW from renewable sources (including Hydro), with an average PLF of 50%.



2.6 Though Per Capita emission levels are far less (compared to the USA, Russia, EU & China), India has also given the following pledges in COP26 as the target for 2030, which is aimed at, not only in terms of CO2 reduction but larger self-interest of reducing energy imports by 2047 (current import is about Rs.12.5L Crores per annum, the majority being transportation fuel):

- To increase the renewable capacity to the level of 500GW
- Aim for 50% consumption from renewable power
- Reduction of 1b tonne CO2 emission (from the present level of 2.6b tones)

2.7 Next to the energy segment, transportation & industries emit CO2 from the usage of fossil fuels. With the energy segment de-carbonization plans already in the brisk phase, Green hydrogen usage in transportation & energy segments, again with renewable sources, will also be in equal focus.

2.8 This paper analyses the present policies of Green Hydrogen / Green Ammonia and identifies the potential various sectors. Also, the necessity of absorbing the CO2 generated from different industries through the hydrogen carriers like Methanol & DME (Dimethyl Ether) and the urgent need for policy guidelines in recognizing Green Methanol as fuel have also been discussed.

3.0 Green Hydrogen Policy, Green Hydrogen Mission & its Significance

3.1 The Prime Minister in his Independence Day speech in 2021, aggressively pitched for green energy and announced the National Hydrogen Mission. The mission aims to help the country achieve its target of producing 5 million tonnes of green hydrogen by 2030 and the related development of renewable energy capacity. This leads to hectic planning of the efforts to achieve the target. Subsequently, the Power Ministry introduced the green hydrogen and ammonia policy on February 17, 2022.

3.2 The power ministry's green hydrogen/ammonia policy primarily addresses open access, grid banking, and faster approvals for green hydrogen/ammonia projects. Green Hydrogen / Green Ammonia shall be defined as Hydrogen / Ammonia produced by way of electrolysis of water using Renewable Energy, including Renewable Energy that has been banked and Hydrogen/Ammonia produced from biomass. In nutshell

- Green hydrogen/ammonia manufacturers will be allowed to purchase renewable power from the power exchange or set up renewable energy capacity themselves or through any other developer

- The policy grants open access to procure electricity within 15 days of application. The manufacturer can bank renewable power for 30 days with distribution companies and take it back when required. The distribution licensees can procure and supply renewable energy to the manufacturers of green hydrogen/green ammonia in their states at concessional prices

- Renewable energy plants will be given connectivity to the grid on a priority basis to avoid any procedural delays

- Provisions to set up bunkers near ports for the export of green ammonia

3.3 Green hydrogen of 5 million tonnes roughly translates to 35 GW of electrical power on a 24x7 basis or about 150GW renewable power. This is almost one-third of the renewable energy capacity target of 500GW for 2030.

3.4 One key point to be noted in the Power Ministry's policy is that the words hydrogen & ammonia have been used interchangeably, signifying equal importance for Ammonia. Green Methanol is another potential, rather most significant, carrier to get recognition under this policy!

3.5 NITI Aayog's June 2022 report on 'Harnessing Green Hydrogen' and MNRE's 'National Green Hydrogen Mission, January 2023' have stressed the importance of inter-ministerial governance structure, state-level actions, R&D needs, etc for successful implementation. National Green Hydrgogen Mission, January 2023 has also identified the need of setting up an 'Empowered Group' under the chairmanship of the Cabinet Secretary with the involvement of various ministries and organizations.

3.6 Apart from electric batteries, hydrogen and other hydrogen carriers (like methanol, ammonia & dimethyl ether) are likely to shape up as strong storage mediums, with the augmentation of renewable power generation.

3.7 This note gives a brief on major direct (as hydrogen) and indirect (through carries like ammonia, methanol, and dimethyl ether) utilities in the prominent sectors, including the possibilities of ammonia and methanol as a fuel for blending (like the success of ethanol blending in the country). This blending plan requires more initiatives and policies for blending methanol, from the Ministry of Petroleum and Natural Gas.

4.0 Hydrogen, Ammonia & Methanol as transportation Fuels

4.1 At present, major (over 90%) use of hydrogen & ammonia is catered in oil refineries for desulphurization (the hydrogen used is derived from natural gas) and fertilizer units for ammonia (hydrogen from natural gas with Haber-Bosch process for ammonia).

4.2 When green hydrogen production is augmented, it is expected to replace the current requirements initially and then will extend its usage in the production of Green Steel (replacement of natural gas in the DRI process) or even in cement. As an energy carrier in the transportation segment, Fuel Cell Vehicles (FCVs) will make use of Green Hydrogen.

4.3 Beyond the direct applications (industrial applications in the refinery, fertilizer, steel & cement) and FCVs, Hydrogen requires a 'Carrier' for handling & long-distance transportation for meeting distributed applications, owing to the inherent limitations in safety & cost for Hydrogen directly.

4.4 Among the various options as 'Carrier' that have been explored, Ammonia & methanol are likely to emerge as the prominent options. Ammonia (NH3) is among the largest-volume chemicals produced and distributed in the world and is mainly known for its use as a fertilizer in the agricultural sector. Another option would be methanol, as this fuel has the potential to make use of the CO2 liberated from any process, but could not be properly utilized or captured.

4.5 Ammonia's use as fuel has been explored for decades and has also been used as a marine fuel on a trial basis, but the need of using Ammonia as sustainable carbon-free fuel is gaining momentum. In recent years, it has sparked interest in the possibility of working as a high-quality energy carrier and as a carbon-free fuel in internal combustion engines (ICEs). Ammonia, being eco-friendly fuel, is likely to be mandated for marine and as well as stand-by or emergency power engines.

4.5.1 When FCVs gain momentum, the same ammonia fuel can be transported to various distribution points and can be decomposed in ammonia crackers to hydrogen which, then will be compressed for filling the FCVs at 700 bar pressure.

4.5.2 Methanol (CH3OH), also known as wood alcohol, is considered an alternative fuel. Countries like China, Italy, Isreal & the USA are already using Methanol as a transportation fuel. China uses about 7MT of methanol as transportation fuel & the country will use about 15MT (about 1875 Cr liters) of methanol by 2025. As an engine fuel, methanol has chemical and physical fuel properties with versatility as stand-alone fuel and also in blending with gasoline, diesel & ethanol, in IC engines. Methanol can also be used in DMFC (Direct Methanol Fuel Cell, a prospective future technology) Vehicles! In the search for a hydrogen carrier generated through renewable power, methanol is the most significant & promising fuel. Such usage by the transportation industry will pave the way, like the success story of ethanol, in achieving decarburizing goals.

4.6 Although slightly lower in energy content than petrol and diesel, methanol can replace both these fuels in the transport sector (road, rail, and marine). In addition, this would bring down GHG emissions in terms of particulate matter, NOx, and SOx, thereby improving urban air quality. According to data from the Chinese Ministry based on the pilot programs, methanol vehicles are 21 percent more energy efficient and reduce carbon dioxide emissions by 26 percent when compared with petrol vehicles.

4.7 A notification for M15, MD95, and M100 blends has been issued by the Ministry of Road, Transport, and Highways. Test standards and plans for the M15 blend are being evolved in consultation with the Indian Oil Corporation Limited, the

Automotive Research Association of India, and the Society of Indian Automobile Manufacturers. In the railway sector, RDSO is working towards blending methanol in the range of 5-20% through direct fuel injection in locomotives.

4.8 As the ethanol blending program is on full track in the country (E10 already achieved & E20 in some parts) to achieve E20 by 2025, green methanol would be an ideal hydrogen carrier to blend with gasoline-ethanol, with a minor or no modification in the IC engines. Blending with diesel in small proportions (MD15 blend was adopted in the recently launched Inland Water Cruise at Mahabahu, Brahmaputra) in the initial phase and using them subsequently in the flex engines (which can be designed to accommodate methanol) for MD95 or M100, are the technical possibilities.

4.9 Apart from the huge comfort for the transportation segment to continue with IC engine technology, methanol has also the advantage that its production can be augmented without any fear of triggering the debate over food stock (ethanol case) usage, as the raw materials/feedstocks for methanol are purely industrial and renewable sources.

4.10 With careful consideration of the factors like flammability limit, corrosion aspects, safety considerations, ignition energy, self-ignition temperature, storage considerations (ammonia requires storage at pressure or refrigerated tanks), and flame speed/flame propagation, both methanol & ammonia are potential transportation fuels, either as blend or by deployment in flex engines or dual-fuel engines. But, in consideration of the storage, safety & corrosion considerations, methanol is likely to become a prominent in-land transportation fuel, while ammonia will dominate the marine fuel segment.

4.11 As direct usage of Hydrogen through FCVs with its various infrastructure needs, will take more time, usage of methanol or ammonia as fuel in this segment will help green hydrogen demand growth. Making Dimethyl Ether (DME) from green methanol to use along with LPG is also an option, to use in automobiles. Additionally, methanol in fuel cell vehicles is also seen as a prospective future technology. Hence, the transportation segment will have a mix of gasoline, diesel, CNG, Ethanol, Methanol, Ammonia, DME & EVs, for the next few decades.

5.0 Green Hydrogen, Ammonia & Methanol Prospects – Sector-wise Opportunities

5.1 Oil Refinery (Hydrogen produced in about 18 GW electrolyzers)

5.1.1 Indian oil refineries require about 2.6 million tonnes of hydrogen, which is presently catered by the SMR (Steam Methane Reforming) process, with about 6-7 times CO2 being vented out.

5.1.2 Instead of spending on CCS (Carbon Capture & Storage, by driving deep into the earth), it would be worthwhile to produce green hydrogen, through Renewable Power as per the Provisions of Hydrogen Policy.

5.1.3 Electrolyzers of about 18 GW in the Oil Refineries can be installed, for replacing the grey hydrogen with green hydrogen.

5.2 Fertilizer Industry (Hydrogen produced in about 20 GW electrolyzers)

5.2.1 Currently, over 95% of the ammonia produced (all through the SMR route) is used for urea (a major user with about 80%) & other ammonia fertilizers.

5.2.2 India imports about 25-30% of ammonia (including fertilizer import), in a total demand of about 180 lakh tones (equivalent to hydrogen demand of about 3 million tones or 20 GW electrolyzers).

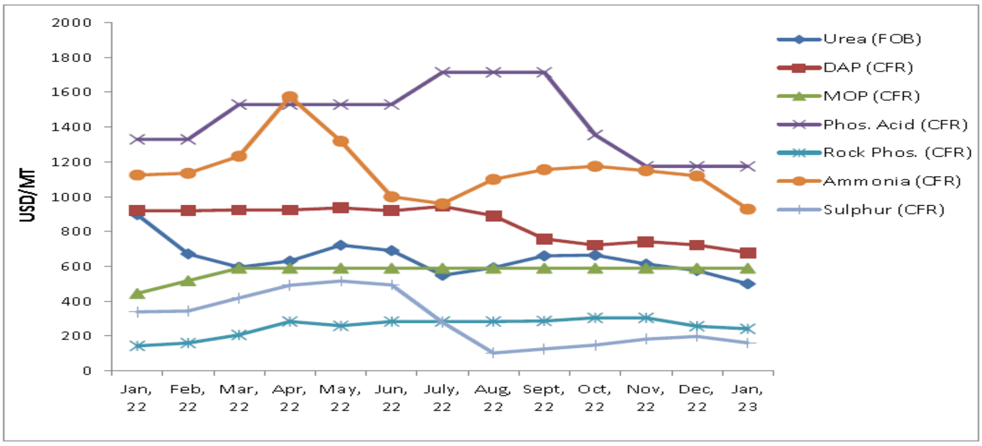
5.2.3 Like the refinery sector, fertilizer plants produce CO2 (through the SMR process) but are mostly consumed internally, as the ammonia produced through the Haber-Bosch process is combined with CO2 to form Urea.

5.2.4 However, with the launch of first-time-in-the-world Nano urea with 1.5 bottles/day plant (each 500ml nano urea will replace 45kg urea, for over 80%

crops) at IFFCO's Kalol plant and another eight (8) plants scheduled for implementation by IFFCO by 2025, it is likely that ammonia demand for fertilizer will fall by about 70%. In other words, India would become a surplus country in terms of fertilizer urea/ammonia production, in the next 2-3 years.

5.2.5 After the transition to nano urea, fertilizer factories with their Haber-Bosch Ammonia Production units will likely become a manufacturing hub for Green Ammonia production, for meeting the ammonia demand of other sectors (mostly, marine transportation & export segments).

5.2.6 With the current ammonia (through the grey hydrogen route) price hovering over $1000 per tonne, the annual subsidy being spent for fertilizer (about Rs.1.5 lakh Crore per annum, with current production price) can be diverted for green ammonia production for marine transportation & export, as the demand for ammonia towards urea is like to drop with the full-scale production of nano urea.



5.3 Sugar cogeneration and other bio-mass-based captive / cogen plants with Ethanol Units (capable of powering over 5.5 GW electrolyzers)

5.3.1 Indian sugar cogeneration plants with about 7.5 GW installed capacity are currently facing tariff challenges, with many utilities capping the generation and fixing the tariff below Rs.3.5 per unit. These plants are helping the government for achieving the blending of 20% ethanol in gasoline by 2025 (it is about 10%, at present), by producing 1G ethanol from molasses & cane syrup.

5.3.2 Installation of electrolyzers to produce hydrogen and then synthesized at about 50 Bar with CO_2 (co-produced in the ethanol process) for making Green Methanol would be a perfect synergy & dream combination with multiple benefits, as below:

a. Renewable power from cogen plants gets fully utilized for producing green fuel. If required, wheeling of solar or wind generation, as permitted for green hydrogen products, can be supplemented.
b. CO_2 produced in fermentation will get better value addition. The CO_2 that ultimately gets into the fuel through this process doesn't contribute to Net Emission, as this CO_2 is part of the photosynthesis of agro produces.
c. Readily available steam, water & power in the complex, for hydrogen & methanol production.
d. Methanol blends of M15, MD95 & M100 have already been notified by the transport & oil industries, which would reduce the import of fossil fuels in proportion.
e. Opportunity for the transportation segment to utilize Green Hydrogen (with methanol as a carrier) immediately, as it is likely to take more time for infrastructure development for hydrogen (directly, through FCVs) and Ammonia based fuels.
f. Rejuvenate the sugar & agro-industry, through the co-production of green methanol with ethanol.

5.3.3 A typical sugar plant with a 30MW cogeneration plant with 120 kLPD ethanol plant, can produce about 50 kLPD Methanol, by making use of surplus power of about 20MW & 60TPD CO_2 from the ethanol plant.

5.3.4 Initiation by the concerned ministries with measures like right pricing for green methanol, interest subversion benefits, subsidy for electrolyzers (similar to UP Govt's subsidy of up to 60% on electrolyzes cost for the year 2023, for more than 50MW electrolyzers), subsidy green methanol production, long-term & preferential procurement policy for green methanol, etc.

5.3.5 About 0.8 million tonnes of hydrogen can be produced (about 500 Crore liters of methanol per annum) with about 5.5 GW electrolyzers in the Sugar Plant's Bagasse Based Cogeneration Plant and the Ethanol Plants.

5.3.6 Proposed flex engines (well established in Brazil & under development by the major two & four-wheeler manufacturers in India) may be designed to accommodate methanol, in the blend.

5.3.7 Sugar plants with cogeneration plants and ethanol plants can also produce Green Urea (requires 60% ammonia & 70% CO_2, by weight), as they get CO_2 from the fermenters in the ethanol unit. However, the government's aggressive push for nano urea, which is likely to jolt even the fertilizer/ammonia industry in a big way (of course, the fertilizer segment can support the fuel ammonia program or export green ammonia), is likely to affect marketability for conventional urea and hence not suggested.

5.4 Steel & Cement Plants

5.4.1 The concept of making green steel, by using green hydrogen instead of coal in the DRI kilns, is the subject being talked about, in the steel industry.

5.4.2 This segment is likely to get a boost after the targets in easier applications (refinery, fertilizer, and transportation) are achieved.

5.4.3 As coal would continue to dominate in steel & cement production, CO_2 capture from these plants (about 1.5-2T CO_2 release per tonne of steel and about 0.6T of CO_2 per tonne of cement) may be explored for producing green methanol.

5.5 Thermal Power Plants

5.5.1 NTPC's Vindhyachal unit has already begun CO_2 capture from flue gas and the pilot plant for methanol production by installing an electrolyzer is under progress.

5.5.2 As coal would continue to dominate our energy demand for the next few decades, CO_2 capture from these plants (particularly, after the flue gas desulphurization units) may be explored for producing green methanol. Even with partial capture of CO_2 from the thermal plants along with green hydrogen from electrolyzer, it would be possible to meet the entire fuel demand of the nation through green methanol, by replacing crude imports.

5.5.3 However, CO_2 purification to the level of methanol production requires further research to achieve cost viability.

5.6 Renewable Power Producers (over 300 GW electrolyzer with ammonia/methanol plants)

5.6.1 As elaborated in this report, the major industries requiring hydrogen directly (like oil refineries & fertilizer units) are likely to install the electrolyzers in their establishments, by drawing renewable power as permitted by the recent hydrogen/ammonia policies. Even, renewable power producers may tie up with direct hydrogen users for selling power or even hydrogen by installing electrolyzers, at the consumption points.

5.6.2 Renewable power producers will also have a great role to play in meeting distributed generation of ammonia, for green ammonia export (fertilizer as well as marine fuel), by establishing port storage facilities.

5.6.3 The transportation segment (converting the current fuel requirement into green methanol or hydrogen) requires over 300 GW of electrolyzers and corresponding renewable power generation. There is a greater opportunity for renewable power producers & developers to produce green hydrogen & green methanol, by collaborating with thermal power plants & other production units, by capturing CO2.

5.6.4 Once the carbon capturing & purification systems are commercialized and CO2 mandates are framed, it would open up a huge market for Green Methanol for renewable energy developers.