Kashish Shah, Energy Finance Analyst
April 2022

Institute for Energy Economics and Financial Analysis
IEEFA.org

Green Ammonia: Low-Hanging Fruit for India's Green Hydrogen Dream

A Clean Solution to Reduce the Trillion-Rupee Fertiliser Subsidy Bill

Executive Summary

India's maiden green hydrogen policy has opened the door to a promising green hydrogen economy. Green hydrogen – produced through electrolysis of water using electricity from renewable energy sources – could be used either as a chemical feedstock or as a fuel for various industries such as fertilisers, steel, power, transportation and maritime.

The production cost for green hydrogen is about US$5.5/kg in most geographies – higher than grey hydrogen produced using gas at below US$2/kg. Reducing the production cost of green hydrogen hinges on two important input costs – the cost of electrolysers and renewable energy. The cost of electrolysers needs to fall below US$250/MW from US$700-1,000/MW currently, while the cost of renewable energy has to come down to US$20/MWh from US$30-35/MWh.

Reducing the green hydrogen production cost hinges on two key input costs – electrolysers and renewable energy.

However, in the last two years, fossil fuel prices have hit record highs and have been extremely volatile due to the Covid-19 pandemic and the Russia-Ukraine war; and prices are expected to remain high until the end of this year. High and volatile fossil fuel prices have pushed up the cost of production of grey hydrogen, making green hydrogen cost-competitive even at more than US$2/kg.

Many Indian energy companies have set aggressive targets to reduce the cost of green hydrogen. Reliance Industries Limited (RIL) has announced a target of below US$1/kgH2 by the end of this decade.

The evolution of the hydrogen economy will depend on how the various segments of the value chain – upstream, midstream and downstream – are integrated to deliver hydrogen at a minimum price.

The most commercially viable use case for green hydrogen is green ammonia (NH_3) for fertilisers. The Indian government identifies green ammonia as the prime use for green hydrogen and hence the stated incentives are for green hydrogen as well as green ammonia projects.

IEEFA's recently published report reviewed the growing burdens of subsidy and import dependence for fertilisers in India. The recently announced Budget 2022/23 pegged the fertiliser sector subsidy at Rs1.05 trillion (US$14.2bn), exceeding a trillion rupees for a third consecutive year.

In this report, we review the cost competitiveness of producing green ammonia using various modes of electricity inputs (grid electricity, round-the-clock renewable power and solar plus batteries integrated with green ammonia production). Globally, many projects are implementing a model of fertiliser production facility that integrates onsite solar, battery storage and electrolysers.

According to the International Energy Agency's (IEA) hydrogen project database as of October 2021, there is 8MT of green hydrogen to green ammonia production capacity planned worldwide. In this report, we cover some of the top green hydrogen to green ammonia projects.

Green ammonia could help the government to significantly reduce its trillion-rupee fertiliser subsidy bill. It could also create export capabilities whilst remedying India's dependence on imported liquefied natural gas (LNG) for fertiliser production.

The green hydrogen policy provides a host of production side incentives. Other policy interventions are expected in the next phase of the policy which will focus on demand creation through the mechanism of a green hydrogen purchase obligation.

Deep localisation of the value chain will be key for successfully utilising green hydrogen for India's energy transition.

Table of Contents

Green Hydrogen Today

Over the past two to three years, there have been substantial developments globally to commercialise green hydrogen to decarbonise energy-intensive industries. The utility of green hydrogen spans industries such as transport, refining, fertilisers, steel and energy storage. However, there are several challenges for these sectors to transition to green hydrogen as the main feedstock. Determining a long-term pathway to make green hydrogen viable for all possible uses will be a process of learning by doing.

India’s recently announced green hydrogen policy has opened doors for developing a promising green hydrogen economy. The policy has answered the call from the domestic energy industry, which has shown a strong interest in this clean fuel technology.

Hydrogen’s potential for use as a fuel and a chemical feedstock has been known for decades, but it lacked economically viable means to scale its usage. Recently, there has been a resurgence in interest in green hydrogen due to deflation in critical input costs for producing it – electrolysers and renewable energy sources of solar and wind.

A decade-long deflation in the cost of electrolysers has brought the production cost of zero-emissions hydrogen close to that of hydrogen produced using fossil fuels such as coal and gas. The cost of renewable energy has also fallen drastically, with solar and wind now cheaper than coal and gas, making powering the electrolysis process cheaper than before.

However, for the overall production cost of green hydrogen, currently at US$5.5/kg$H_2$, to reach parity with the cost of producing grey hydrogen (produced from gas), at US$2/kg$H_2$ these input costs need to come down further.

Blue hydrogen – produced from fossil fuels but abated by carbon capture, utilisation and storage (CCUS) – has been marketed as a low-carbon hydrogen alternative. However, after more than a decade of attempts, such CCUS projects have yet to achieve commercial viability.[1]

In countries with greater renewable energy resources (better solar irradiance), the cost of production for green hydrogen is below US$3/kg$H_2$.

In countries with greater renewable energy resources (better solar irradiance), the cost of production for green hydrogen is below US$3/kg$H_2$. In Qatar and Australia, it is US$2.62 and US$2.61 respectively, materially lower than that of blue hydrogen at

[1] IEEFA. Blue Hydrogen — technology challenges, weak commercial prospects, and not green. February 2022.

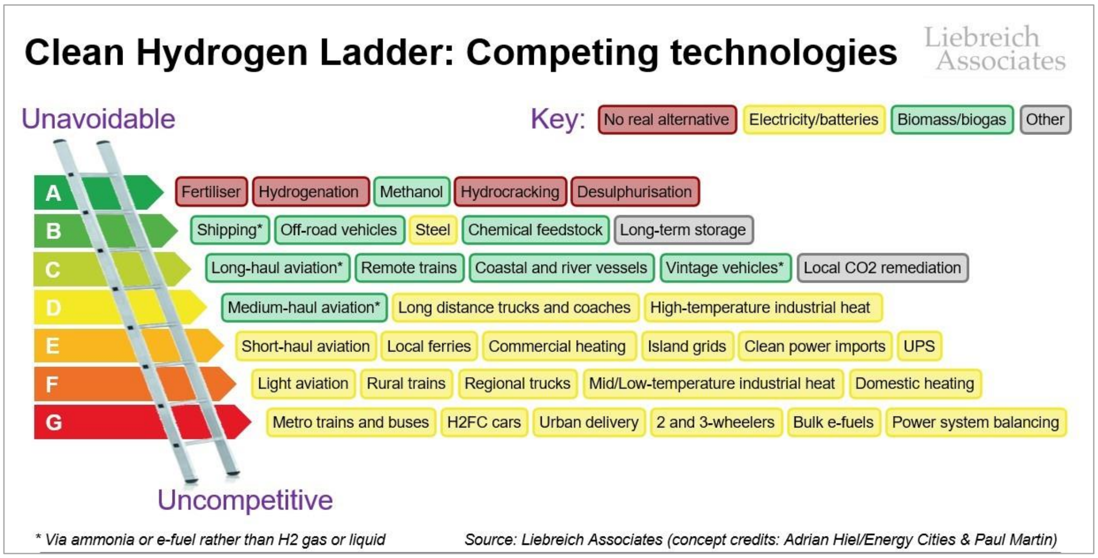
US$4.61-4.80.[2]

This captures only the production side. The evolution of the hydrogen economy will depend on how the various segments of the value chain – upstream, midstream and downstream – are integrated to deliver hydrogen at a minimum price.

Figure 1 maps a large range of green hydrogen use cases and ranks the viability of the fuel for the respective cases.

Additionally, the graphic expands on competing alternatives to green hydrogen for respective use cases. The red boxes (fertilisers, hydrogenation, hydrocracking and desulphurisation) are examples where green hydrogen is more viable than any alternatives. Yellow boxes signify where electricity or batteries are more viable than green hydrogen currently. Fertilisers are the top use case for green hydrogen.

Figure 1: Viability of Green Hydrogen Across Various Sectors



Indian Fertiliser Landscape: Import, Subsidy and Fossil Fuel Dependence

India's fertiliser demand has been strong during the last decade – more than 50 million tonnes (MT) of chemical fertiliser were used annually on average.[3] Natural gas, the most crucial feedstock for fertilisers today in India, accounts for 70-80% of the cost of production, depending on feedstock prices and the energy efficiency of the production plant.

Natural gas is used to produce ammonia, which is the main intermediary for

[2] RECHARGE. Green hydrogen now cheaper than blue in Middle East, but still way more expensive in Europe. 24 February 2022.
[3] Lok Sabha. Fertiliser Consumption. March, 2020.

providing nitrogen in all nitrogen-containing fertilisers. Urea (CH_4N_2O) is the main nitrogenous fertiliser in India,[4] constituting about 55-60% of total fertiliser demand.

IEEFA's recently published report reviews the growing subsidy burden and import dependence for fertilisers in India.[5] The recently announced Budget 2022/23 pegged the fertiliser sector subsidy at Rs1.05 trillion (US$14.2bn), exceeding a trillion rupees for a third consecutive year.

The subsidy goes directly into regulated pricing for fertilisers and favourable gas pricing. The government provides relief in the input cost by the pooling of gas used in the fertiliser sector. Urea units are connected to a national grid to ensure supply of gas at a uniform price by pooling the price of domestic gas and imported LNG.

Recently, global fertiliser prices have increased drastically due to high and volatile gas prices. In October 2021, the urea price hit Rs51.4/kg (US$690/tonne), a 144% year-on-year increase.[6] Gas prices increased from US$10.75/MMBtu (metric million British thermal unit) in January 2021 to US$33.00 in January 2022.[7] However, urea for the agriculture sector remained at a subsidised retail price of Rs5.3/kg (US$71/tonne), reflecting the heavy subsidy of 90% on the global benchmark price of urea.

Subsidy outgoings have taken a further hit with the Russia-Ukraine war. Urea prices surged to an all-time high of US$794/tonne or Rs60.4/kg as of 23 March 2022.[8]

Spot prices for LNG are expected to remain high and volatile due to the war, which is disrupting supplies to Europe and pushing up gas prices.[9]

LNG spot prices in the Asian market are expected to stay close to US$28/MMBtu by the end of this year (NYMEX JKM swaps forward prices, Thomson Reuters). Surging oil prices are also likely to result in higher contract gas prices out of Qatar and Australia which still use oil-linked gas contracts.

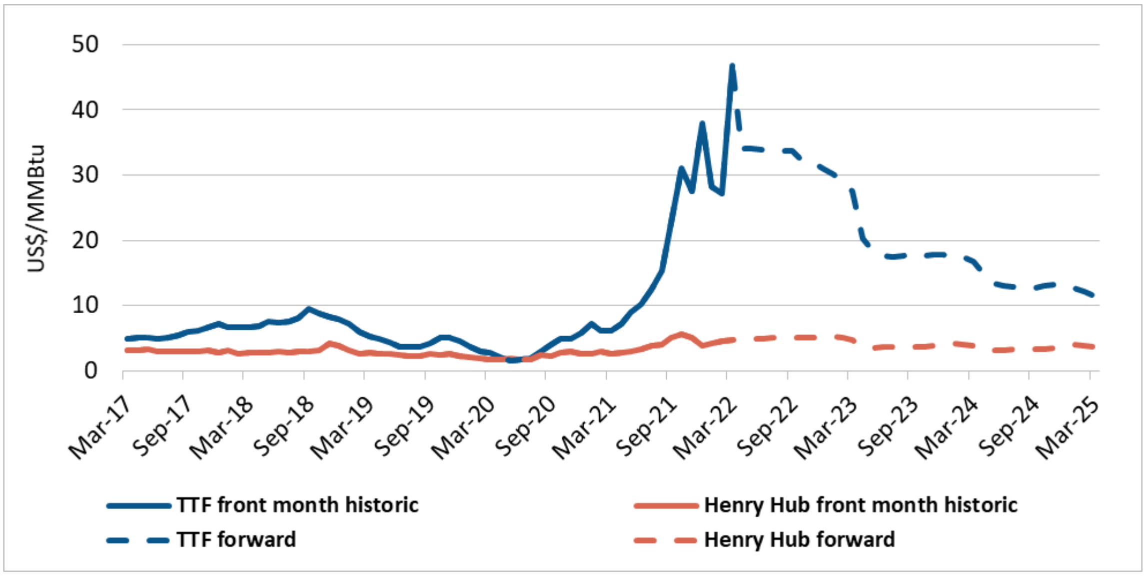
Figure 2 shows LNG price volatility in the North American and European markets over the past five years. Recently, gas prices touched an all-time high and are expected to remain on the higher side for 2022, putting upward pressure on urea and other fertiliser prices.

---

[4] MoPNG. Guidelines for Pooling of Gas in Fertilizer (Urea) Sector. May 2015.
[5] IEEFA. LNG in India's Fertiliser Sector: A Trillion-Rupee Subsidy Burden. March 2022.

[6] The Hindu. India faces record fertilizer subsidy in 2021-22. December 1, 2021.
[7] Thomson Reuters.
[8] Urea FOB US Gulf Mar '22 (JCH22).
[9] Bloomberg Quint. European Gas, Power Rebound as Tensions Over Ukraine Mount. January 21, 2022.

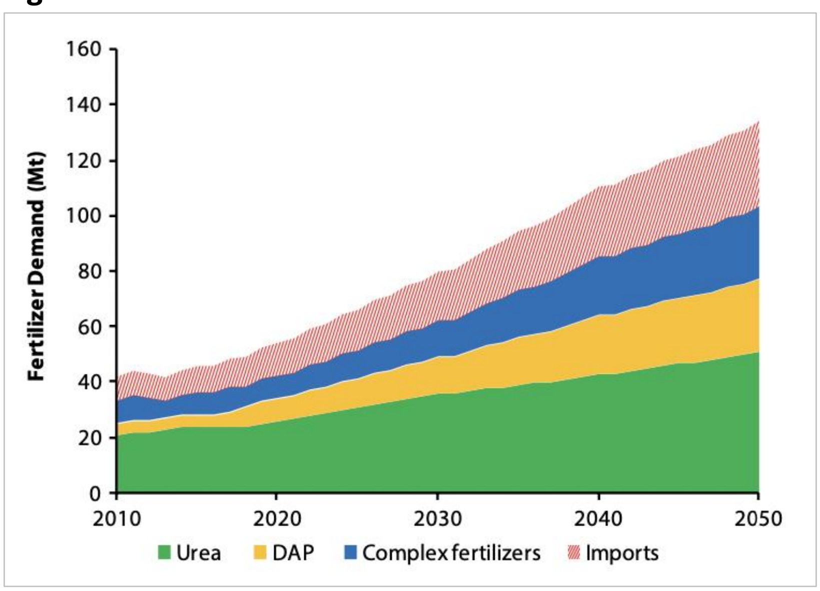
Figure 2: Gas Price Volatility in North American and European Market



Source: Refinitv (Thomson Reuters).
Note: Henry Hub is the price marker for the North American market and TTF is the benchmark gas price for Europe.

The long-term fertiliser demand in India is projected to grow to ~130MT by 2050 from the current ~55MT. More than doubling of fertiliser demand will consequently increase the burden of subsidies on the fiscal budget.

Figure 3: Demand for Fertilisers in India 2010-2050



Source: TERI, Ministries of Chemicals and Fertilisers, Fertiliser Association of India.

The current hydrogen demand for fertilisers is estimated to be about 3MT annually, which is 50% of India's total demand. Given the projected rise in the demand for fertilisers, the demand for hydrogen in the fertiliser industry alone could rise to 7.5MT by 2050 (TERI 2021).[10]

Globally, the production cost of green hydrogen is projected to fall dramatically in this decade. The Government of India, through its maiden green hydrogen policy (discussed below), now aspires to bring down the cost through domestic production. This initiative affirms the Indian private sector's interest in exploring the potential of the clean fuel.

Globally, the production cost of green hydrogen is projected to fall dramatically in this decade.

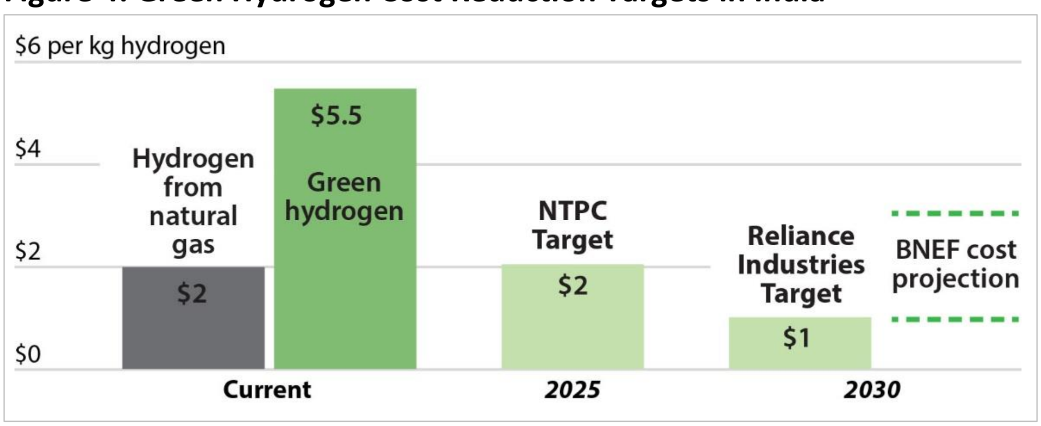
In light of the emergence of a clean alternative, we prescribe a push for use of ammonia produced from green hydrogen to decarbonise India's fertiliser sector.

Green Hydrogen to Green Ammonia

The current method of producing ammonia (NH_3) uses hydrogen produced from a carbon emission-intensive process known as steam methane reformation (SMR).[11] Green hydrogen produced from electrolysis would increasingly become a viable option to eliminate emissions in ammonia production.

India's top energy companies have announced substantial plans to invest in green hydrogen. Reliance Industries' (RIL) stated objective of bringing the cost of green hydrogen below US$1/kgH2 in a decade is the most bullish but other companies have noteworthy plans.[12]

Figure 4: Green Hydrogen Cost Reduction Targets in India



Source: BNEF, Various media outlets; IEEFA graphic.

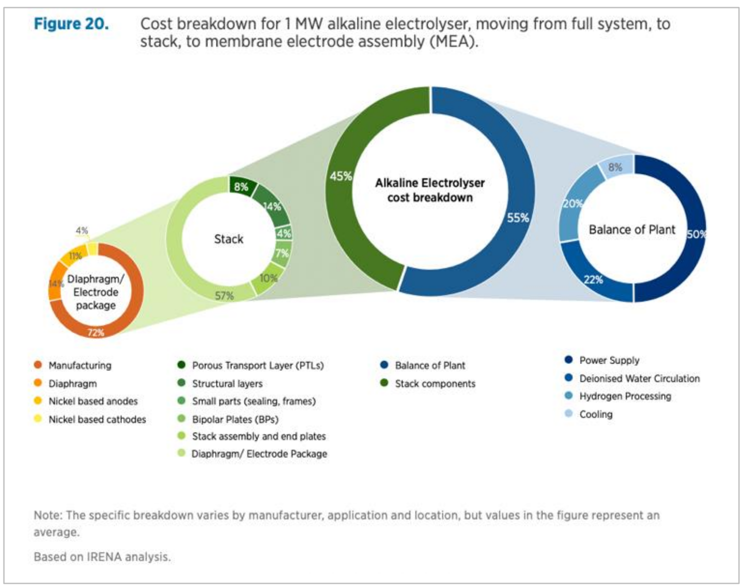
[10] TERI. The Potential Role of Hydrogen in India. July 2020.
[11] Steam reforming or Steam Methane Reforming (SMR) reacts methane with steam at high temperature in the presence of a catalyst to give hydrogen, carbon monoxide and some carbon dioxide.
[12] IEEFA. Battery Storage and Green Hydrogen: The Next Chapter in India's Clean Energy Story. October 2021.

RIL has announced a capital outlay of Rs75,000 crore (US$10Bn) in the next three years to develop manufacturing capacity for clean energy technologies, including electrolysers, to produce green hydrogen. NTPC aims to bring the production cost below US$2/kg by 2025-2026, which is much faster than global projections. Being a government-owned entity, NTPC's bullish targets reflect the Government of India's plans for the sector.

Renewable energy developer ACME has already commissioned a semi-commercial green hydrogen production capacity in Bikaner, Rajasthan (discussed below). Many developers plan to take advantage of the synergy between renewable energy and green hydrogen to expand their business portfolios.

For green hydrogen to become cost competitive with fossil hydrogen, it is imperative to reduce the cost of the two critical inputs, electrolysers and renewable energy, which account for 55% and roughly 25% of production costs, respectively.

Figure 5: Cost Breakdown of a 1MW Electrolyser System



Source: IRENA.

Alkaline and Proton Exchange Membrane (PEM) are the two most commercially proven and widely employed electrolyser technologies globally.

IRENA estimates the electrolyser costs will reduce from US$500-1000/kW for alkaline electrolysers and US$700-1400/kW for PEM to below US$200/kW to produce green hydrogen at below US$2/kg.[13] Moreover, the per unit cost of electricity must fall below US$20/MWh (Rs1.6/kWh) to achieve cost parity by 2030.

For India this is a huge opportunity for building an electrolyser manufacturing base. To avoid over-dependence on imports, as with solar cells and modules, deep

---

[13] IRENA. Green Hydrogen Cost Reduction. December 2020.

localisation of the value-chain will be critical.

Cost of electricity is the other important input cost for hydrogen production. In India the electricity from renewables is now available below Rs2.4/kWh (US$30/MWh). Continued improvements in efficiencies of solar and wind technologies are expected to further reduce costs.

Policy tailwinds for domestic manufacturing of solar panels are poised to massively expand India's module manufacturing capacity base to 51GW and that of solar cells to 33GW by 2025.[14]

Domestically produced electrolysers and solar modules will bring down the costs for production of green hydrogen and subsequently eliminate import reliance.

Cost of Ammonia Production

Ammonia Using Natural Gas

Steam methane reformation (SMR), using natural gas, is the most widely used process globally for producing grey hydrogen that in turn is used for producing ammonia. The emission intensity of this industrial process is among as the highest, along with steel and cement.[15]

This mode of ammonia production also suffers from high volatility in global gas prices.

In its report from 2020, TERI assesses the cost of ammonia production in India at between Rs30,000 and Rs40,000/tonne (US$394-526) with the gas price pegged at US$6-10/MMBtu.[16] In India, gas pricing is based on the average of the benchmark price of imported LNG and the price of domestically produced gas.

Global natural gas and LNG prices increased sharply in 2021. The LNG spot prices for the Asian market surged by 242% in 2021. The Asian benchmark prices rose to US$39.37/MMBtu in December. The Russia-Ukraine conflict has exacerbated the situation and has crunched supply and created uncertainties in the global gas market.

In the medium-term, LNG prices (Asian benchmark) are gradually expected to come down to ~US$20/MMBtu. This is still a multiple of the US$6-10/MMBTU used by TERI as the input gas cost for ammonia production, significantly pushing up the cost of producing ammonia from SMR.

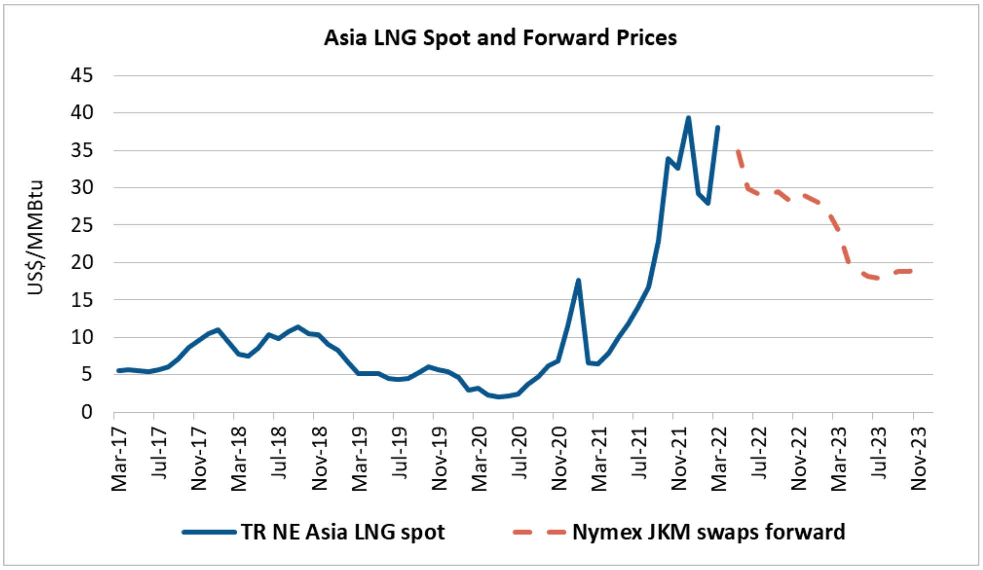
---

[14] JMK Research. Photovoltaic Manufacturing Outlook in India. February 2022.

[15] IEA. Ammonia Technology Roadmap. 2019.

[16] TERI. The Potential Role of Hydrogen in India. July 2020.

Figure 6: Asia LNG Pricing and Volatility



Source: Thomson Reuters, IEEFA analysis.

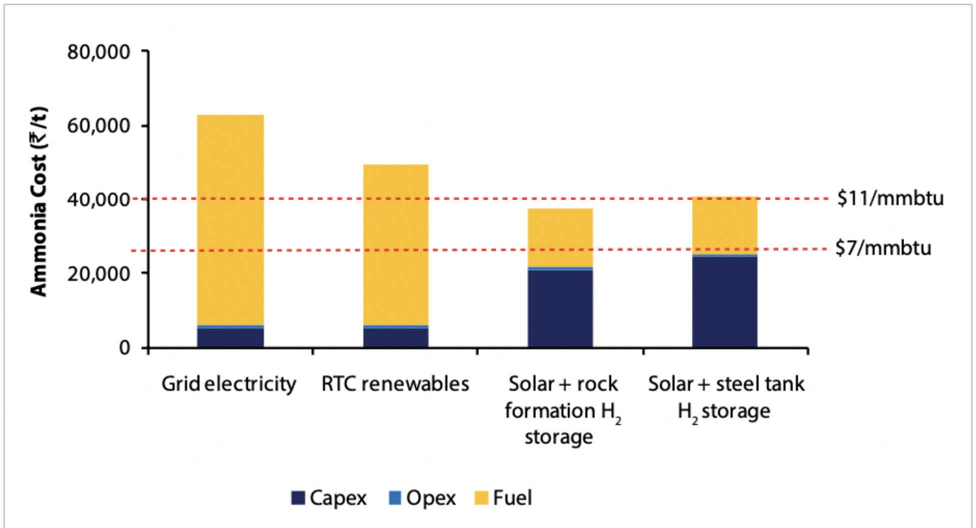
Further to the cost comparison between grey and green hydrogen, assumed parity at US$2/kg$H_2$ probably does not hold true given inflated gas prices globally. Green hydrogen in that case will be competitive with grey hydrogen at a higher price.

Ammonia Using Green Hydrogen (Electrolysis Route)

TERI assesses the cost competitiveness of various electricity input modes for producing green ammonia to be competitive with the cost of producing ammonia using gas.

Figure 7 shows a comparison of these modes of production, assuming 2030 costs and efficiencies for electrolysis and natural gas. In the electrolysis route, the utilisation rate of the electrolyser plant has a material impact on the cost sensitivity. At lower utilisation rates, the levelised cost increases due to lower capital recovery. Higher utilisation rates require constant supply of power either through a grid connection or round-the-clock supply of renewable energy. (Grid electricity in India most likely involves drawing power from coal plants, so to "greenify" the production process would require purchase of renewable energy certificates. This makes the grid electricity mode more expensive.)

Figure 7: Cost of Ammonia Production from Different Modes of Operation, 2030



Source: TERI.

An alternative mode of operation is to co-locate the renewable energy source, such as solar, with the electrolyser plant. This would mean that the electrolyser could access electricity prices of approximately Rs1.6/kWh (US$20/MWh) in 2030. At this price of electricity input, green ammonia becomes competitive with grey ammonia with gas pricing pegged at US$7-11/MMBtu, according to TERI's analysis.

However, the solar output is not consistent even at an improved average load factor of about 28% by 2030. This is a challenge for the Haber-Bosch process,[17] used to produce ammonia, which needs a continuous supply of hydrogen – implying a need for continuous supply of green electricity. A possible way around this is to oversize the solar+batteries capacity to operate the electrolysers at higher utilisation rates. Additionally, paired hydrogen storage could ensure a near constant supply of green hydrogen for ammonia production.

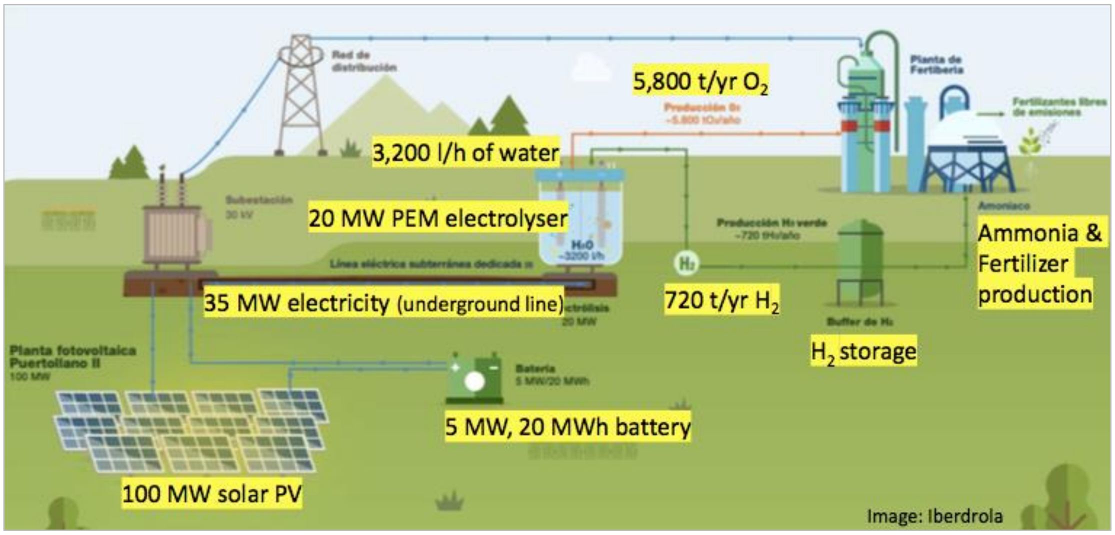
Integrated Green Hydrogen to Green Ammonia Facilities

Figure 8 depicts a pilot-scale fertiliser facility of Spanish fertiliser producer Fertiberia. Spanish utility company Iberdrola is a partner in commissioning this project, the first of its kind. Iberdrola will commission the 20MW on-site electrolyser capacity, with 100MW solar power and 5MW/20MWh battery storage, to integrate with Fertiberia's plant in Puertollano.[18] The plant is planned to be massively scaled-up, with electrolyser capacity expanded to 800MW by 2027 via an

[17] The Haber process, also called the Haber–Bosch process, is an artificial nitrogen fixation process and is the main industrial procedure for the production of ammonia today. The process combines nitrogen and hydrogen, using an iron catalyst at high temperature and pressure.
[18] Iberdrola. Iberdrola and Fertiberia launch the largest plant producing green hydrogen for industrial use in Europe. July 2020.

investment of EUR1.8bn (US$2.1bn).[19]

Figure 8: Fertiberia & Iberdrola Green Ammonia and Fertiliser Facility (Spain)



Source: Iberdrola.

This model of integrating solar and electrolyser has already found takers in India.

ACME Solar, one of India's biggest solar developers, operates a commercial pilot of an integrated green hydrogen and green ammonia production facility in Bikaner, Rajasthan.[20]

ACME's desire to establish itself in the green hydrogen business has become more evident with its announcement of a mega US$3.5bn project to develop green hydrogen and green ammonia production in Oman.[21] In August 2021, ACME signed a land agreement in the Special Economic Zone at the Port of Duqm in Oman. The plant will be an integrated facility using 3GW of solar and 0.5GW of wind energy to produce 2,400 tonnes per day of green ammonia with an annual production of about 0.9MT. The facility is to be commissioned in 2022 and export green ammonia to Europe and Asia.

Sizable Green Ammonia Developments Globally

According to the IEA's hydrogen project database as of October 2021, there is 8MT of green hydrogen to green ammonia production capacity planned globally.

[19] Ammonia Energy Association. Green ammonia in Australia, Spain, and the United States. 29 October 2020.
[20] ACME. World's First Green Hydrogen and Green Ammonia Plant.
[21] Business Standard. ACME Group to set up green ammonia, green hydrogen facility in Oman. 23 August 2021.

Below are some of the largest projects planned for green hydrogen to green ammonia production.

Table 1: Largest Planned Green Hydrogen to Green Ammonia Projects

Project Name	H2-Hub Gladstone (phases 2 & 3)	Hoasis (TCP Gecomp)	Project GERI	HNH	HØST PtX Esbjerg Green Ammonia Plant
Location	Gladstone, Queensland - Australia	Antofagasta, Chile	Geraldton, Western Australia - Australia	Magallanes, Chile	Esbjerg, Denmark
Electrolyser Capacity	3GW	2.1 GW	1.5GW	1.4GW	1GW
Green Ammonia Production Capacity	1.8MT/year	0.25MT/year	1MT/year	0.85MT/year	0.6MT/year
Investment Size	AU$4 billion	US$5.3 billion		US$3 billion	US$1 billion
Proponents	The Hydrogen Utility (H2U)	TCI Gecomp	BP Australia Pty Ltd, GHD Group Limited	AustriaEnergy, Ökowind	Copenhagen Infrastructure Partners (CIP) along with leading Danis agriculture and shipping companies

Source: IEEFA.

H2-Hub (TM) Gladstone, Australia

The Hydrogen Utility (H2U), an Australian based pure-play Hydrogen developer, has proposed a large-scale chemical complex in Gladstone, Queensland to produce renewable hydrogen and ammonia. The proposal aims to integrate up to 3GW in electrolyser plant and deliver up to 5,000 tonnes of ammonia per day. H2U is targeting approvals by 2023 and first production by 2025.[22]

Project GERI, Australia

Project GERI (Geraldton Export-Scale Renewable Investment) is a green ammonia project owned by BP Australia. BP partnered with GHD advisory for a feasibility study to determine domestic and export market potential for renewable hydrogen and ammonia at demonstration scale (~20ktpa ammonia) and commercial scale (~1Mtpa ammonia).

While the demonstration-scale facility will have ammonia as the main output, this study has also explored a range of alternative products as per market demand. Some of these include compressed hydrogen for transport applications, hydrogen injection to gas distribution networks, liquid hydrogen and industrial oxygen.

The project aims to expand to commercial scale with 1.5GW of electrolyser capacity, powered by 4GW of solar and wind combined capacity.[23]

---

[22] CSIRO. H2-Hub (TM) Gladstone.
[23] PV Magazine. bp study confirms Australia's green hydrogen export potential, and calls for carbon price. 12 August 2021.

HØST PtX Esbjerg Green Ammonia Plant, Denmark

In February 2021, Copenhagen Infrastructure Partners announced plans for potentially Europe's largest green ammonia production facility at Esbjerg with a 1GW electrolyser.[24] Annual production of 600,000 tonnes of green ammonia would give a massive push to decarbonise infrastructure and agriculture (green fuel in maritime industry and fertiliser production). CIP will use its decade-long expertise in offshore wind to power the electrolyser. Offshore wind provides higher utilisation rates of 50-55% compared to that of onshore wind (30-35%) and solar (20-22%).

Additionally, excess heat from the plant will be used to heat one third of the households in the city. CIP signed a MoU with leading Danish agricultural and shipping companies such as Arla, Danish Crown, DLG & Maersk to develop this project. The Esbjerg projects aims to start full operation from the end of 2026 and replace all imported fertilisers in Denmark, with a target to become CO_2 neutral by 2030.

Ammonia as an Energy Carrier

Natural gas is transported in the form of liquefied natural gas and then re-gasified on delivery. Similarly, hydrogen could be converted to ammonia for transportation and converted back to hydrogen for industrial use.

According to Wood Mackenzie, ammonia, as an energy carrier, dominates the current wave of hydrogen export projects.

More than 85% of the proposed capacity integrates ammonia and hydrogen to some degree, with ammonia intended for export markets and the remainder, hydrogen, largely aimed at domestic markets.[i]

Ammonia is currently preferred for hydrogen exports mainly for following reasons:

- Ammonia has a better volumetric energy density than hydrogen (less space required to store equivalent energy content). Ammonia's energy density is three times that of compressed hydrogen and 1.5 times that of liquefied hydrogen.
- Both can be stored in liquid form, hydrogen requiring cryogenic tanks maintained at -253°C, while ammonia requires less cooling and can be stored at about -33°C.
- Sophisticated cooling equipment and mitigation hazards make hydrogen more expensive to transport, whereas ammonia is liquid at ambient conditions, requiring lower storage volumes.

[24] S&P. Denmark's CIP proposes 1 GW electrolyser for green ammonia production at Esbjerg. 24 February 2021.

The existing supply chain of ammonia also gives it an upper hand. The synthesis, storage and shipping of ammonia is a well-established industry. The existing market for ammonia is about 180 million tonnes per annum (Mtpa), mostly integrated with the production of derivatives, such as urea, or ammonium nitrate. The seaborne trade in ammonia is about 20Mtpa.

—

[i] Recharge. 'More than 85% of export-oriented low-carbon hydrogen projects plan to ship ammonia, not H2'. 13 January 2022.

Readiness for Transition: Challenges and Solutions

India's green hydrogen policy has provided a range of production incentives. The government identifies green ammonia as the prime use for green hydrogen and hence the stated incentives are for green hydrogen as well as green ammonia projects.

Measures include a single-window clearance system, allocation of land in renewable energy parks, priority access to the interstate transmission network, open access procurement within 15 days, waiver of interstate transmission charges for 25 years and a 30-day energy banking policy.

India has had tremendous success in developing ultra-mega solar parks, with solar parks of more than 2GW capacity already operational. Allowing green hydrogen production in solar parks would build on this success. Access to land, transport and co-location of solar would be advantageous for green hydrogen development.

Waiver of interstate transmission charges is a potential work-around for the problem of over-concentration of renewable energy capacity in a handful of states.

States with greater renewable energy potential, such as Tamil Nadu, Karnataka, Gujarat and Rajasthan, are the top choices for renewable energy developers to commission projects, disadvantaging other states.

In the near term, the waiver of interstate transmission charges for green hydrogen projects would incentivise investment into green hydrogen production facilities even in states with relatively lower renewable energy potential or capacity. These facilities could contract long-term power purchase agreements (PPAs) to buy cheaper RE power from other states, allowing these states to decarbonise their local industries.

Through these measures, the government is promoting the transmission of renewable energy and the setting up of green hydrogen production near the point of consumption. This also includes building bunkers near ports for storage and easy export of green ammonia.

Further, the options for banking renewable energy for 30 days and sourcing renewable power through open access provide flexibility to the project owners.

Creation of Demand

Current incentives mainly focus on the supply side. Developers and investors would further need a visible offtake pipeline for their product. This could be done by implementing a green hydrogen consumption obligation (GHCO) mechanism for fertiliser production and petroleum refining, similar to Renewable Purchase Obligations (RPO). Strong offtake agreements will make the projects bankable.

Financing

A policy brief by FTI Consulting recommends creating a national hydrogen transition fund for national projects using carbon transition taxes that could provide subsidy or incentive funding.[25] A leading example of state funding for green hydrogen is the Australian Renewable Energy Agency (ARENA).[26]

In May 2021, ARENA topped up its ongoing funding for commercialising green hydrogen projects by A$100m (US$72.3m) for three projects with 10MW electrolysers.[27] This is in addition to 16 R&D projects, as well as feasibility studies into large-scale projects and smaller-scale demonstrations looking at renewable hydrogen production, power-to-gas (PtG), and hydrogen mobility.

The Indian Renewable Energy Development Agency (IREDA) could play a similar role in the proliferation of green hydrogen projects by supporting pilot projects and, eventually, commercial scale-up.

The next phase of policy incentives could include production-linked incentives (PLI) similar to those provided for solar modules and battery manufacturing. This could bridge the viability gap for interested manufacturers that are ready to risk capital for a technology that so far has very little headway in the Indian market.

Indian renewable energy developers have successfully raised debt funding through the international green bonds market. As numerous developers look to derive value from the synergy of renewables and green hydrogen, the international green bonds market will remain a key funding avenue.

CO2 Requirement for Urea

TERI's report *"The Potential Role of Hydrogen in India – 'Harnessing the Hype'"*[28] highlights the requirement of carbon dioxide as an input as the other key technical challenge to transitioning India's fertiliser industry to extensively use green

---

[25] FTI Consulting. India's Energy Transition Towards a Green Hydrogen Economy. December 2020.
[26] ARENA.
[27] Bioenergy. ARENA approves over AU$100 million in funding for green hydrogen. 8 May 2021.
[28] TERI. The Potential Role of Hydrogen in India – 'Harnessing the Hype'. 2020.

ammonia.

The production of urea (CH_4N_2O) requires the addition of one carbon dioxide molecule to two ammonia molecules, which means an external carbon source is required. When urea is produced using natural gas, CO_2 is recovered from the reformation process and recycled for urea production. However, for a switch to green ammonia, an additional CO_2 source would be required.

TERI recommends adding additional electrolyser capacity to existing natural gas plants in the short to medium term. The resulting CO_2 should be used or sold for other industrial usages, for instance, carbonated beverages. In future, these plants could be switched to using biomass instead of gas.

Conclusion

Green ammonia is the most viable of all applications in the green hydrogen economy. The projected growth in fertiliser demand in India will further intensify dependence on subsidies and imports unless it is switched to a cleaner and domestically produced feedstock.

Green ammonia could significantly help the government in reducing the trillion-rupee subsidy bill from the fertiliser sector.

Green ammonia is the most viable of all applications in the green hydrogen economy.

In the long term, it also has the potential to reverse India's dependence on energy imports. Green ammonia, as a chemical feedstock or even as an energy carrier, is an avenue for creating export capabilities in addition to remedying import dependence on fossil fuels.

Domestic renewable energy developers, energy utilities and oil and gas companies are exploring opportunities to link their existing capabilities with the emerging opportunity.

India's new green hydrogen policy puts equal emphasis on green ammonia, identifying it as a top use for the clean fuel, and provides the vital incentives to encourage pilot-scale production facilities. For proponents, this will be an important learning-by-doing experience, a model almost all green hydrogen to green ammonia projects are employing before betting big on commercial-scale expansion.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

About the Author

Kashish Shah

Kashish Shah is an Energy Finance Analyst with the Institute for Energy Economics & Financial Analysis (IEEFA). He specialises in financing, policy and technology matters of the Indian electricity market. He has a master's degree in economics from the University of Sydney and an engineering degree from NMIMS University in Mumbai. Previously, Kashish has worked in the Global Analytics Division of the Royal Bank of Scotland with a focus on regulatory policies. He has research experience in India's public sector in his work for a member of the Indian Parliament and a University of Sydney-based research group.