H2 Summit

Green Hydrogen Investment Strategies for India

# WHITE PAPER

## Strategies That Can Help India Become ME of $GH_2GNH_3$

INITIATIVE BY

Deesha
TOWARDS NET ZERO

ORGANISED BY

Infinity Expo

SUPPORTED BY

GH2 Green Hydrogen Organisation

igef Indo-German Energy Forum

Innovation Norway

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# FOREWORD

“Reducing emissions is a key goal for countries across the world. At the same time energy demand is increasing so the transition to a low carbon energy system is essential to meeting the immense challenge of global warming. We cannot do this without green hydrogen made from renewable electricity. It is the only way we can fully decarbonise key industrial sectors such as steel, cement and fertiliser production and long-haul transport in shipping and aviation.

The Indian government has made an impressive pledge of net zero by 2070. It is now putting bold measures in place to create a green hydrogen economy replacing fossil fuels. Led by Prime Minister Narendra Modiji, India’s National Hydrogen Mission is grasping the immense potential of green hydrogen to reduce the dependence on oil and gas imports. It was heartening to see how fast and dedicated Indian business responded to the call from the prime minister.

As an agricultural powerhouse and significant user of fertilisers, India has the potential to decouple its food production from fossil fuels. Green hydrogen can be used to make carbon-free green ammonia, which in turn can be a key input to fertilisers. This will reduce India’s import needs for fertilisers and reduce its heavy subsidy bills.

India’s green hydrogen policy is putting the country on the path to being a green hydrogen superpower. The range of incentives aimed at increasing the supply of green hydrogen can be matched with similar incentives to stimulate the demand of green hydrogen. Government procurement rules and regulations can be tweaked to drive the demand for lower carbon solutions such as green hydrogen.

The introduction of green hydrogen standards or codes in the Indian green hydrogen economy will boost the credibility of this sector and improve the confidence of investors. The adoption of internationally recognised standards that certifies that hydrogen made in India is genuinely green is also key to satisfy India’s export ambitions. In Green Hydrogen Organization we are eager to work with Indian business and officials.

No other country needs a fast-track green hydrogen economy more than India. This will limit the financial burden of oil and gas imports. It will curb pollution in its growing urban cities, improve food and decarbonise its energy sector with cheaper and clean energy access to all.

I congratulate the team at Deesha Power Solutions and the Green Hydrogen Organisation in bringing together this white paper for readers and patrons who share a similar green vision for India. I look forward to meeting you all! Let us come together, provide leadership and, for the sake of the planet, for Indian development and for your commercial endeavours, work tirelessly to shape the green hydrogen economy in India that aims to become the middle east for GH2GNH3 in the world.

A planet to save, an Indian economy to build even stronger, not a day to lose.”

Erik Solhiem, Chairman
Green Hydrogen Organisation

# ACKNOWLEDGEMENTS

This white paper is our humble attempt to share our passion and belief through research supported thought process on “Strategies That Can Help India Become Middle East of GH2GNH3”. Through this white paper we have been able to bring out national aspiration.

We wish to acknowledge contribution of all key stakeholders and leaders from entire GH2GNH3 industry value chain, for supporting the final outcome of this white paper on “Strategies That Can Help India Become Middle East of GH2GNH3” and we take this opportunity to thank them. While working on engagements related to renewable energy and energy transition, we interacted with different stakeholders and each one of them had a point of view for creating something worthwhile for India’s energy security and further expansion to exports thereon. Need was felt to bring these stakeholders together and that was the genesis behind organizing this event and developing this white paper.

We thank Hon. Shri Bhagwanth Khuba, Minister of State (MNRE, Chemicals and Fertilizers) for taking his time out from his busy schedule and inaugurate the GH2 Summit and release this white paper.

Overall, we interacted with 35+ decision makers across industry value chain Viz. electrolyzer companies, investors, lenders, developers, state government bodies, Balance of Plant (BoP) solution providers, H2 consumers and various experts. We would like to thank each one of them for their learned inputs and constructive suggestions.

Further, we would also like to acknowledge GH2 Summit organizer M/s Infinity Expo and our partners viz GHO Geneva, IGEF Germany and Innovation Norway without their helping hand such a wide reach-out for primary interactions would not have been possible.

Finally, we thank our white paper sponsors M/s Ion Exchange (India) Pvt Ltd and M/s India Gas Exchange.

We hope that a small step, in terms of culmination of thoughts through this white paper, could start long journey of India becoming an energy hub of 21st Century with all stakeholders marching in same rhythm and hope that it will light up million minds for proactive actions in the years to come.

Jai Hind!!!

Shardul Kulkarni, MD& CEO
Deesha Power Solutions

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# MESSAGE FROM CHAIRMAN - GH2GNH3 SUMMIT 2022

Global Sustainability Initiatives will disrupt various Industrial initiatives. This is the beginning of Industry 5.0

**We all know Industrial revolution journey.**

- Starting 18th Century, Industry 1.0 was focused on Water and Steam powered mechanical manufacturing,
- That continued till 20th Century almost 200 years, when we saw Electrically powered products with division of labour, this we called as Industry 2.0 that lasted for 70 years.
- In early 1970s till late 2010 (40 years) we say growth was supported through focus on Electronic and IT for improved automation and manufacturing, this we called as Industry 3.0
- Industry 4.0 was all about cyber physical & Digital systems wherein we talked about integration IOT and stuff around that supported by 4G telecom networks. This has been for past 10 years.
- Now, the new disruptive but globally constructive term Industry 5.0 as a next wave, and it is going to capitalize on new setup based on sustainability and climate change agenda. Implementing SDGs, ESG, Goal Net Zero, GH2GNH3 and various sustainability linked initiatives are already into foray.

As we see from these industrial revolutions, Change is not only Constant but accelerated too from 200 years to less than 10 years.

We see several early adopters who are serious on adhering Scope 1, Scope 2 and Scope 3 norm. Companies have to put ESG at the center of future strategy development and are willing to re-look and align their current product portfolios.

Industry 5.0 will have very positive impact on environment; however, it would disrupt conventional coal-based and hydrocarbon base energy intensive industries.

This transformation would need huge funding. As per McKinsey report capital spend on physical assets of energy and land use system, world would need to raise USD 3.5 Trillion Per year globally. Government bodies, financial institutions, Large Business Houses need to come together and plan the strategy of Financing Net Zero,

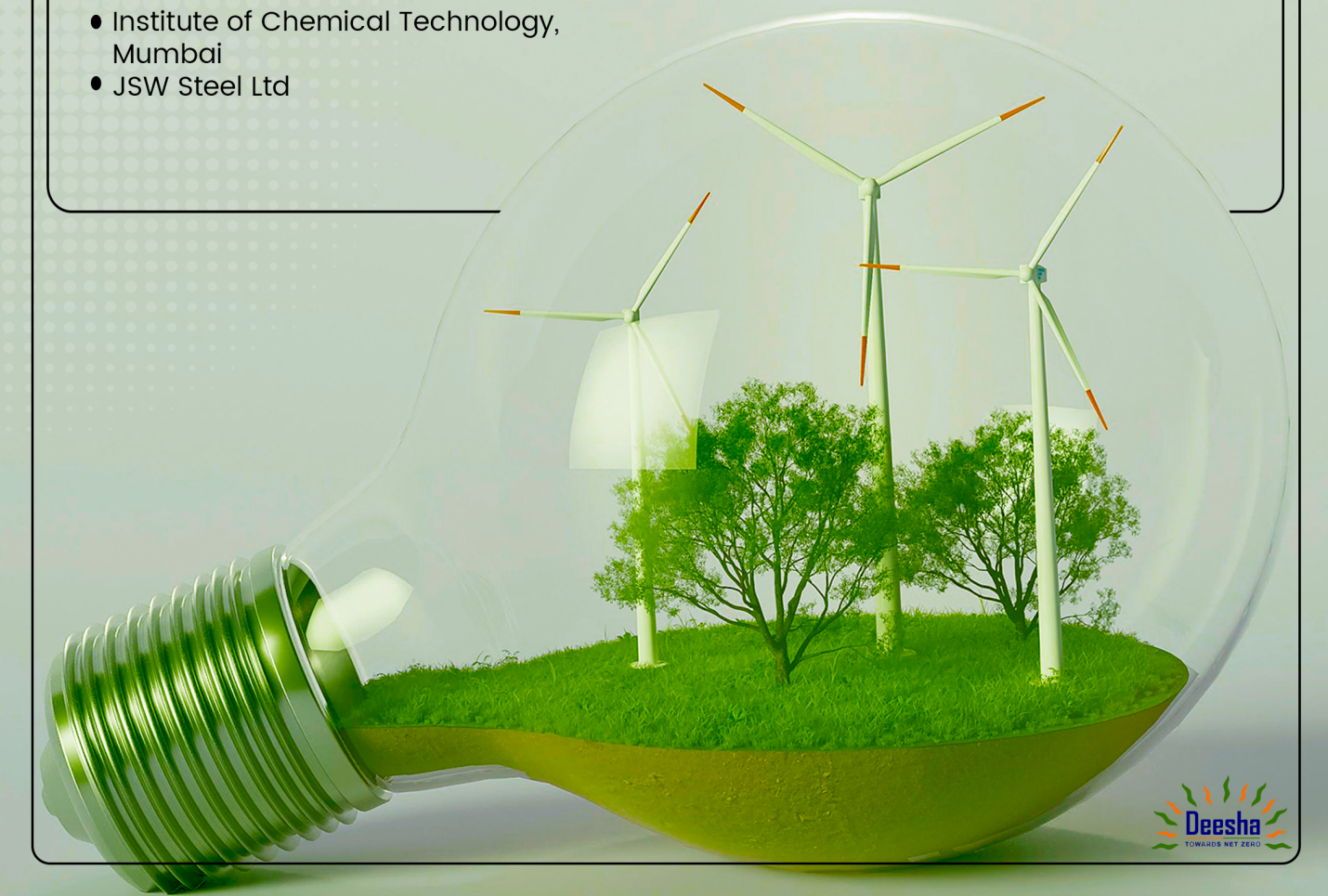
For India we would need USD 2.3 Tn for Industry and USD 1.5 Tn for low emission fuel in next decade.

GH2GNH3 summit has been conceived to deliberate all the facet of this opportunity with the context of several G2G initiative and commitment from our Hon. Prime Minister Shri Narendra Modi to make India Global Hub of GH2

Manish Panchal, Chairman
GH2 Summit 2022

# Extensive primary interactions with the key stakeholders have been undertaken

- ACME Cleantech Solutions Pvt. Ltd.
- Ador Powertron Ltd
- AGV Energy, Malaysia
- Black & Veatch Pvt. Ltd
- CAC-H2 Pte Ltd, Singapore
- Chambal Fertilisers & Chemicals Ltd
- DCM Shriram Industries Ltd
- Eastern Electrolyser Ltd
- Enel Green Power India Private Limited
- Fuel Cell India
- Godrej Industries Ltd
- Greenko Group
- Guidance Bureau, State Govt of TN
- H2 Association of India
- Holcim Ltd
- HomiHydrogen
- India Gas Exchange
- Inox India Ltd
- Institute of Chemical Technology, Mumbai
- JSW Steel Ltd
- Kalpataru Ltd
- L&T
- Megha Engineering & Infrastructures Ltd.
- O2 Power
- Ohmium
- Plug Power Inc
- Statkraft India Private Limited
- Spirare Energy Pvt Ltd
- Tata Chemicals Ltd
- Tata Industries Ltd
- Tata Projects Ltd
- Tata Steel Ltd
- Technithon Technologies Pvt Ltd
- Thinkgas Distribution Pvt Ltd
- thyssenkrupp Industrial Solutions (India)
- Pvt Ltd
- Vibrant Energy, Singapore



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# ABOUT AUTHORS

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Clean Energy Enthusiast | GH2GNH3 Expert

Shardul is MD & CEO of Deesha Power Solutions Pvt Ltd. He is an energy transition professional with ~21 years of experience in power and renewable energy. During this tenor, he facilitated investments in energy transition projects with cumulative investment of USD 1 billion+ across multiple geographies viz South East Asia and Western Africa.

In the past , he worked with blue chip organisations like SBICAP, Crisil Infra, Singapore PE Advisory and Tata Strategic, Now he is advising multiple clients for their foray in GH2GNH3. Among other, he is associated as GH2 Expert for a Singaporean Fund.

He has been invited at many industrial events to share his unique point of view in the areas of Green Hydrogen, Net Zero, Energy Transition waste to energy , Energy Efficiency & Managing Cost of Energy, ash management, coal gasification, etc

Further, he has authored 15+ thought leadership articles on various energy matters including GH2 and Energy Transition arena, In addition to this, he has a YouTube channel "Hydrogenwala" to spread awareness about green hydrogen and green ammonia to industry at large.

**Manish Panchal**
Strategic Thinker | Business Leader | Investor |
Author of the Book 'DEFINE YOUR ORBIT'

Manish is an Executive Director - Investment Banking Business at Equirus Capital a leading Merchant Bank of India. He is also a Mentor at Deesha Power. He has overall 32 years of experienc with equal mix of indusry and Strategy and Operation Consulting.

Prior to joining equirus he has served as Senior Leader at DuPont Sustainable Solutions (DSS)- a global leader in Operation Risk Management and ESG Consulting, And, prior to DSS he has worked as Sr. Practice Head Chemicals & Energy practice at TATA Strategic Management Group, india's leading Strategy Consulting Firm where he helped 50+ large and medium size corporations for Sustainable Business Growth.
Manish is a 'NEW ENERGY' enthusiast and his area of expertise is Strategy Development, Operationalizing Strategy Execution (O ganic & Indorganic), M&A, Tumaround Management and Oper tion Excellence,

He also has to his credit 50+ business articles published in various industry journals, He has been member of FICCI Chemicals & Petrochemicals Task Force and Think Tank Commitlees.

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# 1 EXECUTIVE SUMMARY

## Context

- White paper aims at discussing GH2GNH3 global best practices, adaption strategies for India its aspirational positioning to be "ME of GH2GNH3".
- H2 is called as God Molecule due to its chemical property that when it burns in presence of O2, water is formed.
- Hydrogen is getting used as a chemical in many industrial applications such as refinery, fertilizers, chemicals, glass, food, electronic, pharma, steel etc while Hydrogen is going to be an imminent promising fuel for air, water and surface mobility
- H2 making is an energy intensive process, type of energy used determines its colour coding such as gray/blue/green
- India needs to harness GH2 for energy security and energy democretisation reasons, while GNH3 is required for security of feedstock for fertilizer industry

## Current Status

- Global GH2 market is expected to reach to USD ~20 billion by 2030 which is further likely to touch ~USD 700 billion by 2070.
- EU is leading GH2 adoption initiatives with net zero targets, but US going to catch soon with production incentive upto USD 3/KG of GH2.
- Subsequent announcement of Hon PM on National H2 Mission in Aug 2021, plethora of GH2 policy initiatives are announced over last one year and now it is progressing in right direction of exports.
- India's current hydrogen production is ~6 MMTPA which expected to enhance by~5x by 2030, while cost of GH2 is likely to drop to 1/3rd of today's value.

## Future Aspirations

- India may target to reach production of ~210 MMTPA or ~30% of GH2 global production by 2070.
- Domestic GH2 needs to reach to the scale of ~80 MMTPA coupled with GH2 exports of ~130 MMTPA resulting into likely annual turnover of ~USD 500 billion.
- India would need a total investment of ~USD 4 trillion and the same is proposed to be financed through equity, debt, green bonds and carbon financing.

## Voice of Industry Leaders

- Industry believes that energy & food security coupled with decarbonization are the principle reasons why India should adopt GH2GNH3.
- ~70% of respondents opined that inflection point in terms of Rs/KG of GH2 pricing for its wide spread adoption in India would be in range of USD 2-3/KG .
- Respondent opined that GH2 adoption is likely to happen on priority across four sectors viz Refinery, Fertilizers, Steel & Chemicals.
- 81% of the respondents believed that India can become ME of GH2GNH3 primarily due to conducive govt policies; balance raised concerned about infra readiness.

## Possible Strategies to Help India Become ME of GH2GNH3

- Domestic GH2 market of 80 MMTPA by 2070 could be created with calibrated policy support, incentives and mandates
- To create a scale, PLI like scheme could be introduced for electrolyzer and other sectoral manufacturing.
- RE pricing for GH2GNH3 could be targeted in the range of $ 2.5 cents to 3.75 Cents/kWh by 2025 and ~ 1.88 cent/kWh by 2050.
- Fiscal incentives such as GST exemption and zero customs duty for all inputs could ensure landed GH2 pricing below USD 2/KG GH2 Export market of ~130 MMTPA by 2070 could be initiated with executing MoUs with partner countries incorporating technology and finance cooperation; GH2GNH3 clusters could be developed across coastal lines of India.
- GoI need to address GH2 definition/standards/codes/safety procedures which are compliant to international/EU standards
- "Green Bank" and "Carbon Discovery" may be incorporated with appropriate legislation to fund debt requirements of GH2GNH3 projects.

# 2 CONTEXT

### *2.1 Introduction*

India in line with its vast demography has been a big energy consumer with ~85% of its crude oil needs and ~48% of natural gas needs being met through imports. This has not only led to prohibitive costs which form 23% of the country's total imports but has also had it face troika issues named "Empission" viz economic, imports and emissions. Its current position as the worlds third largest emissions producer does tend to put it in a vulnerable territory

Green Hydrogen as an energy transition comes at an opportune time when the nation is working towards energy security through self-reliance approach with a strong commitment to sustainability. Prime Minister Shri Narendra Modi's vision on Green Hydrogen is very encouraging to say the least.

Through this Whitepaper we are making an attempt to bring to the forefront GH2 adoption strategies against the backdrop of national demand and global best practice that can help India achieve its ambitious mission of becoming a global player in the GH2GHN3 sector

Among others, this white paper also aims to ponder upon need of standards & safety procedures, technology options and most importantly financing options.

### *2.2 H2 Properties*

| ***Property*** | ***Property*** |
|---|---|
| Auto Ignition Temperature: 500 deg C | Makes it relatively safe as compared to other hydrocarbons (sub 100 deg C) |
| Calorific Value: 33,889 kCal/KG | ~3 times higher than natural gas CV; Important consideration for comparison ($ per kCal) |
| Density (KG/M3): 0.08375 | ~14 times lighter than air; This means that when released, hydrogen will typically rise and disperse rapidly, greatly reducing the risk of ignition at ground level. |

*Source: Deesha Power Secondary Research*

**Chat Box 1**
**Why The Name - God Molecule?**

•Hydrogen occurred during the very first second after the Big-Bang, which marked the birth of universe
•When H2 is burnt in presence of O2, water is formed. Like God, Hydrogen is the giver of water and hence the name God Molecule

Electricity & Mobiles were the business disruptions of 19th & 20th centuries respectively. Hydrogen , that to green hydrogen, is all set to become the biggest business disruption of 21st century. World is increasingly getting divided between those who knows about hydrogen or otherwise. Those who want to become makers of hydrogen economy or the takers.

## 2.3 Hydrogen Industrial Uses

### 2.3.1 Existing uses

Hydrogen is getting used as a chemical in many industrial applications such as refinery, fertilizers, chemicals, glass, food, electronic, pharma, steel etc as mentioned below:

| | | | |
|---|---|---|---|
| **Refinery** | ✓ To produce lighter hydrocarbons, which are more marketable<br>✓ To remove sulphur towards meeing Air Quality Act requirements | **Silicon** | ✓ To create specially controlled atmospheres in the production of semiconductor ciruits |
| **Fertilizer** | ✓ To produce amonia which is base material further fertilizer derivatives | **Optic Fiber** | ✓ To make preforms and also in Optical fiber drawing machines |
| **Chemical** | ✓ To produce chemicals through hydrogenation route for further applicatons in soaps, insulation, plastics, ointments and other specialty chemicals | **Pharma** | ✓ To produce sorbitol (though hydrogenation of glucose) which is a base chemical for skin care/oral care applicatons such as cosmetics, adhesives, surfactants, and vitamins A and C |
| **Glass** | ✓ To remove impurities in atmosphere around float Glass production ( as a special conditioning chemicals | **Steel** | ✓ To ranneal the steel in Bell type Annealing Furnace or contincous annealing line.<br>To galvanise the steel in galvanizing lines. |
| **Food** | ✓ To hydrogenate liquid oils (suh as soybean, fish, cottonseed and corm) converting them to semi solid materials such as marrgarine and peanut butter | **Power** | ✓ To serve as a heat transfer medium for cooling high speed turbine generators in thermal power generation<br>Also used to react with oxygen in the cooling water system of boiling water nuclear reactors in nuclear power generation |

*Source: Deesha Power Intelligence*

Refinery , Fertilizer and Chemical industries require hydrogen on 24x7 basis. Hence almost entire hydrogen is produced at site through steam methane reformation of natural gas.

Majority of the other industries as mentioned above need hydrogen sporadically. Hence the same supplied in batches. H2 transportation through road and that to using cylinders wherein hydrogen is compressed to ~150 bars.

### 2.3.2 News uses

Hydrogen is going to be an imminent promising fuel for air, water and surface mobility as mentioned below:

| | | | |
|---|---|---|---|
| **Surface Mobility** | ✓ To propel heavy duty trucks & commercial vehicles<br>✓ To propel trains | **City Gas Distribution** | ✓ To blend hydrogen with natural gas<br>✓ To transport blended gaseous fuel using pipelines |
| **Marine Transport** | ✓ To propel large shipping vessels<br>✓ To replace bunker fuel | **Turbine** | ✓ To blend hydrogen with natural gas<br>✓ To use blended fuel for power generation |
| **Aviation** | ✓ To use electrolytic green hydrogen and captured CO2 to produce synthetic fulel<br>✓ To propel large air cargos and replace ARF | **Energy storage** | ✓ To produce electrolytic GH2 using cheap energy<br>✓ To use this GH2 in peaking hrs to replace costly fossil fuel based energy |

*Source: Deesha Power Intelligence*

Among aforementioned applications, pilots for surface mobility has started in India. In Singapore, Keppel Shipyard is planning to use GH2 for marine applications.

Indian Railway has recently awarded a contract for conversion of diesel power mode to hydrogen fuel as retro fitment of one Diesel Electric Multiple Unit on Sonipat Jind section of 89 km. It's envisaged that cost of diesel is higher than cost of hydrogen and hence project is likely to have a payback period of less than two years. (Source:https://urbantransportnews.com/news/indian-railways-to-launch-hydrogen-fuel-powered-train-as-pilot-project)

### *2.4 H2 Colour Coding*

Industry nomenclature for various colours of H2 is presented below:

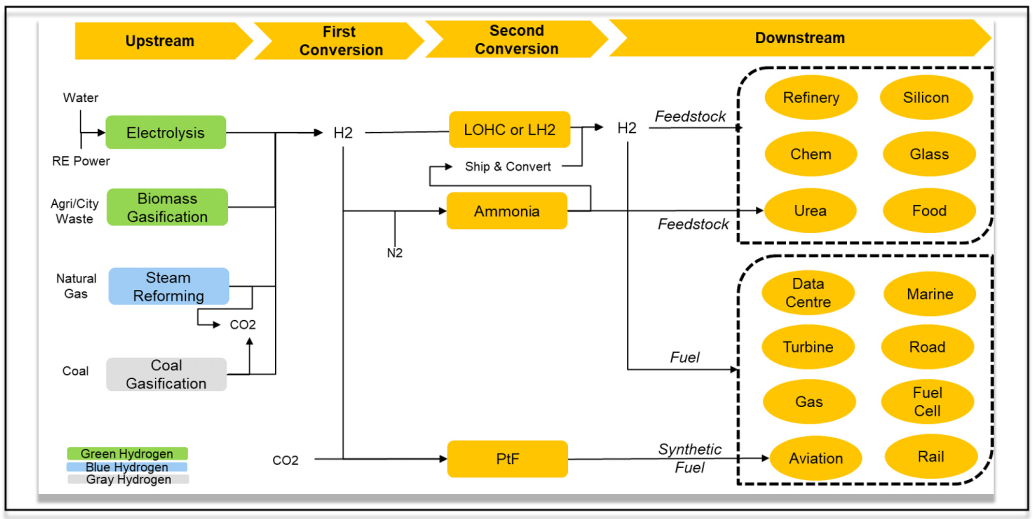
| Colour | Fuel | Process | Products |
|---|---|---|---|
| Brown/ Black | Coal | Steam reforming or gasification | $H_2+CO_2$ (released) |
| white | N/A | Naturally occurring | $H_2$ |
| Grey | Natural Gas | Steam Reforming | $H_2+CO_2$ (released) |
| Blue | Natural Gas | Steam Reforming | $H_2+CO_2$ (% captured and stored) |
| Turquoise | Natural Gas | Pyrolysis | $H_2+C$ |
| Red | Nuclear Power | Catalytic Splitting | $H_2+O_2$ |
| purple/Pink | Nuclear Power | Electrolysis | $H_2+O_2$ |
| Yellow | Solar Power | Electrolysis | $H_2+O_2$ |
| Green | Renewable Electricity | Electrolysis | $H_2+O_2$ |

*Source: Industry*

At the moment, India's entire consumption of hydrogen is considered as gray hydrogen as the same is produced through steam methane reformation of natural gas without any carbon capture. Every SMR based H2 produces ~9-14 KG of Co2, which is extremely carbon intensive process

### *2.5 H2 Colour Coding*

Hydrogen value chain is presented below:




*Source: Industry*

The value chain of green hydrogen describes the single steps from the origin towards the use of the energy carrier: green electricity production, H2 production, H2 distribution and H2 storage as well as various H2 applications.

#### *2.5.1 H2 Production*

There are different ways to produce hydrogen. Examples include production from renewable energies through electrolysis, steam reforming of biomethane and pyrolysis of biogenic feedstocks (green hydrogen) and natural gas through steam reforming with (blue hydrogen) and without (grey hydrogen) the sequestration and storage of CO2 (CCUS – Carbon Capture Use and Storage).

Further processing of hydrogen to remove impurities might be necessary depending on the target application.

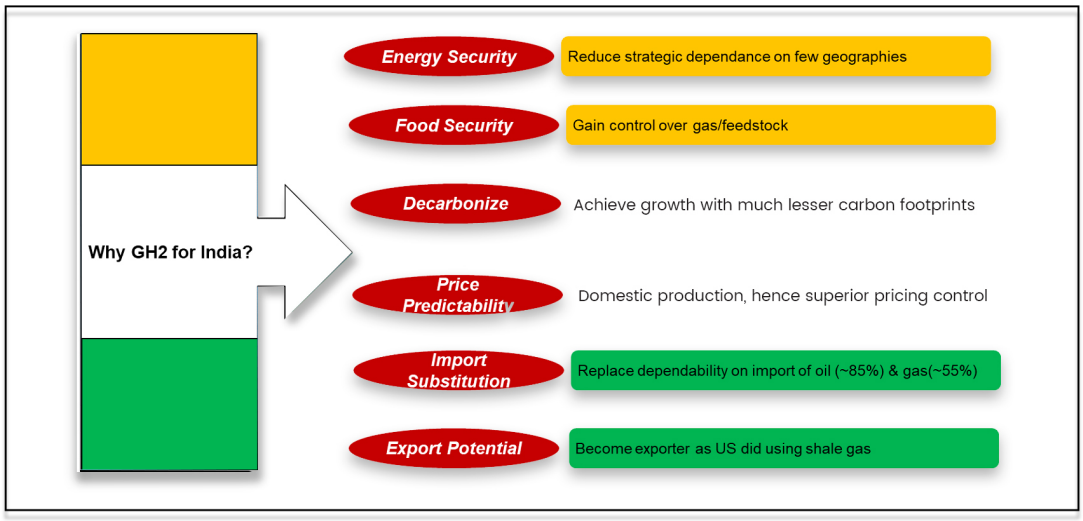
### *2.5.3 H2 Applications*

In energy and material applications, operators and component manufacturers need to understand the risks related to high-pressure equipment, safe handling of hydrogen and conformity of parts, equipment, and plant.

In mobility applications, homologation, global market access, and component testing for hydrogen vehicles are critical but not yet fully standardised.

### *2.6 Why India Should Invest in GH2?*

Below mentioned graphic illustrates strategic reasons why India should invest in GH2:



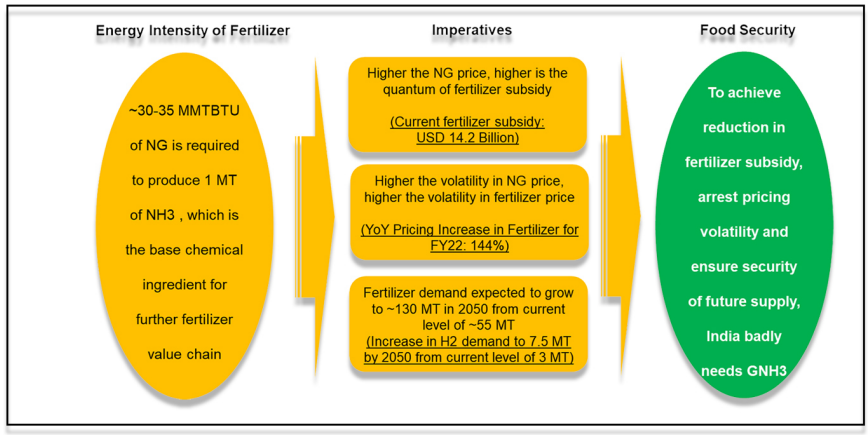

*Source: Deesha Power Perspective*

India related impartives for GH2 are explianed below:

- **Energy & Food Security:** Adventurism by few oil & gas producing countries always pushes India against wall due to its heavy import dependence. This inturn also affects further hydrocarbon value chain leading upto ammonia grossly affecting fertilizers. By adopting to indegenous GH2, we are opting to do away with the security issue once for all
- **Decrabonisation:** Being responsible largest democracy, India can't and shouldn't shy away sustainability related issues. GH2 could offer significant impetus to Hon PM's vision of net zero economy by 2070
- **Price Predectibility & Stability:** Lack of predictibility and stability in energy pricing is demotivating for industries also adds to inflation eating away signficant real income of lower strata Indians. Biggest advantage that GH2 offers is it decouples energy and inflation.
- **Import Substitution:** Locally produced GH2 and its further value chain will signficantly avoid imports of oil, gas, petroleum products, ammonia and urea. This will save precious forex which could be used for infra creation
- **Export Potential:** Using shale gas, US not only met its domectic demand but also became net exporter of energy. GH2 could be India's shale oil towards the path of exports that too a dominent export hub due cheap (& abundent) availability of RE power and water across Indian states

### *2.7 GNH3 for India*

Below mentioned graphic illustrates strategic reasons why India should consider GNH3 applications:




*Source: Deesha Power Perspective*

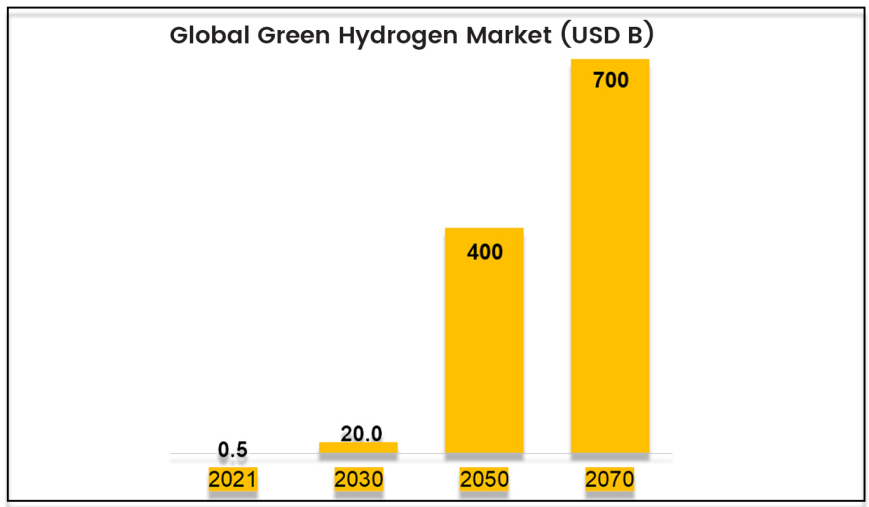
GNH3 is required for security of feedstock for fertilizer industry in following three ways:

- Insulation from ever increasing NG pricing
- Decoupling of NG pricing volatality with NH3 pricing
- Feedstock security through domestic production

## *3. CURRENT STATUS*

### *3.1 Global GH2 Market*

Global GH2 market situation during 2020-2030-2050-2070 is depicted in picture below:




*Source: Allied Market Research*

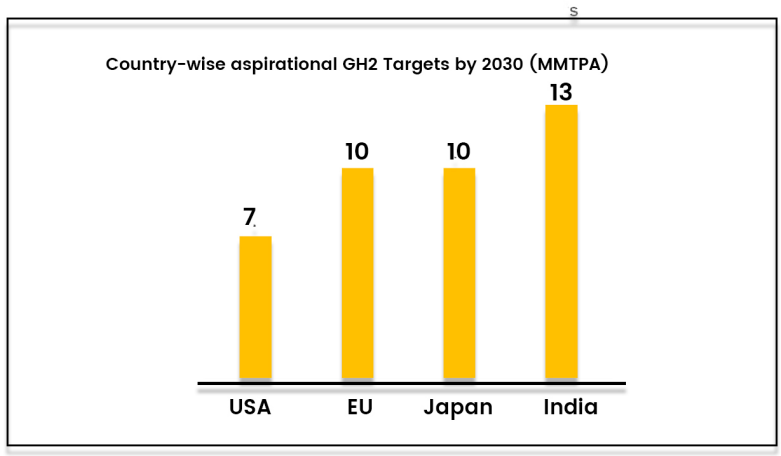
As depicted above, global GH2 market is slated to grow to USD 700 Billion by 2070. Drivers and restraints for GH2 are mentioned below:

- Drivers
  - Democratisation of Energy Access
  - Energy Security
  - Decarbonisation drive
  - Volatility in NG pricing due to geopolitical issues
- Restraints
  - High initial capex and opex
  - Logistics
  - Safety of hydrogen

It is envisaged that economics and inter-government cooperation will help the envisaged growth of this market.

### *3.2 Country-wise Aspirational Targets*

Below mentioned graphic illustrates strategic reasons The graph below gives country wise aspirational GH2 targets by 2030:



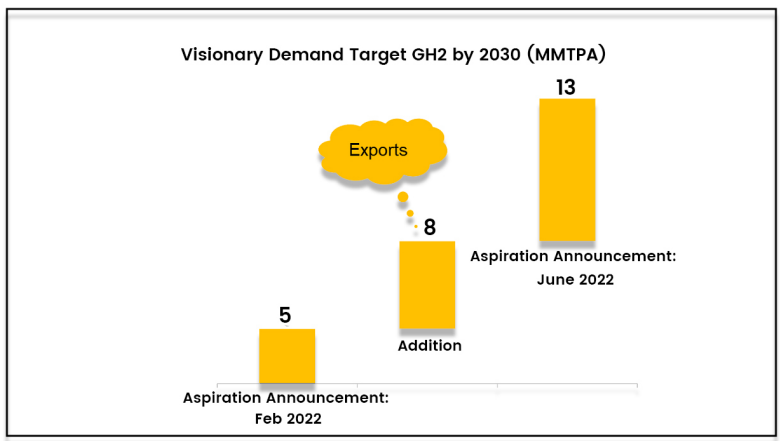

*Source: Deesha Power Secondary Research*

EU has committed for Net Zero GHG emissions by 2050, there by leading GH2 adoption initiatives so far. However, US market is becoming equally interesting with Federal Govt of US announcing production incentive upto USD 3/KG of GH2 or for 10 years or an investment tax credit of up to 30% of the cost of the electrolyser and other equipment. Japan is equally committed with aspiration GH2 adoption @ 10 MMTPA by 2030

India, on the other hand, has announced its aspiration GH2 target but "National Hydrogen Mission" or "the how part" is still a work under progress

### *3.3 India's GH2 Policy Developments*

Enhancement in India's aspirational demand target in GH2 is depicted below:



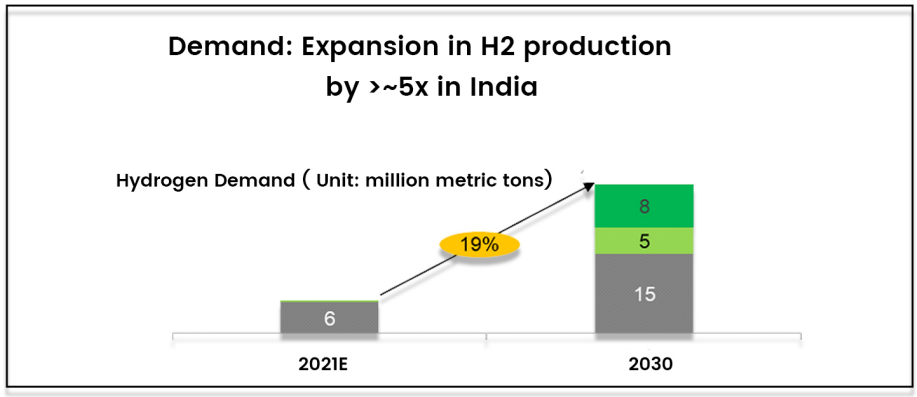

*Source: MoP, GoI*

**GH2 Policy developments for India are as follows:**

- Hon PM announced National Hydrogen Mission while celebrating diamond jubilee of India independence
- This was followed by a Green Hydrogen policy document in February 2022 with a visionary demand target of 5 MMTPA by 2030
- RE Round-The-Clock Power case, which accounts ~75% of GH2 Opex, was further strengthened by Green Open Access policy in June 2022
- In its precursor to National Hydrogen Mission document, Niti Aayog enhanced visionary demand target of India to 13 MMTPA by 2030 in a recently released report dt ~July 2022

### *3.4 India GH2 Market*

Growth in hydrogen and particularly GH2 is depicted in the graph below:

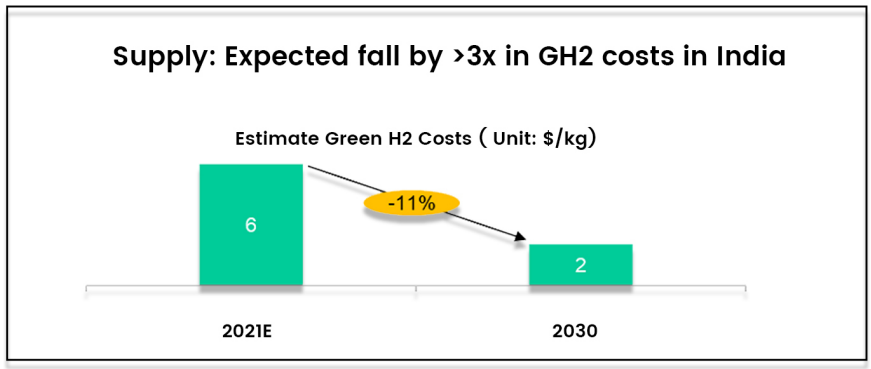



*Source: Harnessing GH2, A Report by NITI Aayog & RMI (https://www.niti.gov.in/documents/reports/)*

Drivers of India market are presented below:

- India's aspirational GH2 demand target comprise of ~5 MMTPA for domestic and ~13 MMTPA for exports
- Demand of domestic green hydrogen is driven by:
- Volatile gas markets
- Movement for carbon pricing
- Net zero targets by big industrial houses
- Additional demand from surface mobility comprising of road/rail/marine sectors

Supply side story is becoming interesting as per the figure mentioned below:




*Source: Harnessing GH2, A Report by NITI Aayog & RMI (https://www.niti.gov.in/documents/reports/)*

Following supply-side developments are driving a reduction in GH2 costs:

Reduction in renewables costs:

- Favorable policies for landed RE RTC power
- Decreasing RE capex
- Giga projects

Reduction in electrolyzer costs:

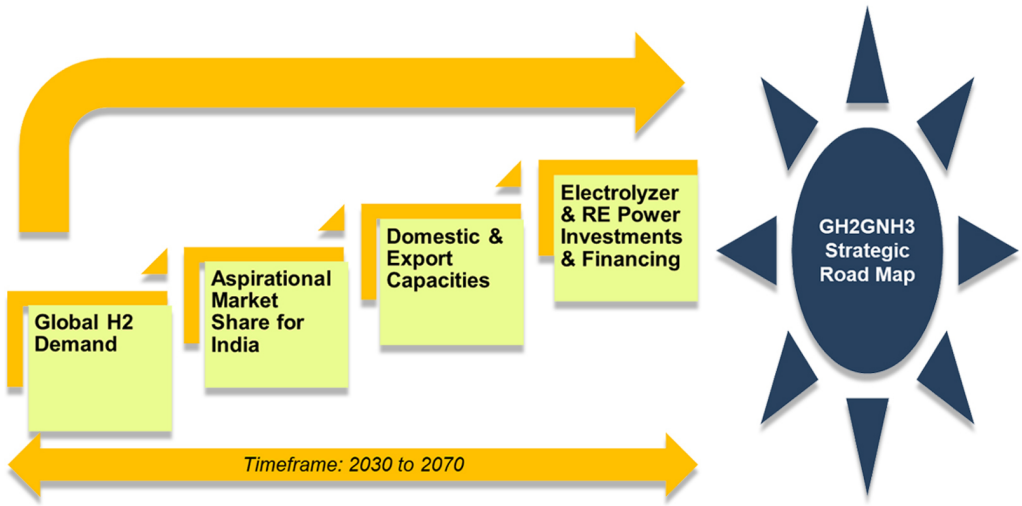
- Increasing scale of production
- Increasing efficiency of electrolyzers
- Decreasing cost of electrolyzers

With these demand and supply side situations, one must say India's GH2 market is close to the inflection point of phenomenal growth spread over next 4-5 decades.

# 4. FUTURE ASPIRATIONS

## 4.1 Methodology Adopted

Systematic methodology that was adopted to chalk out probable aspirations of India is depicted below:

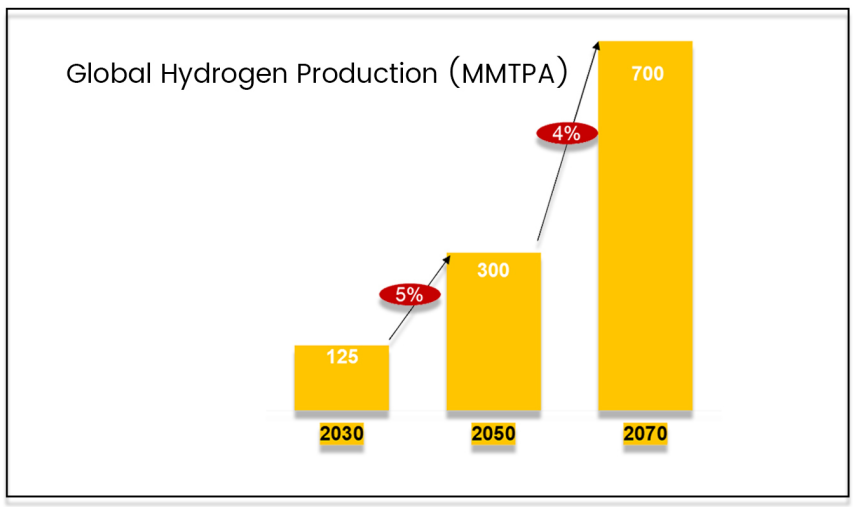



*Source: Deesha Power Analysis*

Step by step methodology has been adopted to arrive at aspirational demand and strategic roadmap for GH2. The same is presented in subsequent sections.

## 4.2 India Aspirational GH2 Target for 2070

Global hydrogen production between 2030-2070 is presented below:



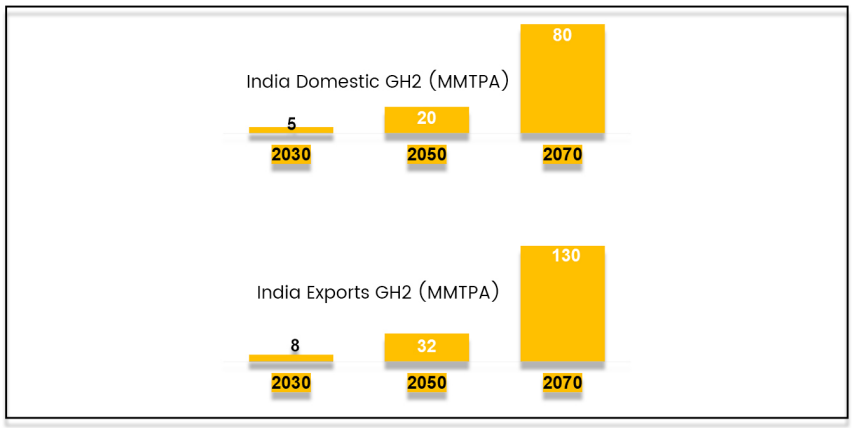

*Source: Deesha Power Analysis*

India's aspirational target GH2 discovery is presented below:

- At 30 Million Barrels Per Day (MBPD) of oil production, ME controls ~30% of global oil production of ~100 MBPD
- Global Hydrogen, a new oil, production is likely to reach to ~700 MMTPA by 2070 assuming 5% CAGR till 2050 and 4% CAGR thereafter, by then entire hydrogen would be GH2
- Accordingly, in order to achieve ME like control over GH2 production, India could target to produce ~30% of 2070 GH2 production or ~210 MMTPA of GH2

### *4.3 Break-up of Aspiration Demand in Domestic and Exports Bucket*

Probable break-up of this aspirational GH2 target in domestic and exports bucket is presented below:




*Source: Deesha Power Analysis*

Domestic GH2 consumption could achieve aspirational demand of 5 MMTPA by 2030. thereafter it needs to quadruple every twenty years.

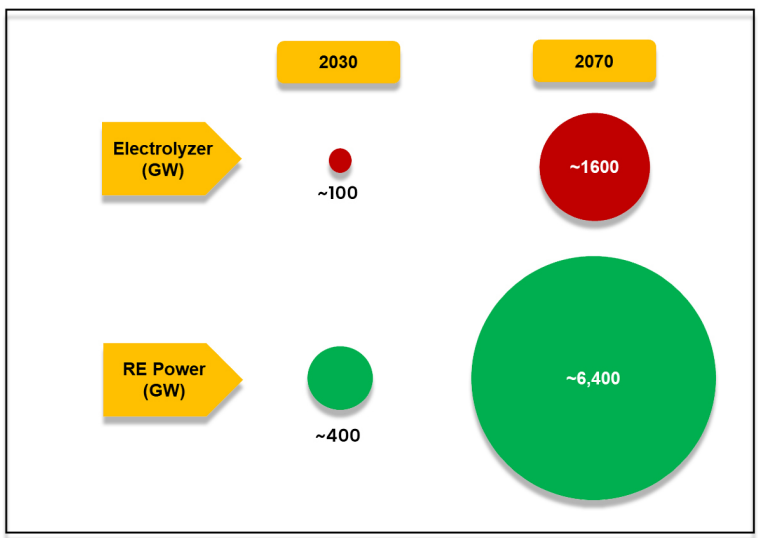
Exports too needs to first achieve aspirational target of 8 MMTPA of GH2 or 40 MMTPA of GNH3 by 2030, thereafter it needs too quadruple twenty years towards achieving dominant position of ~130 MMTPA by 2070.

This translates into CAGR of 7% for GH2GNH3 between 2030 to 2070.

At then pricing of GH2 ~USD 1/KG and GNH3 ~USD 0.65/KG, Indian GH2GNH3 industry could achieve an annual turnover of ~USD 500 billion by 2070

### *4.4 Resultant Electrolyzer and RE Power Capacity*

Electrolyzers (as equipment) and RE power (as a principle input) are main requirements for a successful story of electrolytic GH2. The resultant capacities to achieve India's aspirational target are presented below :




*Source: Deesha Power Analysis*

To achieve target of 210 MMTPA GH2 production, one needs an installed electrolyzer capacity of ~1,600 GW by 2070 (this is with assumption that 1 MW of electrolyzer would produce ~130 MTPA of GH2).

And to power this electrolyzer capacity of ~1,600 MW on 24 hr basis, one needs a RE RTC power. It is estimated that ~6,400 MW of such RE power (primarily solar and wind hybrid) would be required.

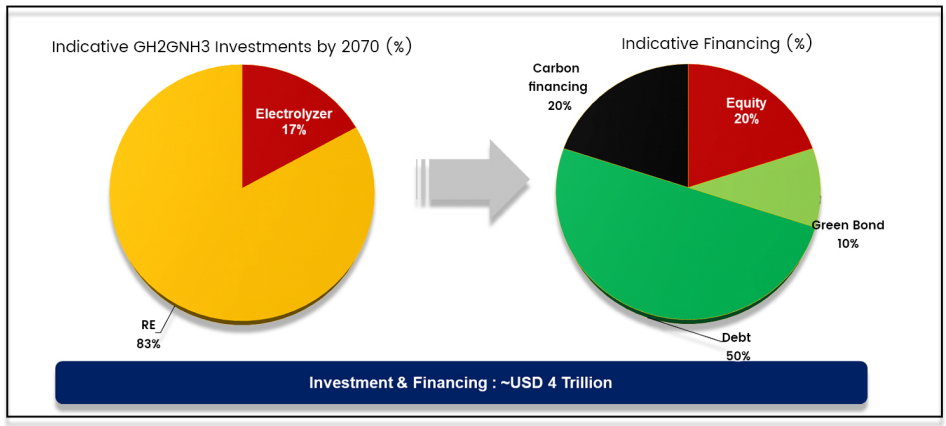
### *4.5 Likely Investment and Possible Financing*

Any respiration requires investment. It's a tricky question how much one may need to budget to achieve an ace position in GH2GNH3.

**An attempt has been made based on:**

- Progressive reduction in electrolyzer capex from USD 800/KW to USD 450/KW by 2070
- Modest reduction in RE power capex from USD 625/kW to USD 550/KW by 2070

The results are presented below:




*Source: Deesha Power Analysis*

India would need a total investment of ~USD 4 trillion (cumulative basis) comprising of:

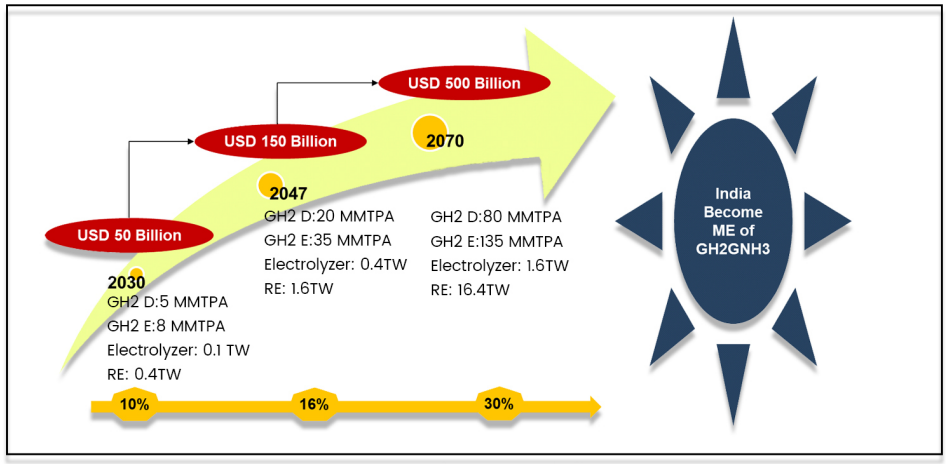
- Electrolyzer Capex of ~USD 0.68 Trillion
- RE Power Capex of ~USD 3.32 Trillion

And the same is proposed to be financed through equity, debt, green bonds and carbon financing in following proportion (cumulative investment and financing requirements):

- Debt: ~USD 2 Trillion
- Carbon Financing: ~USD 0.8 Trillion
- Equity: ~USD 0.8 Trillion
- Green Bonds: ~USD 0.4 Trillion

### *4.6 Strategic Roadmap and KPIs*

Based on the analysis presented above, the strategic roadmap along with key performance indicators (KPIs) are presented below:




*Source: Deesha Power Analysis*

Strategy roadmap has three distinct steps:

- **2030 –** By this, we definitely need to achieve our aspirational target of 13 MMTPA comprising of 5 MMTPA of domestic production and 8 MMTPA of Exports (or GNH3 of ~40 MMTPA). This would require installed electrolyzer capacity of 100 GW and to run this, we need ~400 GW of RE power capacity. This will help us achieve 10% of global market share and the size of GH2GNH3 would touch ~USD 50 billion p.a.

- **2047 –** India shall have centennial celebrations of its independence by then. Definitely, we can target to become energy independent with ~20 MMTPA of GH2 consumption for ourselves. We can further aim to enhance our exports to 35 MMTPA. This will stretch size of industry to USD 150 billion. With this, will we achieve threshold market share of 30% by then? Answer is we need to continue our efforts
- **2070 –** Hon PM's vision is that we should be Net Zero Emission Country by then. With production 80 MMTPA of GH2 for domestic purpose, it looks plausible. It needs to be coupled with the exports of ~130 MMTPA GH2 (or 650 MMTPA GNH3) so that total industry volume would be ~210 MMTPA. At this volume level, we can be ~30% of global GH2 trade and would have possibly touched size of the industry ~USD 500 billion in monitory terms. This scale pf volume and monitory contributions would help India achieve leadership position in global GH2GNH3 industry.

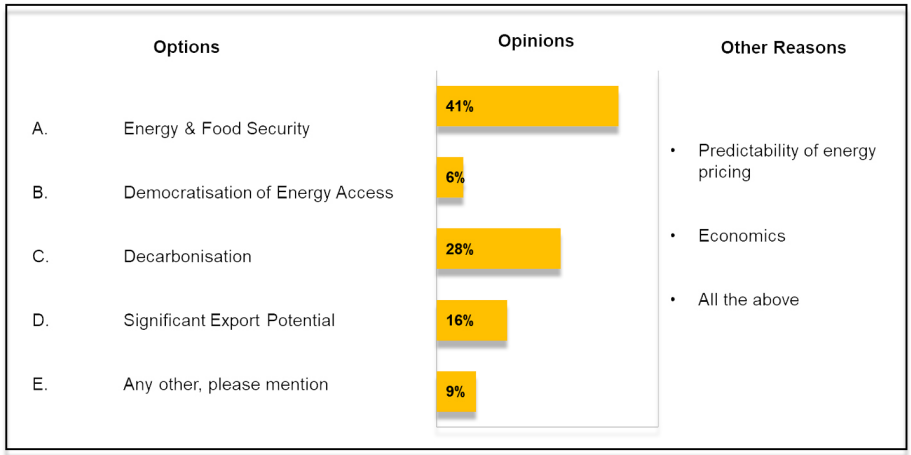
## 5. FUTURE ASPIRATIONS

### 5.1 Structured Questionnaire

Stakeholder's views were sought through structured questionnaire around following aspects:


White paper team got a fantastic response on the participation from ~25 global and Indian organizations, whose names have been mentioned at the beginning of this white paper.

### 5.2 India Imperatives for GH2




*Source: Deesha Power Primary Interactions*

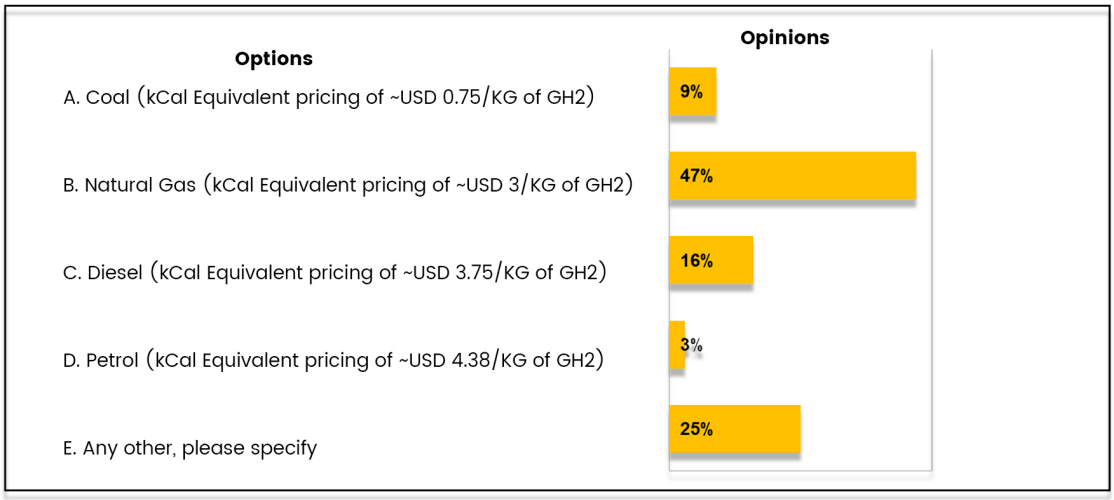
Industry believes that energy & food security coupled with decarbonization are the principle reasons why India should adopt GH2GNH3.

Other reasons include:

- **Predictability of energy pricing –** Industry believed that GH2 would have potential to decouple uncertainty with Indian energy scenario
- **Economics –** Import substitution would do wonders to Indian economy opined few stalwarts

### *5.3 Inflection Point for GH2*

Industry was asked about their opinion in terms of pricing of GH2 that may prove to be inflection point. The responses are presented below:




*Source: Deesha Power Primary Interactions*

~47% of respondents believed that inflection point could be achieved at natural gas parity. Another ~25% believed that the same could occur at pricing of USD 0.93 to USD 2.25 per KG. So in all, ~81% of respondents opined that inflection point in terms of USD/KG of GH2 pricing for its wide spread adoption in India would be sub USD 3/KG.

### *5.4 Sectors to Adopt GH2 Early*

Industry stakeholders were asked to rank the industries wherein earliest adopter sector to start with Rank 1 and so on. The responses are presented below:

| Adoption Ranking | Refinery | Fertilizers | Mobility (Surface/Rail/Aviation) | Chemical | Steel | Cement | Energy Storage | City Gas Distribution |
|---|---|---|---|---|---|---|---|---|
| 1st to Adopt | 38% | 38% | 16% | 3% | 3% | 0% | 3% | 0% |
| 2nd to Adopt | 34% | 22% | 3% | 3% | 19% | 0% | 6% | 9% |
| 3rd to Adopt | 9% | 13% | 3% | 28% | 19% | 13% | 0% | 16% |
| 4th to Adopt | 9% | 3% | 13% | 19% | 28% | 6% | 9% | 13% |
| 5th to Adopt | 0% | 16% | 13% | 28% | 13% | 3% | 9% | 19% |
| 6th to Adopt | 3% | 6% | 6% | 6% | 13% | 34% | 16% | 16% |
| 7th to Adopt | 6% | 0% | 19% | 9% | 3% | 31% | 22% | 9% |
| 8th to Adopt | 0% | 3% | 28% | 3% | 3% | 13% | 34% | 19% |

Early GH2 Adaptors  Late GH2 Adaptors

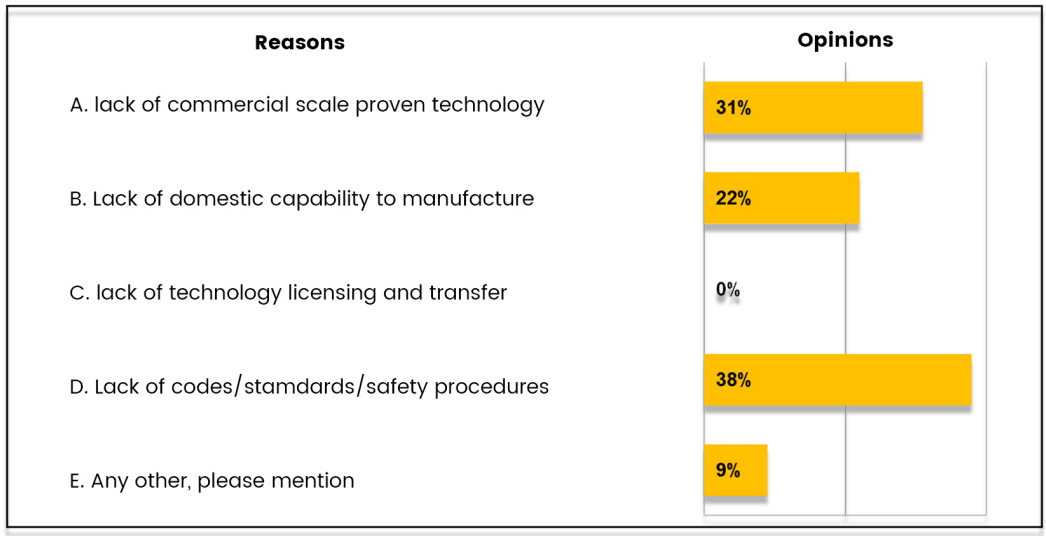
*Source: Deesha Power Primary Interactions*

Respondent opined that GH2 adoption is likely to happen on priority across four sectors viz Refinery, Fertilizers, Steel & Chemicals.

City Gas Distribution and Mobility are the future adaptors and hence the underdogs to figure in top 4 in terms of responses from the stakeholders.

### *5.5 Technical Challenges for GH2 Adoption*

Industry participants were requested to share views on technical challenges for wide spread adoption of GH2 in India. The response is presented below:

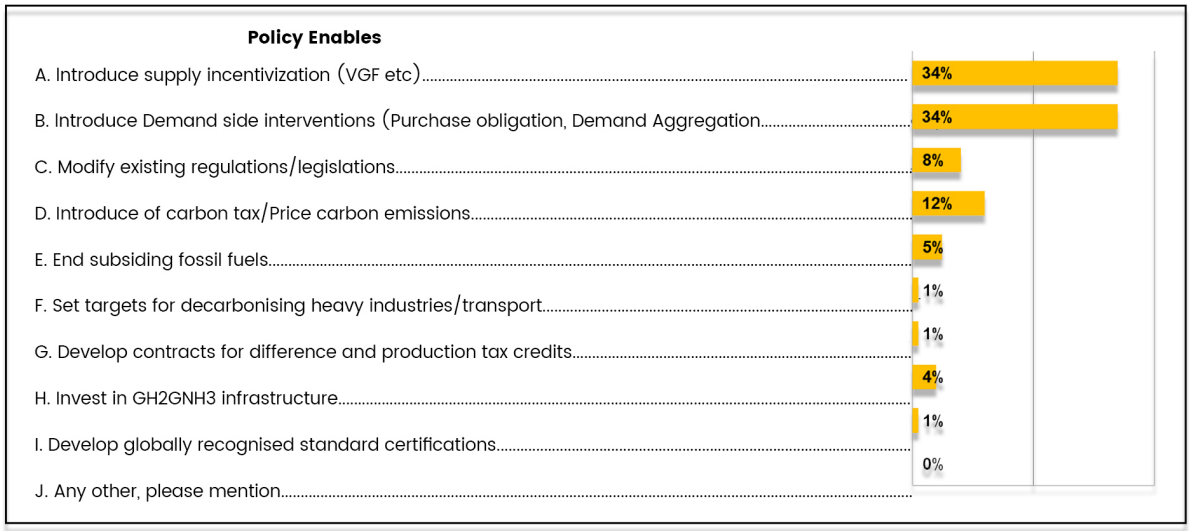



*Source: Deesha Power Primary Interactions*

Lack of codes/standards/safety procedures has emerged as the key technical challenge for wide spread adoption of GH2 in India. Lack of commercial proven technology (other than alkaline) and more so lack of domestic capability to indigenously manufacture were cited as the other important concerns.

Among other, industry developers also cited lack of storage/pipeline infra as a potential bottleneck. Also, some felt that reliance on single technology may not work, one needs to plan technologies as per the sectoral needs and that would ensure widespread adoption of GH2 across Indian industrial/mobility/residential sectors.

### *5.6 Policy Enablers for GH2 in India*

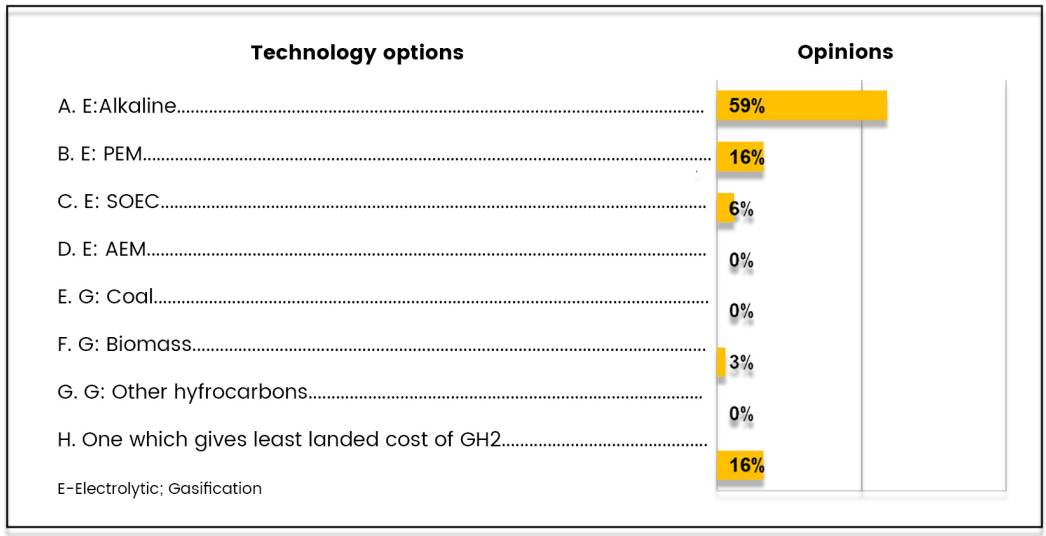



*Source: Primary Interactions by Deesha Power*

Supply incentivization and demand side interventions have emerged as top two policy enablers for wide spread adoption of GH2 in India. Among others, introduction of carbon tax believed to be highly potent policy tool to ensure such adoption

### *5.7 Viable GH2 Technology for India*

Industry stakeholders were asked about their opinion for viable technology for India. Feedback from the participants is presented below:

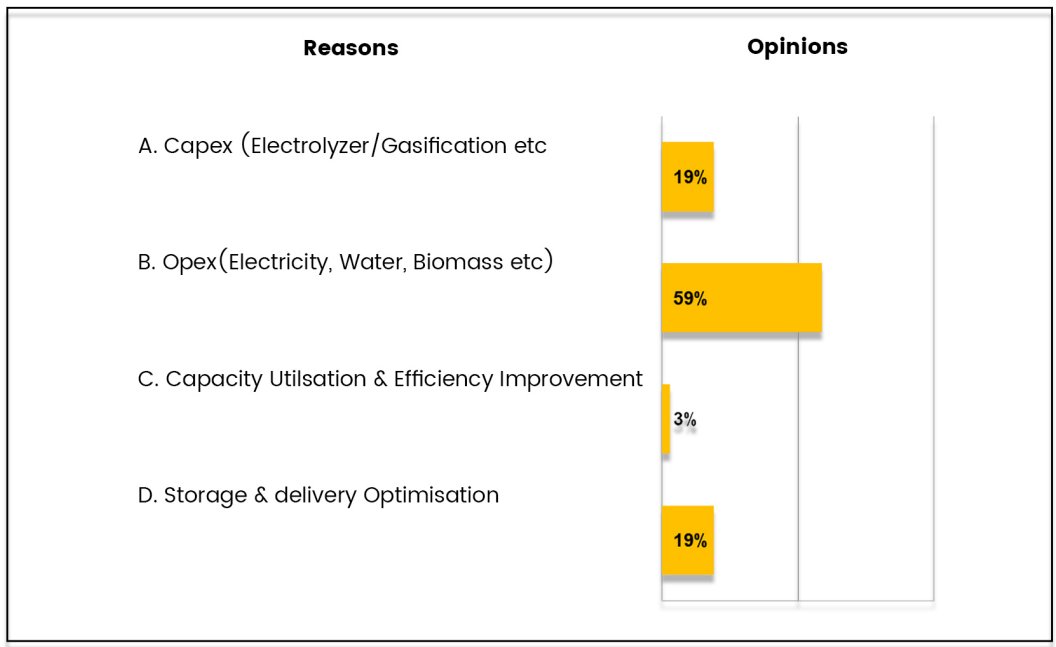



*Source: Primary Interactions by Deesha Power*

As its observed from the picture above, alkaline electrolytic technology has emerged as overwhelmingly viable technology option for India. Many also opined that, India being most cost sensitive market, we should go after such a technology which would give lowest LCOH on landed basis.

### *5.8 Levers for Optimizing GH2 Costs*

An opinion was sought what could be most important lever to optimize GH2 costs in India. The response is presented below:



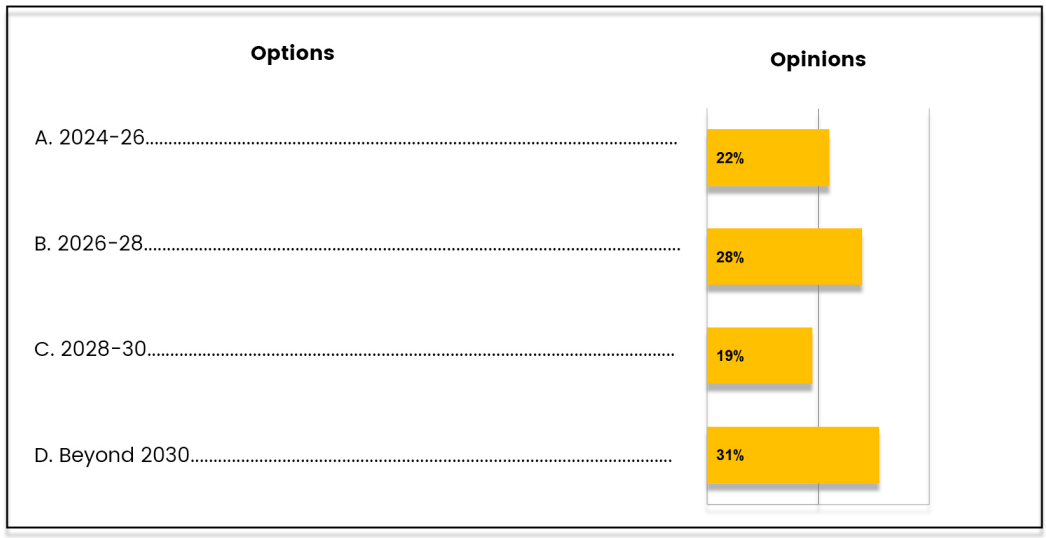

*Source: Primary Interactions by Deesha Power*

Reduction on Opex. is most important lever in optimizing landed cost of GH2, says India Inc. Among others, cost of electricity is prime lever for which following suggestions have been received:

- Waiver of associated Open Access losses and charges
- Banking on Monthly Basis

### *5.9 Pricing Parity of GH2*

India Inc was asked about their views for pricing parity of GH2. The feedback is presented below:

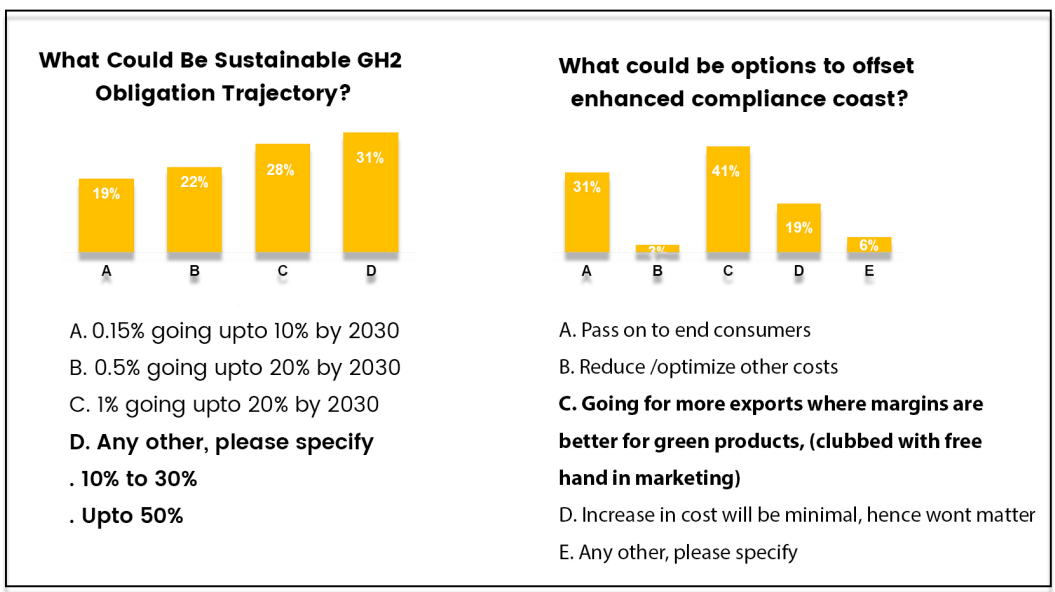



*Source: Primary Interactions by Deesha Power*

Industry is divided in terms of its opinion on achievement of pricing parity by GH2 vis-à-vis other fuels. While a section was very upbeat believing that fuel parity is at the cusp within couple of years. However, there was an equal section believing that it's a long-term phenomenon beyond 2030.

### *5.10 Sustainable GH2 Obligation Trajectory*

India Inc was asked their views regarding sustainable GH2 obligation trajectory for the existing user industries like refineries/fertilizers etc. Also, it was asked what could be best strategy to mitigate the said cost of compliance. Their views are presented below:



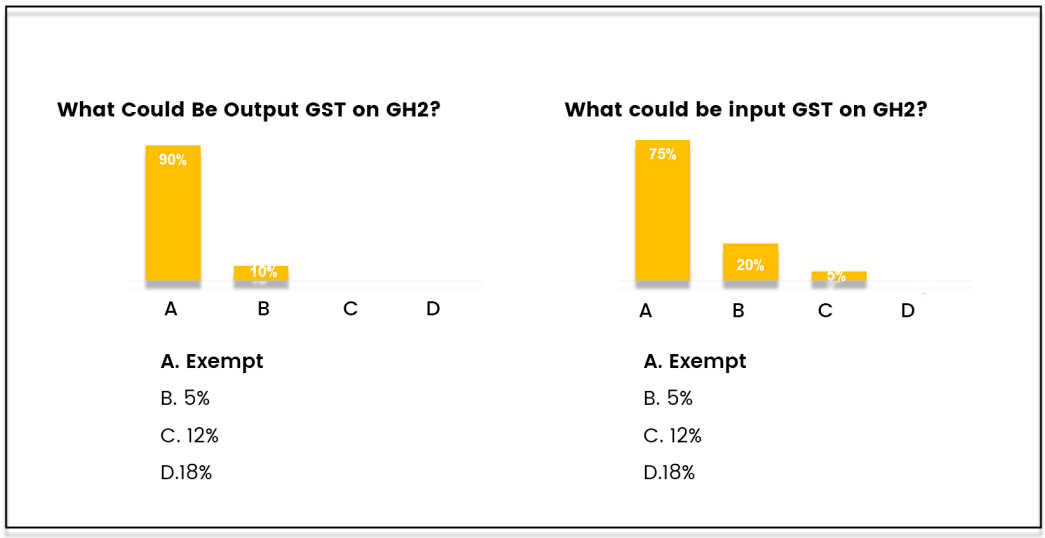

*Source: Primary Interactions by Deesha Power*

Industry is in favor of GH2 obligation and believes higher export proposition could help offset the said compliance cost.

Further, Industry stalwarts opined that, like US Federal Govt, Government of India could support by taking first step forward to offset the cost of GH2 compliance for user industry. This will create confidence and thereafter export could be further incentivized to make a case for reasonable RoI on exporting expenses by user industry.

### *5.11 GST on GH2*

Industry participants were asked about their views on input/output GST on GH2. Their responses are presented below:

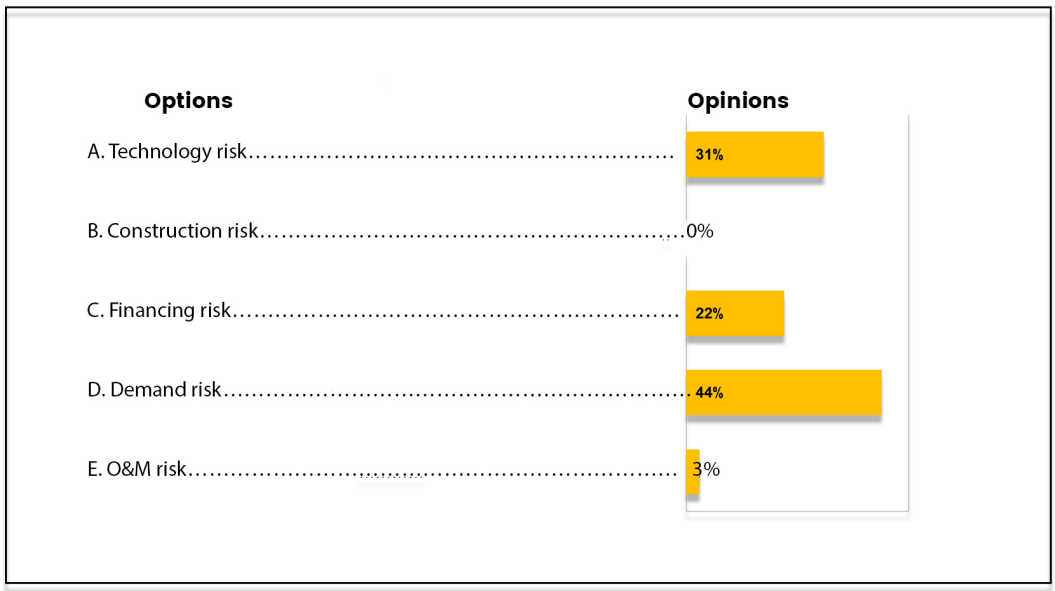



*Source: Primary Interactions by Deesha Power*

Industry believes that GH2 must be GST exempt to start with, may be till 2030 till India achieves critical mass of 13 MMTPA production. Thereafter, it could be taxed at ~5% like commodities as it stabilizes.

### *5.12 Risks for GH2 Projects*

Industry leaders were asked about the risks the GH2 projects are facing at the moment. Their views are presented below:




*Source: Primary Interactions by Deesha Power*

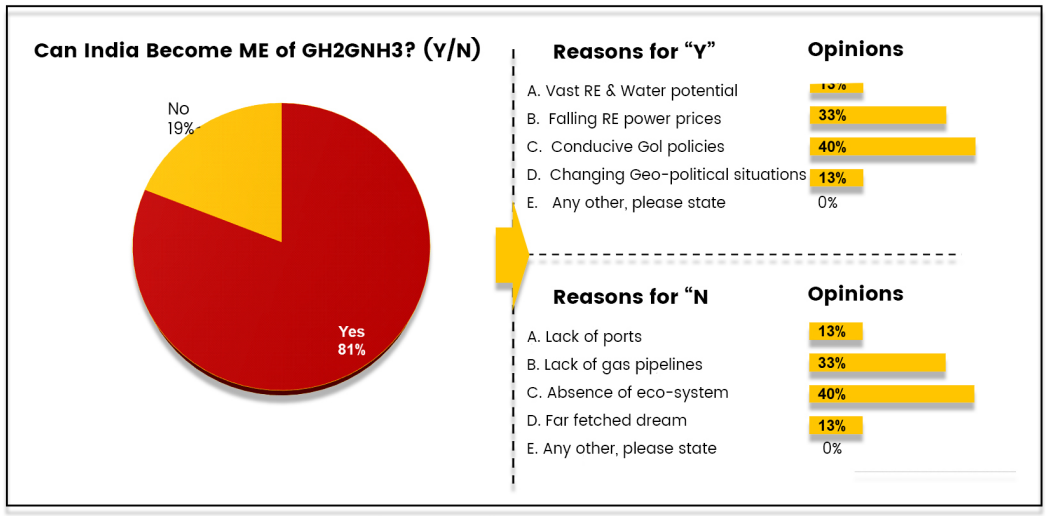
Lack of GH2 demand/guaranteed offtake and resultant no availability of debt financing are the biggest risks at the moment, opined the decision makers.

Few others also talked about techno-commercial risks viz "technically how green my steel could be?" and "whether the industry is ready to pay a premium for green steel".

Many raised concerns that, except for alkaline, other electrolytic technologies do not have operating history. That is the big hurdle to take 10/15/20 year call on the consistent output of hydrogen.

### *5.13 India becoming ME of GH2GNH3*

Industry leaders were asked about their frank opinion whether India can become ME of GH2GNH3 and were asked to give justifications for the same. Their views on this interesting question were presented below:



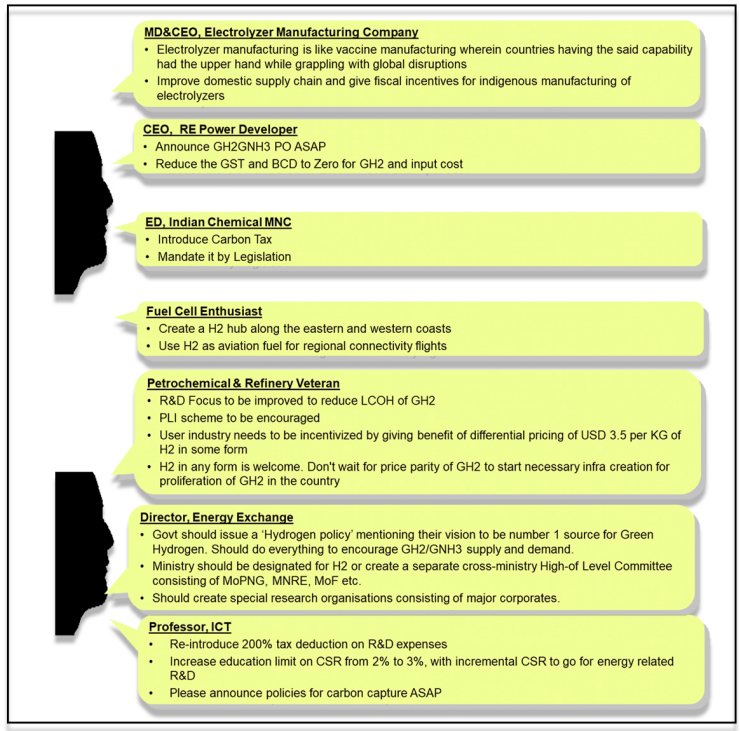

*Source: Primary Interactions by Deesha Power*

Whopping 81% of the Industry Leaders believed that India can become ME of GH2GNH3 primarily due to conducive govt policies and falling RE power prices which is main input for GH2.

Those who opined otherwise were of the view that lack of ecosystem and technical advantage to ME in terms of higher RE PLF could be the hindrances in India's way to become exporting super-hub for GH2GNH3.

### *5.14 Constructive Suggestions*

Constructive suggestions were sought from the Industry Leaders. Their views are presented below:




*Source: Primary Interactions by Deesha Power*

MD of Electrolyzer company said that the electrolyzer is like vaccine wherein countries having the said manufacturing capability had the upper hand while grappling with global disruptions. Other leaders demanded PLI scheme for electrolyzer and introduction of direct carbon tax (though we are paying indirect carbon taxes in many ways such as coal cess etc)

# 6. STRATEGIES THAT HELP INDIA BECOME ME OF GH2GNH3

## 6.1 Four Pillars of Probable Strategy

Four pillars of probable strategy are presented in schematic below:


*Source: Analysis by Deesha Power*

## 6.2 Scale of Operations

Middle Eastern region witnessed scale of operation and that's the reason they are dominant force today in O&G industry. To create a scale of operation in GH2, we need to adopt different strategies pre and post 2047 as mentioned below:

| Strategies | Pre-2047 | Post-2047 |
|---|---|---|
| Pull | Viability Gap Funding | Self Sustaining |
| Push | Mandatory GH2 Purchase | Self Sustaining |
| Incentives | GST waiver, BCD waiver, Income Tax Credits | Moderate taxation |
| Mandates | Scope I Emission Trading | Scope I, II & III Emission Trading |

*Source: Analysis by Deesha Power*

Pre-2047, India may need to adopt to various facets

- Pull- Measures which will pull the industry by giving a helping hand. For example viability gap funding/GH2 production credits like US etc. These measures put money on the table for viable investments
- Push – Measures which will push the industry through regulation. For example proposal of mandatory non-fossil consumption like Green Hydrogen/Green Ammonia/Biomass or Ethanol etc under Energy Conservation (Amendment) Bill, 2022. These measures make industry pay incremental towards compliance
- Incentives- Actual sum spent on Pull/Push measures could be further optimized using fiscal incentives, viz GST waiver on sale of GH2 as well as purchase of electrolyzer. Basic custom duty waiver while importing key components of electrolyzer/its BoP etc
- Mandates – These measures makes carbon as part of game. Example could be trading of carbon certificates as proposed under Energy Conservation (Amendment) Bill, 2022. Another example could be introduction of carbon tax. These mandates enhances the adoption of GH2

One more thing Government of India could propose is, to create a scale, PLI like scheme could be introduced for electrolyzer and other sectoral manufacturing.

- ***PLI Scheme of GoI***

Earlier PLI Scheme

In Nov 2020, GoI announced Production Linked Incentive Scheme for 10 sectors (batteries, Electronics, PV, Food etc) giving financial assistance of ~USD 18 billion

Proposed PLI for GH2

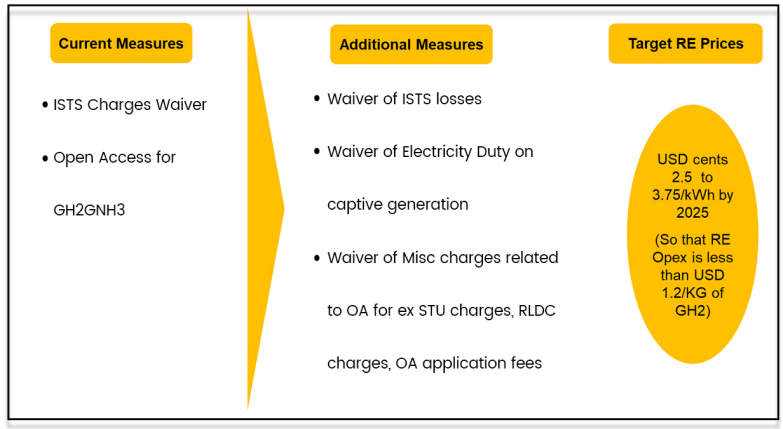
| Sector | Target by 2030 |
|---|---|
| Electrolyzer | 160 GW of production capacity |
| Green Ammonia | 40 MMTPA exports to Japan, Korea & EU |
| Steel | 20 MMTPA of Green Steel |
| Heavy Duty Vehicles | 1000 Trucks, 50 Water Farriers, 10 aircrafts |
| Power | GH2 based FC as storage technology for RTC tenders of SECI |

*Source: Secondary Research by Deesha Power*

Post-2047, GH2GNH3 industry would have been matured. While need of Pull/Push measures would be much lesser, we may introduce moderate taxation. Important is India moving towards trading of Scope-I,II & III emis-

### *6.3 Economical output*

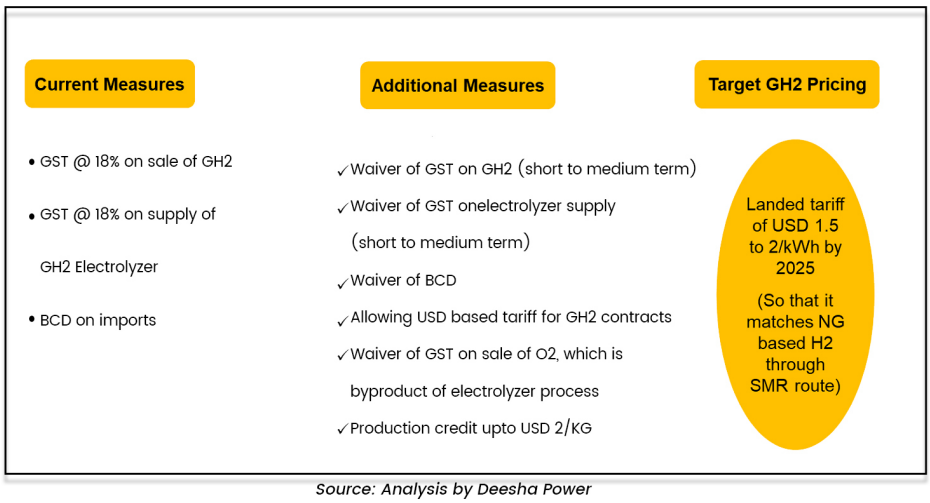
In order to make GH2 competitive in the international market, we need to control the pricing of principal input viz RE power. Strategy to control RE power is presented below:




*Source: Analysis by Deesha Power*

RE pricing for GH2GNH3 could be targeted in the range of $ cents 2.5 to $ cents 3.75 /kWh by 2025. The same needs to be brought down to a level of $ cents ~ 1.88 /kWh by 2050 which would further optimize RE power opex of GH2 to $ 1/KG.

Following fiscal incentives could make output further economical:

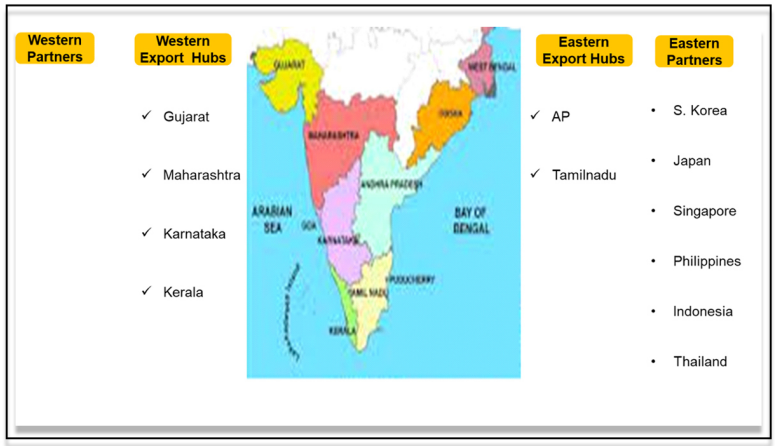



*Source: Analysis by Deesha Power*

Fiscal incentives such as GST exemption and zero customs duty for all inputs could ensure landed GH2 pricing below USD 1.5 to 2/KG.

### *6.4 Exports*

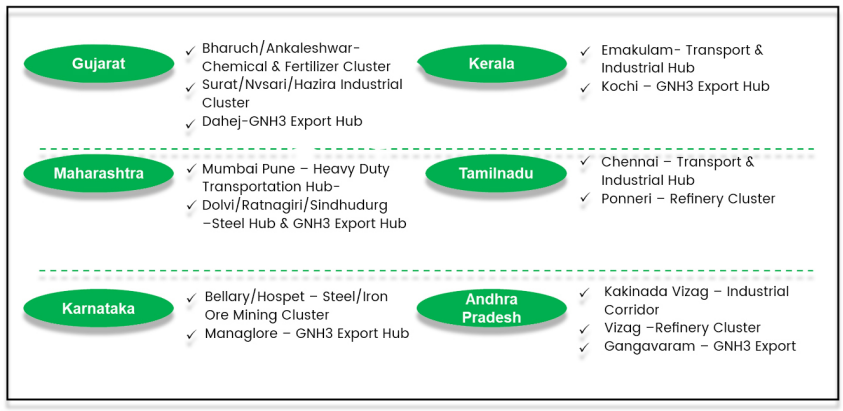
Export is the most important pillar of strategy as the significant portion of GH2 production is proposed to be exported. Strategy for export is presented below:




*Source: Analysis by Deesha Power*

GH2 Export market of ~130 MMTPA by 2070 could be initiated with executing MoUs with partner countries incorporating technology and finance cooperation.

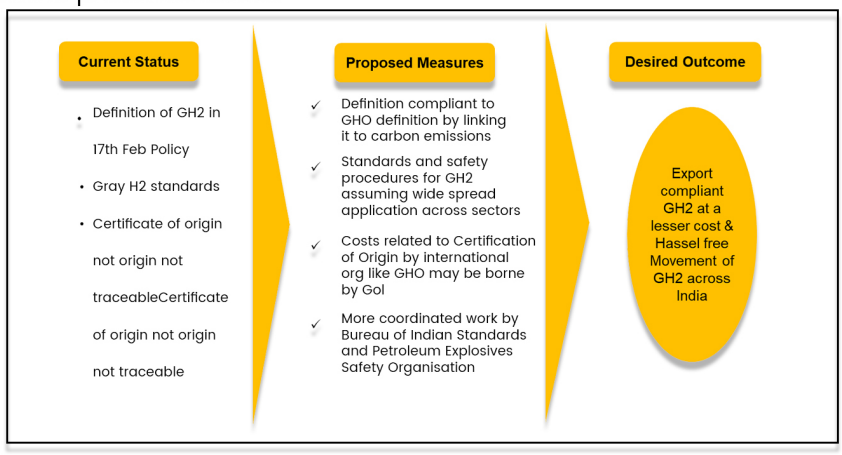
For this, following cluster based approach could be adopted:




*Source: Secondary Research & Analysis by Deesha Power*

Six to seven GH2GNH3 export oriented clusters could be developed across coastal lines of India.

To streamline exports, lot of work needs to be on standards/codes/safety procedure towards GH2GNH3. Strategy around the same is presented below:

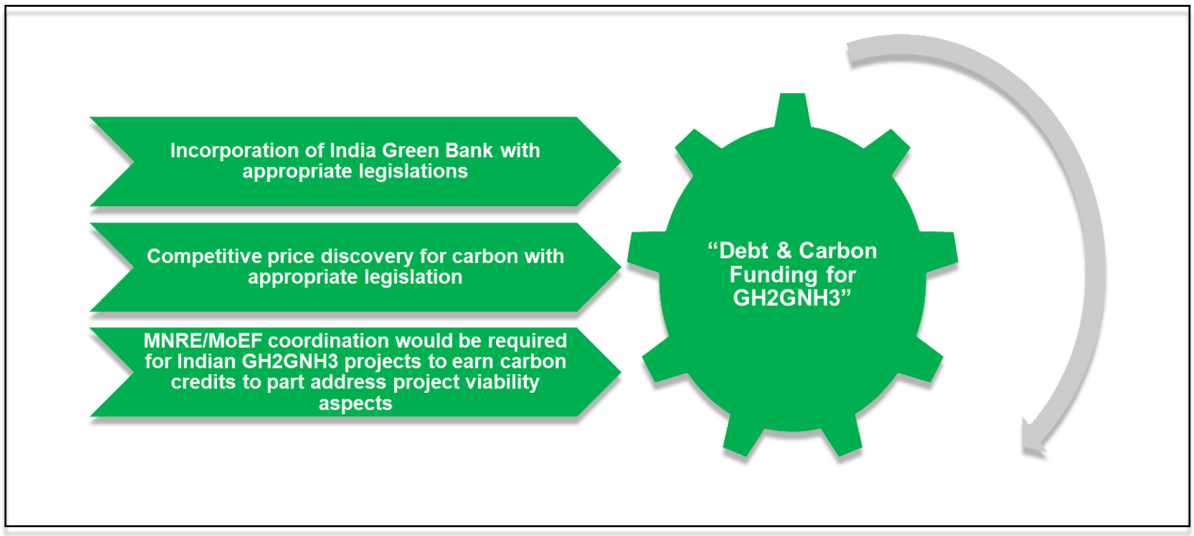



*Source: Secondary Research & Analysis by Deesha Power*

GoI need to address GH2 definition/standards/codes/safety procedures which are compliant to international/EU standards.

### *6.5 Financing*

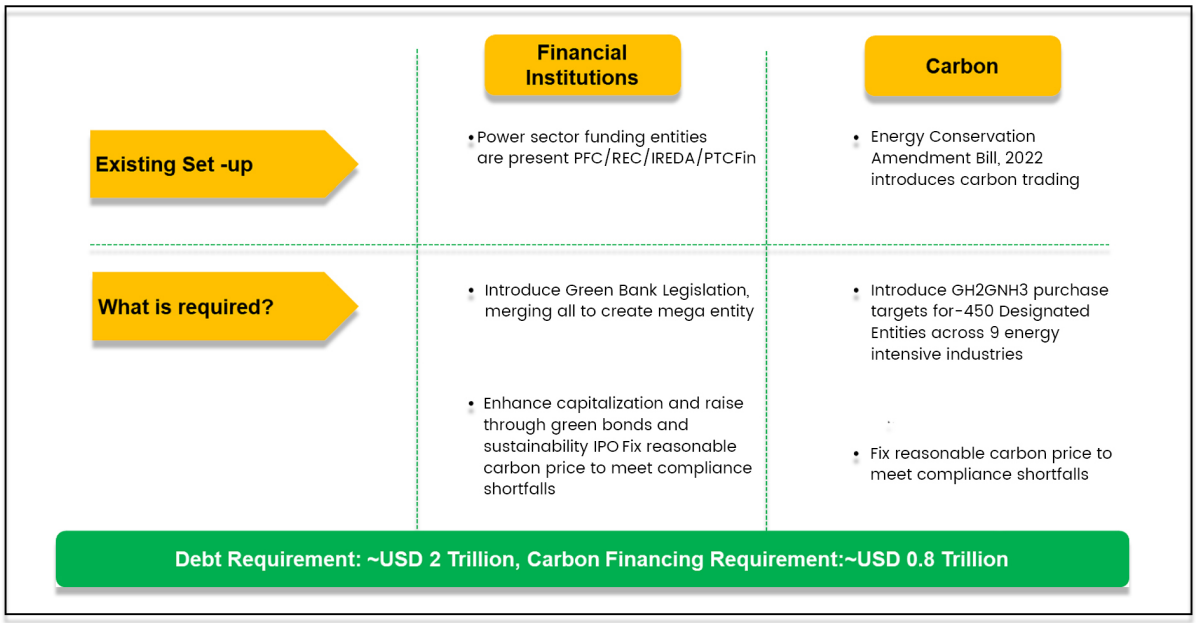
The GW scale for GH2 and TW scale for Electrolyzer & RE Power requires multidimensional financing. Strategy for financing is presented below:




*Source: Secondary Research & Analysis by Deesha Power*

"India Green Bank" and "India Carbon Market" could be instrumental to fund ~USD 3 Trillion funding requirements of GH2GNH3 projects.

Further, one needs to look at what mechanisms we have and what could be additional measures required so that required scale of financing is achieved in the long run as mentioned below:




*Source: Secondary Research & Analysis by Deesha Power*

Existing mechanisms may be enhanced exponentially to achieve funding targets of ~USD 3 Trillion by 2070 under "Green Bank" and "Carbon".

# 7 ANNEXURES

## 7.1 Advertisements

### *7.2 Briefs for Three Policies Related to GH2GNH3*

#### 7.2.1 17th FEB GOI POLICY ON GH2GNH3

- Green Hydrogen from electrolysis of water/gasification of biomass would be considered under ambit of this policy
- 25 year waiver in inter-state transmission charges for projects commissioned before 30th Jun 2025 has been provided
- Open Access (OA) towards supply of RE power to GH2GNH3 projects be granted in 15 days
- Banking of Renewable Energy (RE) power earmarked for GH2GNH3 projects allowerd for 30 days at an incremental RE power purchase cost over IEX prices
- RE power park's land to be made available for GH2GNH3 projects
- Land at ports for generation/storage of GH2GNH3 towards further export/use by shipping industry
- RE power for GH2GNH3 to help in RPO compliance of obligated entity, excess RE power after such compliance, if any would be used to offset concerned Discom's Renewable Purchase Obligation (RPO) compliance
- Special RE power supply rate to such GH2GNH3 projects by Discoms to be determined by appropriate state regulators
- Ministry of New and Renewable Energy (MNRE) to become single point contact for time bound permits and approvals for GH2GNH3 projects, preferably within 30 days of application
  MNRE designated entity (most likely Solar Energy Corporation of india) to aggregate demand for GH2GNH3 towards cometitive price discovery

#### 7.2.2 Green Open Access Rules

- These rules are notified for promoting generation, purchase and consumption of green energy including the energy from Waste-to-Energy plants.
- The Green Open Access is allowed to any consumer and the limit of Open Access Transaction has been reduced from 1 MW to 100 KW for green energy, to enable small consumers also to purchase renewable power through open access.
- Consumer are entitled to demand supply of Green Power from Discoms. Discoms would be obligated to procure and supply green power to eligible consumers.
- These Rules will also streamline the overall approval process for granting open access. Time bound processing by bringing uniformity and transparency in the application as well as approval of open access through a national portal has been mandated. Approval for Green Open Access is to be granted in 15 days or else it will be deemed to have been granted.
- Commercial and industrial consumers are allowed to purchase green power on voluntarily basis.
- Provide certainty on open access charges to be levied on Green Energy Open Access Consumers which includes transmission charges, cross-subsidy surcharge and standby charges. Cap on increasing of cross-subsidy surcharge as well as the removal of additional surcharge, incentivize the consumers to go green.
- There shall be a uniform Renewable Purchase Obligation (RPO), on all obligated entities in area of distribution licensees. Green Hydrogen/Green Ammonia has also been included for fulfilment of its RPO.
- Consumers will be given Green Certificates if they consume green power.

#### *7.2.2 Energy Conservation (Amendments) Bill, 2022*

The Bill seeks to amend the Energy Conservation Act, 2001. The Act promotes energy efficiency and conservation. It provides for the regulation of energy consumption by equipment, appliances, buildings, and industries Key proposals under the Bill are.

- Mandate use of non-fossil sources, including Green Ammonia, Biomass and Ethanol for energy and feedstock
- Establish Carbon Markets
- Bring large residential building within the fold of Energy Conservation regime
- Enhance the scope of Energy Conservation Building Code
- Amend penalty provisions
- Increase members in the Governing Council of Bureau of Energy Efficiency
- Empower the State Electricity Regulatory Commissions to make regulations for smooth discharge of its functions.

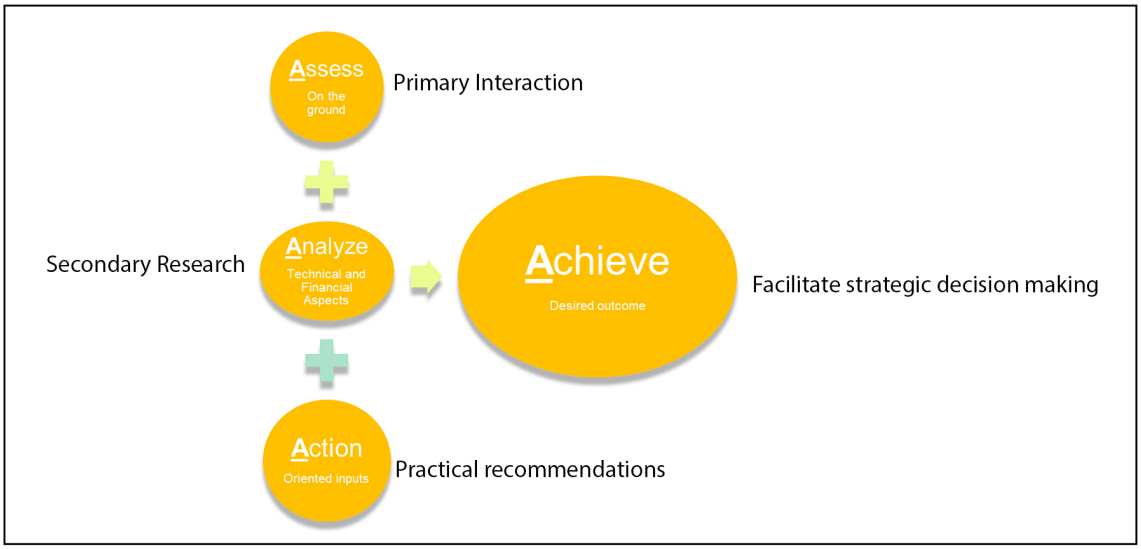
## 7.3 About Deesha Power

### *7.3.1 GH2GNH3 Consulting Offerings*


### *7.3.2 International Clients*


### *7.3.3 Domestic Clients*

### 7.3.4 USPs




### 7.4 Abbreviations

| | | | |
|---|---|---|---|
| AEM | Anion Exchange Membrane | NG | Natural Gas |
| ATF | Aviation Turbine Fuel | O2 | Oxygen |
| BCD | Basic Customs Duty | OA | Open Access |
| CAGR | Compounded Annual Growth Rate | PEM | Proton Exchange Membrane |
| CV | Calorific Value | PLF | Plant Load Factor |
| D | Domestic | PLI | Production Linked Incentive |
| E | Exports | PM | Prime Minister |
| EU | European Union | PV | Photo Voltaic |
| FC | Fuel Cell | RE | Renewable Energy |
| GH2 | Green Hydrogen | RLDC | Regional Load Dispatch Centre |
| GHG | Green House Gases | RTC | Round The Clock |
| GHO | Green Hydrogen Organisation | SECI | Round The Clock |
| GNH3 | Green Ammonia | SMR | Steam Methane Reformation |
| GST | Goods & Services Tax | SOEC | Solid Oxide Electrolyzer Cell |
| GW | Giga Watt | STU | State Transmission Utility |
| H2 | Hydrogen | TW | Tera Watt |
| ISTS | Inter State Transmission Charges | VGF | Viability Gap Funding |
| LH2 | Liquid Hydrogen | USDB | United States of America Dollars Billions |
| LOHC | Liquid Organic Hydrogen Carrier | YoY | Year on Year |
| MBPD | Million Barrel Per Day | | |
| ME | Middle East | | |
| MMTPA | Million Metric Tonnes Per Annum | | |
| MoU | Memorandum of Understanding | | |
| MW | Mega Watt | | |
| MT | Metric Tonne | | |

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