India

Neutral *(no change)*

Highlighted Companies

Thermax Ltd

ADD, TP Rs3275, Rs3059 close

Thermax is a key beneficiary of the green shoots witnessed in private sector capex in multiple industries. The company has a healthy order book with a strong pipeline of small ticket-size orders in cement, biomass, food and beverage, and sugar/distillery segments. The capex momentum, especially in the water and environmental space, augurs well for Thermax.

Summary Valuation Metrics

P/E (x)	Mar24-F	Mar25-F	Mar26-F
Thermax Ltd	55.13	45.39	40.83
P/BV (x)	**Mar24-F**	**Mar25-F**	**Mar26-F**
Thermax Ltd	7.86	6.85	5.98
Dividend Yield	**Mar24-F**	**Mar25-F**	**Mar26-F**
Thermax Ltd	0.31%	0.33%	0.33%

Energy Infrastructure

Electrolyser and green hydrogen update

- India and the Middle East can become a hub for green H_2, given high solar irradiance, supportive government policies & proximity to consumption centres.
- For modular plants (56t H_2/d) in India, it's difficult to go below US$2/kg H_2 (even with govt support) but larger plants in India & MEA can achieve this target.
- Multiple companies in India are working in this space - Reliance Industries, Thermax, John Cockerill India and Adani Enterprises are some of them.

Electrolyser technology is progressing rapidly

The electrolyser technology has taken a quantum jump and now we have a new electrolyser by Hysata which can produce H_2 at as low as 41kWhr/kg. Please note that for old PEM electrolyser, this number is near 50kWhr/ kg H_2 and for alkaline electrolyser it is around 60 kWhr/kg H_2. While the Hysata electrolyser is not yet fully commercialized, its 5MW version is undergoing trials and with the production plant ready, the commercial version can hit the market as early as 2025F. With the commercialization of Hysata technology, we will hit the maximum efficiency possible in electrolysis and now cost reduction in H2 production can only come from a higher scale. Indian companies like Reliance Industries (ADD) and Adani Enterprises (Not Rated) are already working with such projects at a much higher scale.

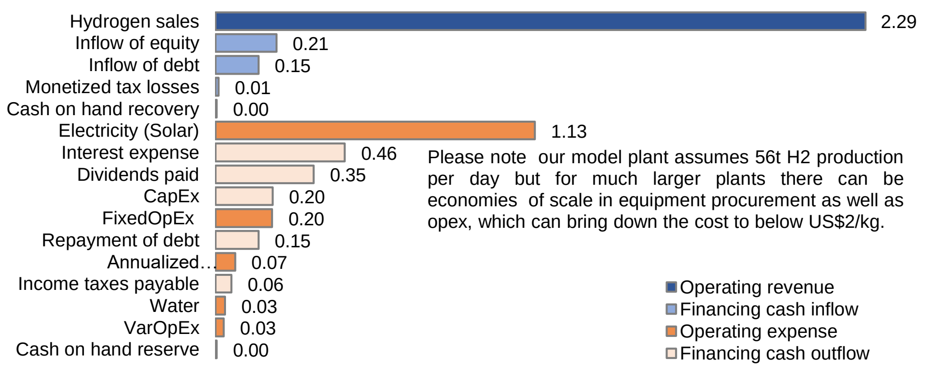
Key to green H_2 is low-cost power - in India & MEA solar is the answer

India as well as the Middle-East & Africa (MEA) are blessed with high solar irradiance. For example, in a large part of Rajasthan, one can get a solar irradiance of 5.5kWhr/m^2/day and in the UAE one can easily get 6kWhr/m^2/day. With normal cell efficiency reaching 17%, one square meter panel can produce 1.02kWhr/day in the UAE and 0.94kWhr/day in India. Building a large plant will lower the panel cost to as low as US$40/m^2 and consequently, the power cost can easily fall to US$2.25 cents/kWhr in India as well as in the UAE. We have assumed no government support in the UAE (but the UAE has lower interest cost advantage), but we have taken the accelerated depreciation benefit in India.

Proper incentives and plant design can lead to below US$2/kg H_2

To achieve lower cost, electrolyzers need to run at high-capacity utilization, which can be done only if there are large solar plants which can charge the storage battery (V_2O_5 based flow batteries) during daytime and during the night the battery can power the electrolyzers. Already, Oman is using the same set-up to power its green H2 plant. We have worked with the same plant set-up and smaller capacity (56t H_2/ day) and we are getting H2 cost of US$2.16/kg in the UAE and US$2.29/kg in India (with incentives for electrolyzer manufacturing and green H2 production). Naturally, higher operational scale in both these costs can come below US$2/kg. At US$2/kg, green H2 can be used to make green ammonia and transported across the world as a green energy source. Please note that unless liquefied natural gas or LNG price falls to US$7/mmBtu, grey ammonia cannot compete with green ammonia.

Figure 1: Small (56t/day) Indian H_2 plants (with incentive) can produce H2 at US$2.3/ kg



SOURCE: INCRED RESEARCH, COMPANY REPORTS

Research Analyst(s)

Satish KUMAR
T (91) 22 4161 1562
E satish.kumar@incredresearch.com

Vipraw SHRIVASTAVA
T (91) 22 4161 1565
E vipraw.srivastava@incredresearch.com

Electrolyser and green hydrogen update

We keep hearing a lot about green hydrogen and the goal of zero emissions by 2050F. High-efficiency electrolysers and low-cost power are key for realizing this goal. In this report, we look at the technological development of electrolysers, green ammonia and how it can keep petrochemical margins under pressure, and also the road map to US$2/kg hydrogen. We have also identified Indian companies that can benefit for this development. As per our estimates, some of the best plays in the electrolyser and green hydrogen space are 1) Reliance Industries, 2) MTAR, 3) John Cockerill India, 4) Thermax, and 5) HEG.

Electrolysis- the basic technology

What is electrolysis?

In chemistry and in manufacturing, electrolysis is a technique that uses direct electric current to drive an otherwise non-spontaneous chemical reaction. The current flows through an electrolyte, which is a substance that conducts electricity because it contains dissolved ions. This flow of electrons triggers chemical changes at the electrodes (negative and positive), resulting in the decomposition of the electrolyte or other materials present.

Electrolysis follows the basic Faraday's law

There are two laws of electrolysis 1) Faraday's first law, and 2) Faraday's second law.

Faraday's first law: This law states that the mass of a substance deposited or liberated at an electrode is directly proportional to the quantity of electricity passed through the electrolyte. In simple terms, the more electricity you pass through, the more product you get at the electrodes.

Imagine pouring more water into a bucket; the more you pour, the more water accumulates. Similarly, with greater electricity, more ions are discharged at the electrodes, leading to a proportional increase in the mass of the deposited/liberated material.

The constant of proportionality in this law is called the electrochemical equivalent (ECE). It tells you how much mass of a specific substance you will get for every unit of charge passed through the electrolyte.

Faraday's second law: This law focuses on the comparison between different substances undergoing electrolysis. It states that for the same quantity of electricity passed through different electrolytes, the masses of the substances deposited or liberated at the electrodes are directly proportional to their chemical equivalents.

The chemical equivalent of a substance is essentially its atomic weight divided by its oxidation state, giving us a measure of how much charge is needed to change one equivalent of the substance.

Mathematically, Faraday's law can be written as

Gram equivalent weight deposited on cathode = Faraday's constant* current * time

Hence, the weight of H_2 gained from electrolysis will depend only on the current passing through the liquid. As power = voltage* current, in any electrolysis the effort is to minimize the voltage required for the process.

Assuming 100% electrolysis efficiency power required to deposit 1kg hydrogen is 39.3 units

To calculate the power required to deposit 1kg of hydrogen in the electrolysis process, we need to consider these factors:

1. **The current efficiency of the electrolyser** - The current efficiency is defined as the % of minimum possible current required to deposit 1kg of hydrogen in the required time.
2. **The voltage efficiency of the electrolyser -** Voltage efficiency is the minimum voltage required to break the hydrogen oxygen bond in water and maintaining 25-degree Celsius temperature of the water in the electrolysis process.

The minimum voltage at which a hydrogen electrolyser can operate is theoretically determined by the thermodynamic potential required for water splitting, which is 1.23 volts at standard temperature and pressure (STP). This voltage represents the minimum energy needed to overcome the free energy barrier of the water-splitting reaction:

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

However, in practical operations, a higher voltage is needed due to various factors that contribute to overpotentials, which are additional voltage losses beyond the thermodynamic minimum. These overpotentials arise from:

1. **Activation overpotential**: The energy required to initiate the electrode reaction (hydrogen evolution and oxygen evolution).
2. **Ohmic overpotential**: The voltage drops due to the resistance of the electrolyte and electrode.
3. **Concentration overpotential**: The voltage drop caused by the depletion of reactants or build-up of products at the electrode surfaces.

Therefore, the actual minimum operating voltage of a hydrogen electrolyser depends on the specific design and operating conditions. Typical operating voltages for various electrolyser types are:

1. **Alkaline electrolyzers**: 1.8 - 2.2 volts.
2. **Proton-exchange membrane (PEM) electrolyzers:** 1.5 - 2.0 volts.
3. **Solid oxide electrolyzers (SOECs):** 0.7 - 1.5 volts (due to high operating temperatures).
4. **Hysata capillary action electrolysers** – 1.51 volts.

Most of the standard electrolysers operate at 50-55kWhr/kg hydrogen

Normally, PEM electrolysers are used to produce hydrogen from the electrolysis process. Alkaline electrolysers are inefficient and solid-state ceramic electrolyzers are still sometimes away. The PEM (proton exchange membrane) electrolysers operate at ~50kWhr/ kg hydrogen.

Electrolysers – their types, advantages and disadvantages

Traditional electrolysers ➤

The principle behind electrolysis remains the same across technologies. However, the technologies differ based on various physical, chemical and electrochemical aspects. At present, there are four main types of electrolysis technologies.

Alkaline electrolysers: Alkaline electrolysis is a mature and commercially available technology used primarily by the fertilizer and chlorine industries. It currently accounts for almost two-thirds of the global electrolyser capacity. It operates at a pressure of 30 bar and uses thick membranes and nickel-based electrodes. While its simple and relatively low-cost stack and the system design makes it the cheapest electrolyser technology, its thick membranes reduce its efficiency to 70-80 per cent.

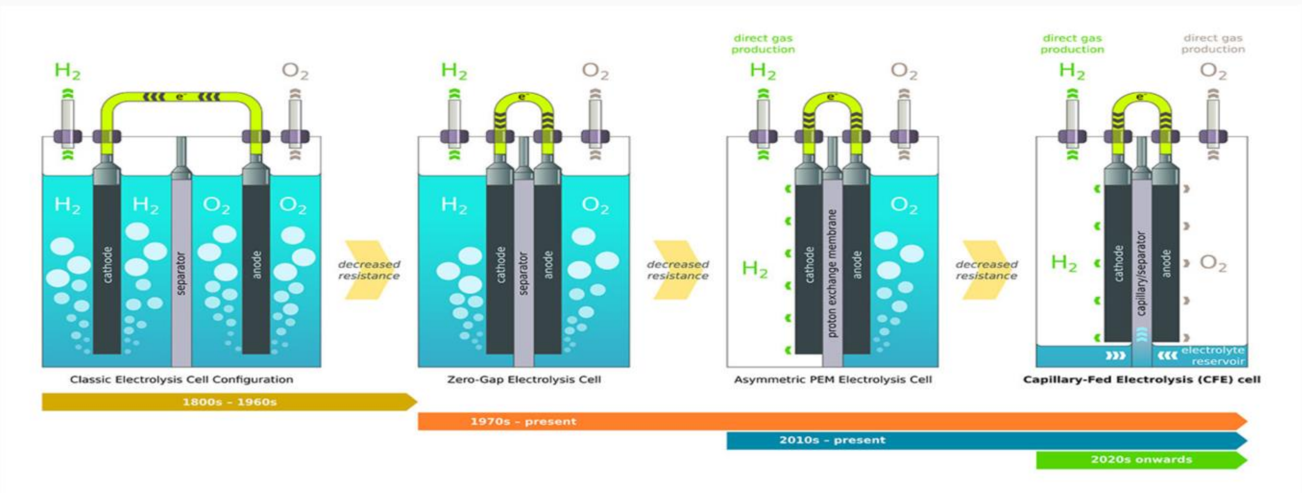
Proton exchange membrane (PEM) electrolysers - Despite being a young technology, PEM electrolysers comprise one-fifth of the global capacity. PEM electrolysers operate at high pressure due to the use of thin perfluoro sulfonic acid (PFSA) membranes, which translates to an efficiency of 80-90 per cent. PEM electrolysers have a compact and simple design, and they have the advantages in terms of operability with intermittent loads, i.e., fast response to varying renewable electricity. However, the PFSA acidic environment makes it necessary to use gold and titanium-plated electrodes and metals such as platinum, iridium, and ruthenium as catalysts, which increase the costs of such electrolysers significantly.

Solid oxide electrolysis cell (SOEC) electrolysers - SOEC electrolysers differ as they utilize heat to make hydrogen from steam and are best placed where there is a heat source available (nuclear or industrial facilities). They operate at high temperatures (500-850 ℃). SOEC electrolysers have shown higher efficiency compared to other technologies; however, on the flip side, it is not suited to withstand load changes. The technology is still at a demonstration level.

Anion exchange membrane (AEM) electrolysers - AEM electrolysers operate at significantly lower temperatures of 50-60 ℃ and a pressure range of 1-30 bar. They combine the less harsh conditions of alkaline electrolysers with the simplicity and high efficiency of PEM electrolysers. It is the latest technology, currently deployed at the large prototype level.

Hysata has come up with capillary electolysers which have higher efficiency ➤

Figure 2: The different types of electrolyzers



Evolution of electrolyser design (Image: Hysata)

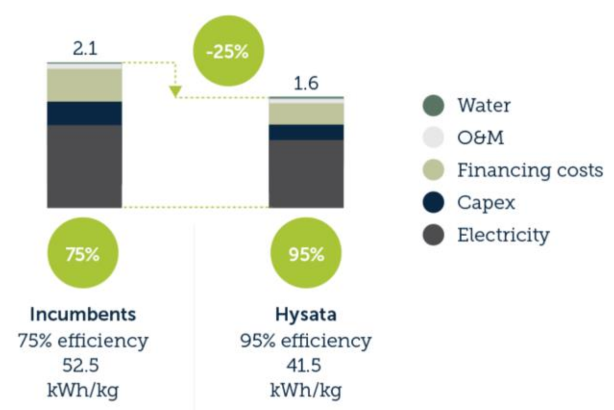
SOURCE: INCRED RESEARCH, HTTPS://ARENA.GOV.AU/BLOG/HYSATA-TO-BUILD-NEXT-GENERATION-HYDROGEN-ELECTROLYSER/#:~:TEXT=HOW%20DOES%20HYSATA'S%20TECHNOLOGY%20WORK,TWO%20PARTS%2C%20HYDROGEN%20AND%20OXYGEN.

Figure 3: The operational parameters of various electrolyzers

Parameter	Alkaline Electrolyzer	PEM Electrolyzer	SOEC Electrolyzer	AEM Electrolyzer
Electrolyte	20% ~ 30% KOH	Perfluorosulfonic Membrane	Yttria-Stabilized Zirconia	Divinylbenzene Polymer Carrier
Diaphragm	Asbestos/Polyphenylsulfone, etc.	Perfluorosulfonic Membrane	Zirconia-based Ceramic Membrane	Anion Exchange Membrane
Anode Catalyst	Nickel-plated Perforated Stainless Steel	Iridium Oxide	Perovskite-type	High Surface Area Nickel or NiFeCo Alloy
Cathode Catalyst	Nickel-plated Perforated Stainless Steel	Platinum Nanoparticles	Nickel/Zirconia	High Surface Area Nickel
Operating Temperature/°C	70 ~ 90	50 ~ 80	700 ~ 900	40 ~ 60
Working Pressure/MPa	0.1 ~ 3.0	4.0 ~ 7.0	0.1	<3.5
System Efficiency/%	60 ~ 75	70 ~ 90	85 ~ 100	60 ~ 90
Hydrogen Purity	≥99.8%	≥99.99%	≥99.99%	≥99.99%
Current Density (A·cm-2)	0.2 ~ 0.6	1.0 ~ 2.0	1.0 ~ 10	0.2 ~ 0.4
Energy Consumption (kW·h·m-3)	4.2 ~ 5.9	<4.3	>3.7	——
Hydrogen Pressure (MPa)	0.1 ~ 1.0	>2.0	>0.01	——
Lifespan (h)	6000-80000	8000-60000	20000	/
Porous Transport Layer Anode	Nickel Mesh	Platinum-Plated Sintered Porous Titanium	Nickel Mesh or Foam Nickel	Foam Nickel
Porous Transport Layer Cathode	Nickel Mesh	Sintered Porous Titanium or Carbon Cloth	None	Foam Nickel or Carbon Cloth
Bipolar Plate Anode	Nickel-plated Stainless Steel	Platinum-Plated Titanium	None	Nickel-plated Stainless Steel
Bipolar Plate Cathode	Nickel-plated Stainless Steel	Gold-Plated Titanium	Cobalt-plated Stainless Steel	Nickel-plated Stainless Steel
Technical Maturity Level	8 ~ 9	8 ~ 9	5 ~ 6	2 ~ 3
Industrialization Level	Fully Industrialized	Fully Industrialized	Laboratory to Industrial Transition	Laboratory to Industrial Transition
Advantages	Simple, Technologically Mature, High Reliability, Can Operate at Normal Temperature and Pressure	Long Lifecycle, Good Stability, Low Electrolyzer Corrosion, High Electrolysis Efficiency, Simplified System, Compact Device Structure, High Hydrogen Purity	High Electrolysis Efficiency, Can Reach More than 90%, Low Energy Consumption, Low Cost	Combines the Advantages of Alkaline Water Electrolysis and Proton Exchange Membrane Water Electrolysis
Disadvantages	Low Hydrogen Production Efficiency, High Energy Consumption, Alkali Leakage Environmental Pollution Issues	High Cost ; Requires Precious Metal Catalysts	High Operating Temperature of 600～1000°C, High Temperature Requirements, Key Materials Easily Age at High Temperatures	Polymer Membrane has Low Hydroxide Ion Conduction Rate, Poor Stability; Catalyst Easily Poisoned by Metal Ions

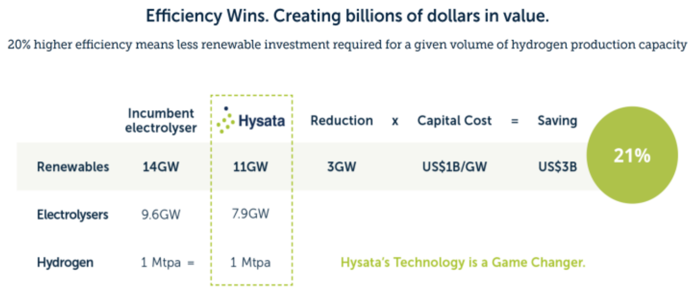
SOURCE: INCRED RESEARCH, HTTPS://SENZAHYDROGEN.COM/PEM-HYDROGEN-GENERATOR-VS-ALKALINE-HYDROGEN-GENERATOR.HTML

Figure 4: Hysata capillary electrolyser has the highest efficiency among existing electrolysers



SOURCES: INCRED RESEARCH, HTTPS://HYSATA.COM/OUR-TECHNOLOGY/

Figure 5: Hysata claims to save ~20% on the higher efficiency front and hence, cost savings of ~21%



SOURCES: INCRED RESEARCH, HTTPS://HYSATA.COM/OUR-TECHNOLOGY/

All electrolysers work by passing an electric current from electrodes through H2O – water. The current splits the water into its two parts, hydrogen, and oxygen. This process consumes energy.

Now, if the entire process was 100% efficient, all that energy would go into splitting the water. But, until now, electrolysers have also produced a lot of heat. That is because, just like an electric heater at home, they have electrical resistance.

The heat generated is not only wasted energy, but it must also be removed. Electrolysers need a lot of cooling and that uses even more energy. So, if you can reduce resistance, a greater proportion of energy is available to split the water. Also, the system generates far less far less heat which, in turn, requires less cooling.

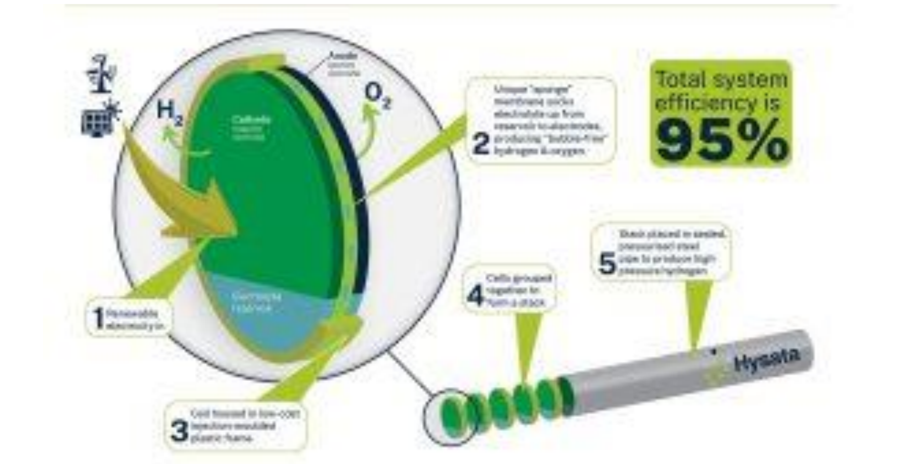
Hysata electrolyser is still in the trial phase ➤

Hysata will receive US$20.9m ARENA funding as a part of a US$47.5m project. Hysata will build and test a 5MW system at its new Port Kembla manufacturing facility.

The plan is to move the entire system to Rockhampton in Queensland for installation and trials, next to the Stanwell Power Station.

Queensland government-owned power company Stanwell Corporation is providing the site and facilities, and is also backing the project with US$3m.

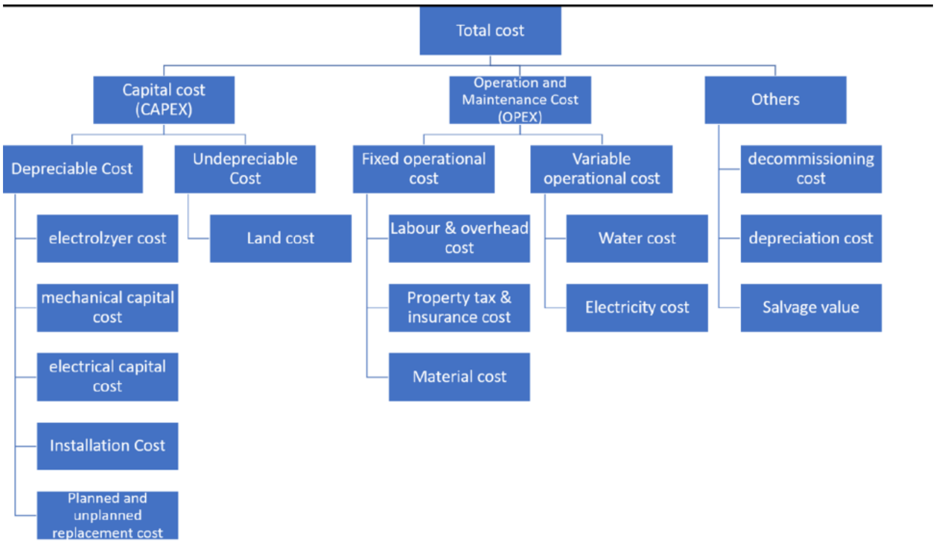
Figure 6: Hysata is manufacturing a pilot plant of 5MW



SOURCE: COMPANY REPORTS, HTTPS://ARENA.GOV.AU/BLOG/HYSATA-TO-BUILD-NEXT-GENERATION-HYDROGEN-ELECTROLYSER/

To ascertain the cost of H2 production, we have to calculate the overall cost ➤

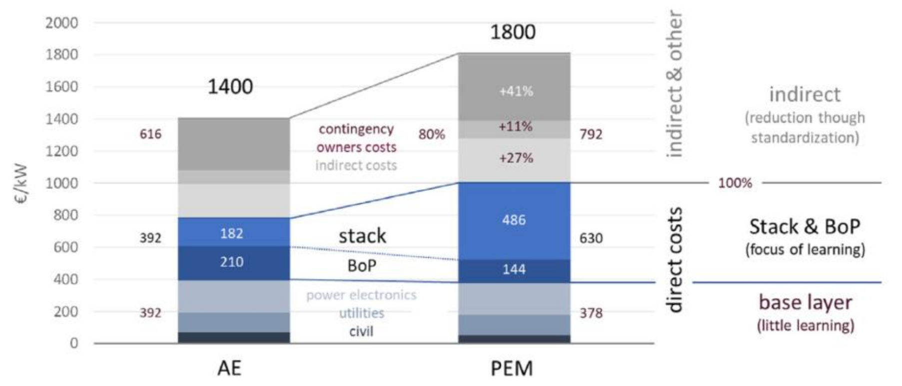
Figure 7: The overall cost of H2 production has various components



SOURCE: INCRED RESEARCH, HTTPS://WWW.RESEARCHGATE.NET/PUBLICATION/375569923_COST_PROJECTION_OF_GLOBAL_GREEN_HYDROGEN_PRODUCTION_SCENARIOS/LINK/654F7617CE88B87031DF50FB/DOWNLOAD?_TP=EYJJB250ZXH0IJP7IMZPCNN0UGFNZSI6IL9KAXJLY3QILCJWYWDLIJOICHVIBGLJYXRPB24ILCJWCMV2AW91C1BHZ2UIOIJFZGLYZWN0IN19

As of now, alkaline electrolyser has a lower cost compared to a PEM electrolyserc ➤

Figure 8: Alkaline electrolyzer has a lower capex cost compared to a PEM electrolyser



SOURCE: INCRED RESEARCH, HTTPS://WWW.SCIENCEDIRECT.COM/SCIENCE/ARTICLE/PII/S0360319923022590/

However, power consumption of alkaline electrolyser is much higher ➤

1. Normal PEM electrolysers have ~80% electrochemical efficiency and hence, they can operate at 51kWhr/kg H2.
2. In the case of alkaline electrolysers, the efficiency falls to around 65-66% and hence, power consumption increases to 60kWhr/kg H2.
3. PEM electrolyzers use noble metal-based electrocatalysts. These electrocatalysts include:
    a. Pt/Pd-based catalysts: Used as the cathode for the hydrogen evolution reaction (HER).
    b. RuO2/IrO2 catalysts: Used as the anode for the oxygen evolution reaction (OER).
    c. The harsh conditions in PEM electrolyzers, such as low pH, high potential, and high oxygen concentration limit the choice of catalyst to the relatively rare and costly platinum group metals. Commercial PEM electrolyzers use expensive platinum-group catalysts such as platinum and iridium.
4. On the other hand, alkaline electrolysers use nickel-based catalyst for the electrolysis process. Apart from catalyst, they need KOH or NaOH dozing in water to make it alkaline.

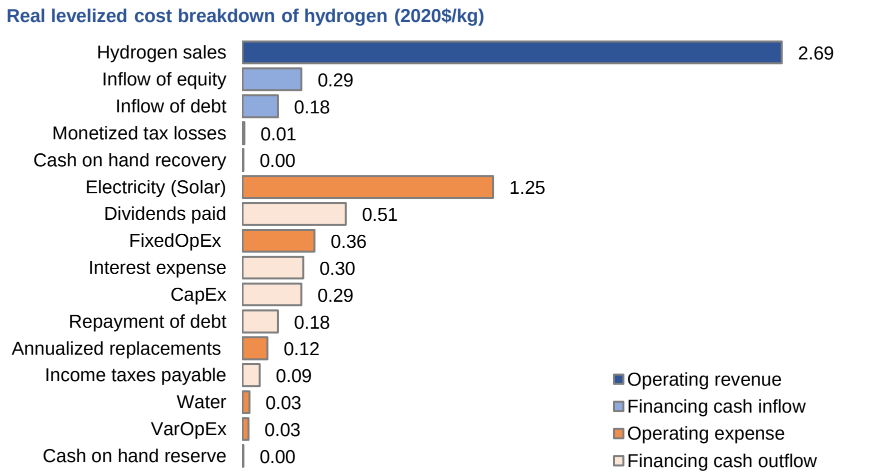
Green H_2- Producing green H_2 in ME and coverting in green NH_3 is viable

Producing green hydrogen from offshore wind power assets will cost US$3/kg. However, if we produce green hydrogen using solar power in areas of high irradiation (like the Middle East), then it's possible to make green H2 even below US$2/kg. The problems for H2 are in transportation and hence, converting it into ammonia is a viable option. Transporting ammonia is relatively easy and hence, most of the new green hydrogen projects in the Middle East are using the ammonia route to transport green hydrogen. High irradiation in the Middle East and relatively lower cost of V_2O_5-based flow batteries makes the project totally viable.

As of now, if one uses offshore wind assets to power electrolysers, then possibly H2 cost can fall below US$3/kg

Offshore wind assets can work at high plant load factor or PLF (around 50%) and if they use PEM electrolysers. then H2 cost per kg will fall to ~ US$3/kg.

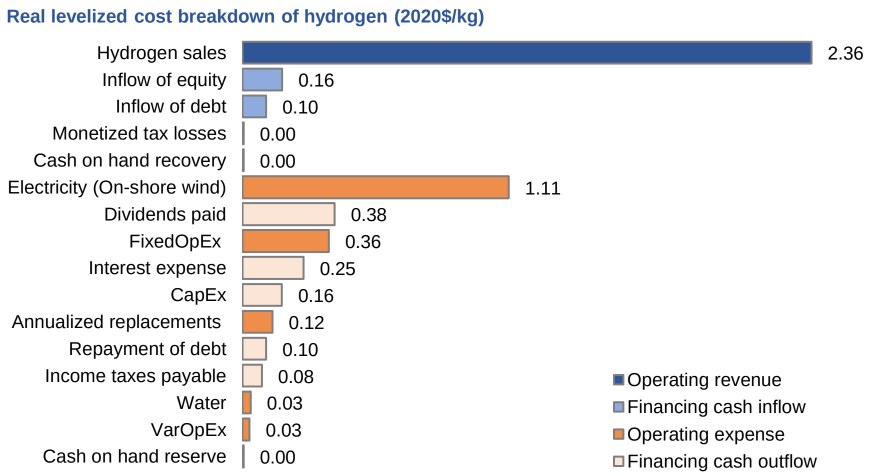
Figure 9: With offshore wind power electrolyser, utilization can be around 40% and hence, cost ~US$3/kg



SOURCE: COMPANY REPORTS, INCRED RESEARCH

Using Hysata electrolyser and offshore wind power, cost of H_2 can be ~US$2.3/kg

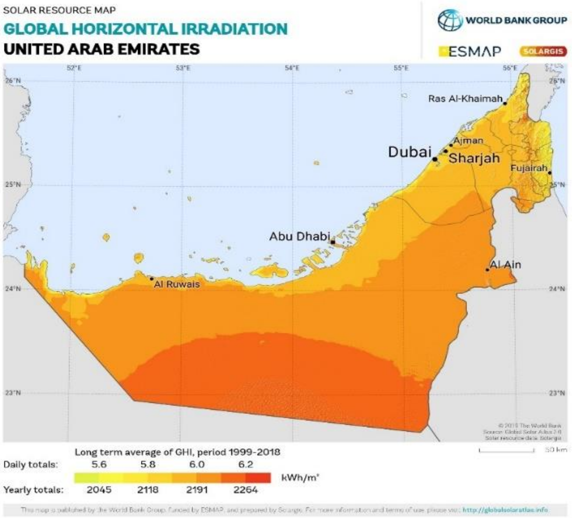
Figure 10: If Hysata electrolyzer becomes successful, then the cost of H2 production can fall to ~US$2.36/kg



SOURCE: COMPANY REPORTS, INCRED RESEARCH

If the PEM electrolyser is based on solar power in deserts with vanadium flow batteries as power storage units, then H_2 cost can fall to US$2.16/kg

Figure 11: For example, solar irradiation is quite high in the UAE at ~6kWhr/m^2



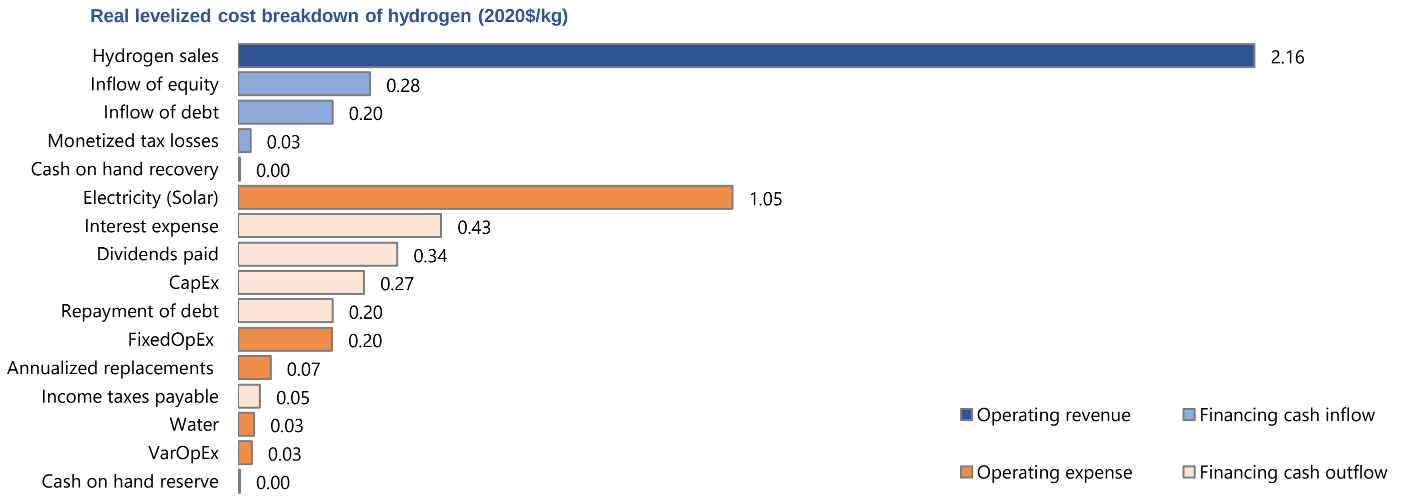
SOURCE: INCRED RESEARCH, HTTPS://SOLARGIS.COM/MAPS-AND-GIS-DATA/DOWNLOAD/UNITED-ARAB-EMIRATES

Figure 12: We have made the following assumptions for calculating green H_2 cost in the UAE

	Value	Unit
Solar irradiation	6.2	kWhr/m^2
Solar panel cost	150	US$/ m^2
Efficiency	20%	
PLF	50%	
Storage battery cost	110	US$/MWhr
Storage battery capacity	14,125	kWhr
Cost of debt	5%	
Equity IRR	10%	
Plant life	25	Years
Electrolyser cost	500	US$/kWhr
Electrolyser type	PEM	
Capacity of H_2 production	28,250	kg/ day
H_2 plant utilization	90%	
Power consumption in electrolyser	50	kWhr/kgH_2

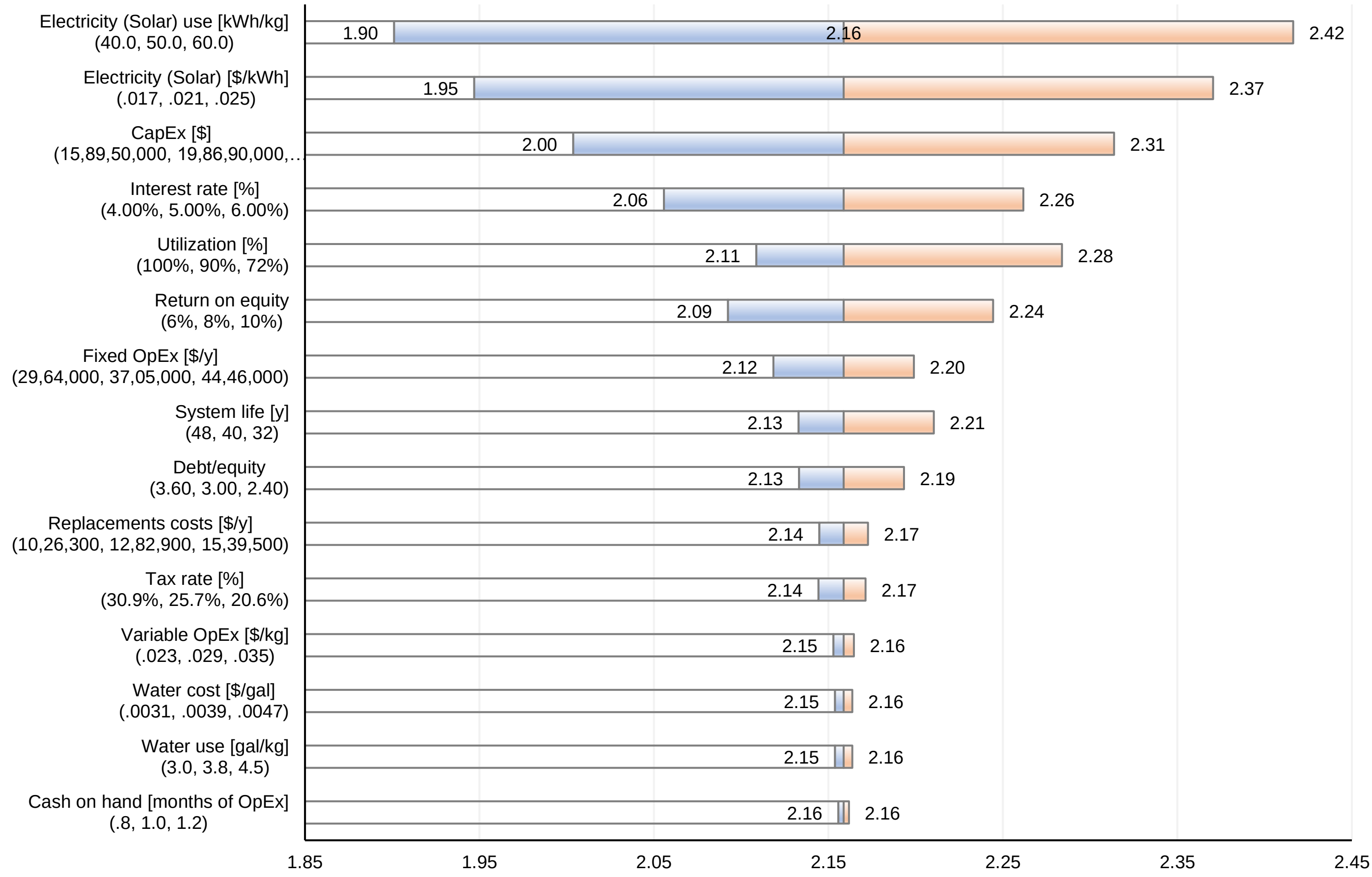
SOURCE: INCRED RESEARCH, COMPANY REPORTS

Figure 13: The levelized cost of H_2 per kg using the current cost of PEM electrolyser comes out to US$2.16



SOURCE: COMPANY REPORTS, INCRED RESEARCH

Figure 14: The variability of cost of hydrogen with all input parameters is shown below (scenario of +/- 20%)



SOURCE: INCRED RESEARCH, COMPANY REPORTS

However, shipping green H_2 across the oceans is challenging

1. Safety concerns: Hydrogen can embrittle materials, escape from containment, and has a wide flammability range.
2. Energy losses: Hydrogen has low volumetric energy density, which makes it difficult to store and transport.
3. Cost: The technology used to produce green hydrogen is still in its early stage and is costly.
4. Infrastructure: Specialized infrastructure is needed for hydrogen transportation.
5. Specialized storage: Hydrogen requires large storage volume or high-pressure tanks.
6. Conversion: Gaseous hydrogen should be converted into a more energy-dense liquid before being loaded onto a ship.

At current ammonia prices, H2 green produced in the Middle East is fully viable

Converting H2 (hydrogen) directly to ammonia (NH3) isn't a typical process. In fact, the more common scenario involves using hydrogen to produce ammonia from nitrogen (N2). This is known as the Haber-Bosch process, a crucial industrial process for fertilizer production and a potential route for storing and transporting clean hydrogen.

1. The cost of ammonia production from natural gas is approximately = natural gas price in mmBtu* 33+ 200 US$/t
2. Through hydrogen route = H_2 cost in US$/kg*177+150 US$/t = 177*2.17+150= US$520/t

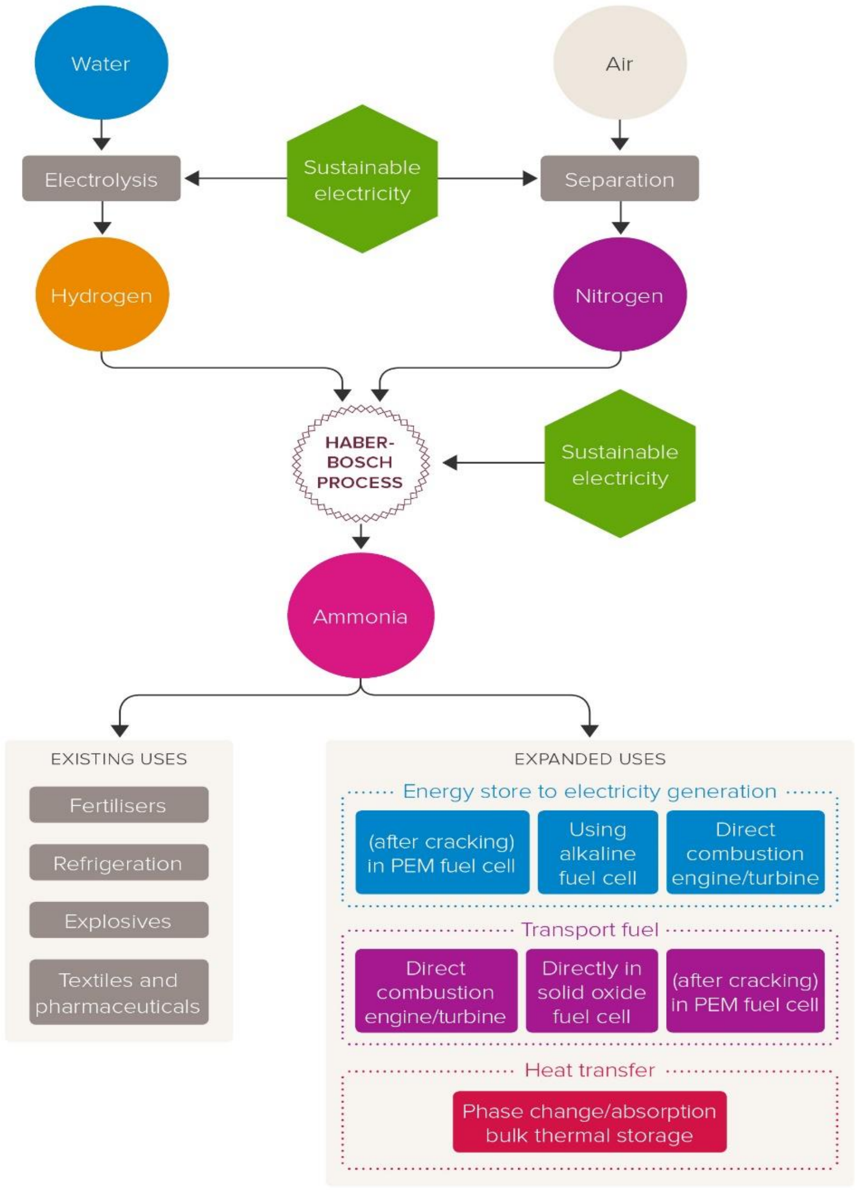
Green ammonia has multiple usage

What is green ammonia?

Ammonia is a pungent gas that is widely used to make agricultural fertilizers. Green ammonia production is where the process of making ammonia is 100% renewable and carbon-free.

One way of making green ammonia is by using hydrogen from water electrolysis and nitrogen separated from the air. These are then fed into the Haber process (also known as Haber-Bosch), all powered by sustainable electricity. In the Haber process, hydrogen and nitrogen are reacted together at high temperatures and pressures to produce ammonia, NH_3.

Figure 15: The production process and usage of green ammonia



SOURCE: INCRED RESEARCH, HTTPS://ROYALSOCIETY.ORG/

What's the future for green ammonia?

The production of green ammonia could offer further options in the transition to net-zero carbon dioxide emissions. These include:

1. **Energy storage** – Ammonia is easily stored in bulk as a liquid at modest pressure (10-15 bar) or refrigerated to -33°C. This makes it an ideal chemical store for renewable energy. There is an existing distribution network, in which

ammonia is stored in large refrigerated tanks and transported around the world by pipes, road tankers and ships.

2. **Zero-carbon fuel** – Ammonia can be burnt in an engine or used in a fuel cell to produce electricity. When used, ammonia's only by-products are water and nitrogen. The maritime industry is likely to be an early adopter, replacing the use of fuel oil in marine engines.
3. **Hydrogen carrier** – There are applications where hydrogen gas is used (e.g. in PEM fuel cells), but hydrogen is difficult and expensive to store in bulk (needing cryogenic tanks or high-pressure cylinders). Ammonia is easier and cheaper to store, and transport and it can be readily 'cracked' and purified to give hydrogen gas when required.

Worldwide there are multiple green ammonia projects and some of them are listed below ➤

Intercontinental Energy

Working on four of the world's largest green ammonia projects, including the 26GW Asian Renewable Energy Hub in Australia and the 25GW Green Energy Oman project.

Neom

A green hydrogen and ammonia complex in Saudi Arabia that is expected to produce 1.2mt of NH_3 per year by the end of 2026F.

Unigel

A chemical company in Brazil that aims to quadruple its output to 240,000t/year by 2025F.

Siemens Energy

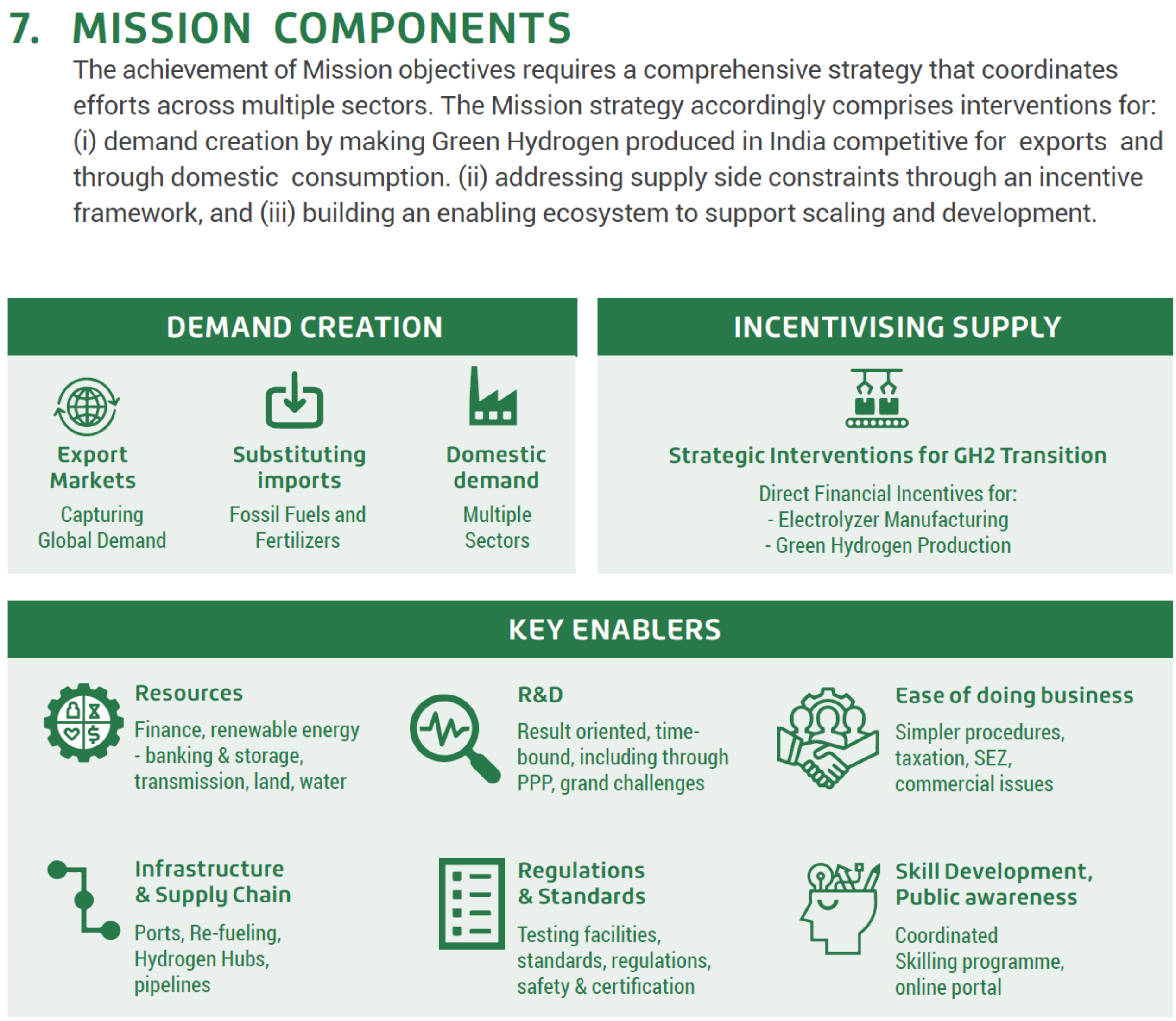
In Nov 2022, Siemens Energy partnered with Fortescue Future Industries and GeoPura to develop an ammonia cracker prototype.

What is the play in India - India's green H_2 objectives are bold and the country has necessary resources

Indian green hydrogen mission - bold objectives

The Government of India has declared its following objective: "*To make India the Global Hub for production, usage and export of Green Hydrogen and its derivatives. This will contribute to India's aim to become Aatmanirbhar through clean energy and serve as an inspiration for the global Clean Energy Transition. The Mission will lead to significant decarbonization of the economy, reduce dependence on fossil fuel imports, and enable India to assume technology and market leadership in Green Hydrogen*."

Figure 16: The mission components as given in the Government of India document is listed below

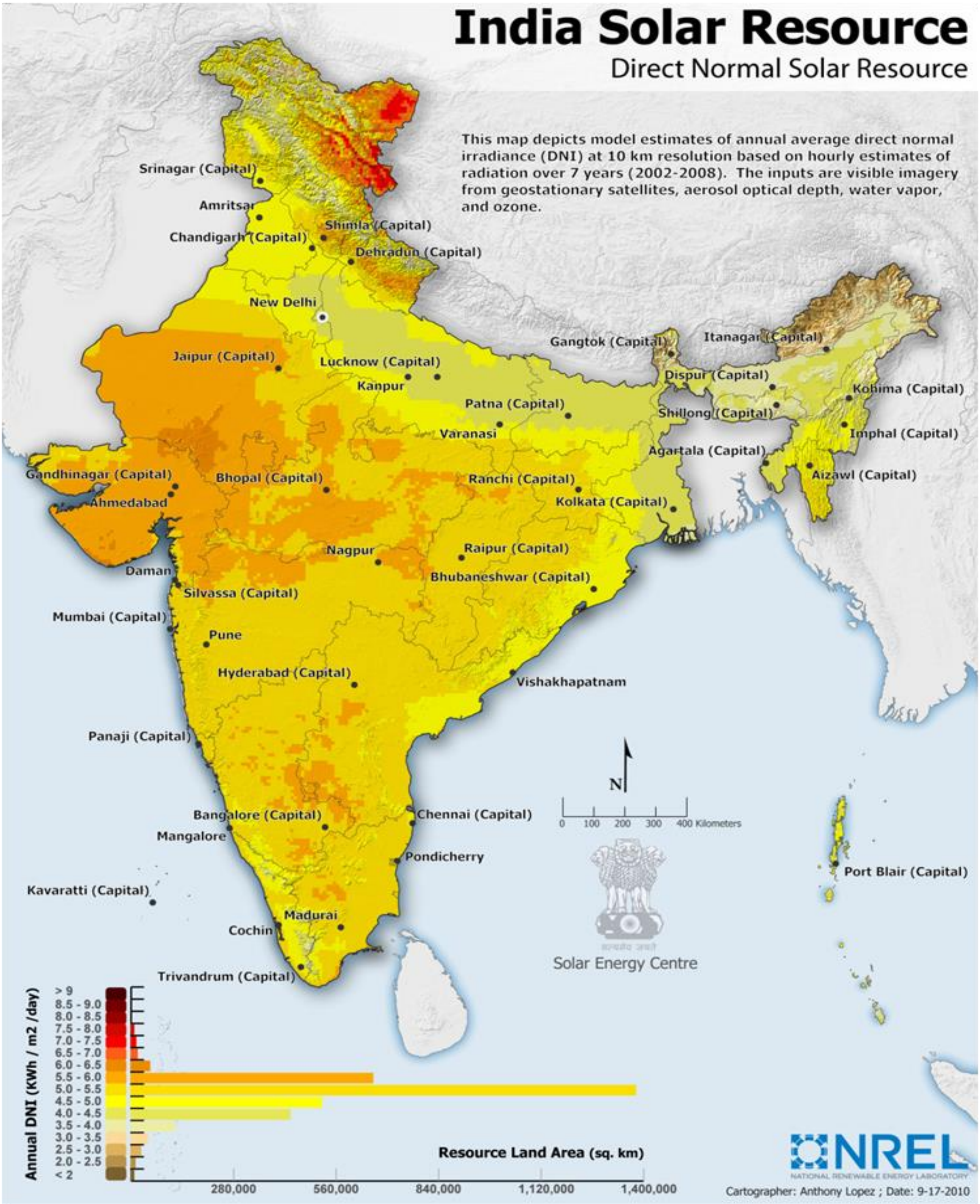


SOURCE: INCRED RESEARCH, HTTPS://ROYALSOCIETY.ORG/

Can India become a hub for green hydrogen? Yes, it can as there are ample resources available for the same

Solar irradiation in some parts of India is better than even the Middle East region. However, because of high interest costs and the desired return on equity investment, green H_2 cost is higher than that in the Middle East. To bring the cost at par with the Middle East, Indian government needs to provide some capital incentives.

Figure 17: India's solar resource, in terms of irradiation, in Rajasthan is worse than the Middle East but is still good at 5.5-6kWhr/m²/day



SOURCE: INCRED RESEARCH, HTTPS://ROYALSOCIETY.ORG/

Figure 18: Assuming a solar project is set up in Rajasthan and with an 80% depreciation in the first year, one can get equity IRR of 9% on the solar project at a power price of US cents 2.25/unit

Size of plant	**27,19,251.34**	**Sq. meter**
Cost of project	$197.54	million
Life of plant	25	Years
Depreciation	80%	in 1st year
MAT rate	25.00%	
PPA rate	$0.023	US$/ kWhr
O&M rate	$0.01	US$/ kWhr
Degradation	-0.50%	Per annum
Capex after five years	1.00%	of original capex
Debt cost	8%	
Debt	70%	
Equity	30%	
Debt repayment	10	years
Construction period	2	years
PLF		

P&L													
Year		0	1	2	3	4	10	11	12	22	23	24	25
Units generated (m units)			928.01	923.37	918.76	914.16	887.08	882.64	878.23	835.29	831.12	826.96	822.83
Revenue (US$m)			$20.88	$20.78	$20.67	$20.57	$19.96	$19.86	$19.76	$18.79	$18.70	$18.61	$18.51
O&M (US$m)			$8.12	$8.08	$8.04	$8.00	$7.76	$7.72	$7.68	$7.31	$7.27	$7.24	$7.20
EBITDA (US$m)			$12.76	$12.70	$12.63	$12.57	$12.20	$12.14	$12.08	$11.49	$11.43	$11.37	$11.31
Depreciation (US$m)			$158.03	$3.95	$3.95	$3.95	$3.95	$3.95	$0.00	$0.00	$0.00	$0.00	$0.00
Interest cost (US$m)			$11.06	$10.51	$9.40	$8.30	$1.66	$0.55	$0.00	$0.00	$0.00	$0.00	$0.00
PBT (US$m)			-$156.33	-$1.76	-$0.72	$0.32	$6.59	$7.63	$12.08	$11.49	$11.43	$11.37	$11.31
Tax (US$m)			$0.00	-$0.44	-$0.18	$0.08	$1.65	$1.91	$3.02	$2.87	$2.86	$2.84	$2.83
PAT (US$m)			-$156.33	-$1.32	-$0.54	$0.24	$4.94	$5.72	$9.06	$8.61	$8.57	$8.53	$8.49
Capex (US$m)		$197.54	-	-	-	-	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94
Equity part of capex		$59.26	-	-	-	-	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94
Debt repayment (US$m)		$0.00	$0.00	$13.83	$13.83	$13.83	$13.83	$13.83	$0.00	$0.00	$0.00	$0.00	$0.00
Cash flow to equity		-$59.26	$1.70	$2.63	$3.41	$4.19	$8.89	$9.68	$9.06	$8.61	$8.57	$8.53	$8.49
NPV(US$m)		$0.00			-0.59	$4.19	$8.89	$9.68	$9.06	$8.61	$8.57	$8.53	$8.49
Debt (US$m)		$0.00											
Equity part (US$m)													
Overall EV (US$m)													
Equity IRR	9%												

SOURCE: INCRED RESEARCH, COMPANY REPORTS

Using PEM electrolyser and government incentives, it looks possible to operate a green H_2 plant at US$2/kg (but the size has to be much larger) ➤

The production-linked incentive or PLI scheme provides a budgetary outlay of **Rs130bn for green hydrogen production and Rs44.4bn for electrolyser manufacturing**. While the green hydrogen production PLI would prioritize those applicants that quote the least amount of incentive under the scheme, the electrolyser PLI would grant fixed incentives while emphasizing on energy efficiency parameters and local value addition level achieved by the applicants.

National Green Hydrogen Mission: The SIGHT (Strategic Interventions for Green Hydrogen Transition) scheme guidelines under the Mission have been notified for electrolyser manufacturing and Mode-I for green hydrogen production.

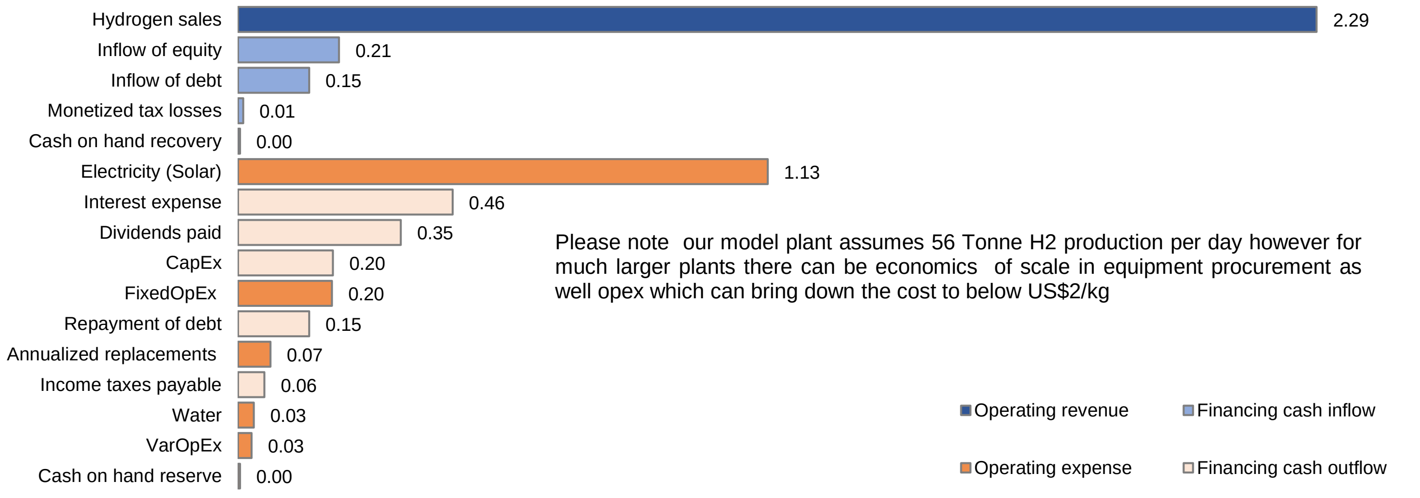
The SIGHT programme for electrolyser manufacturing has an allocation of Rs44.4bn by 2029-30.

The incentives start from **Rs4,440 per kW in the first year and end at Rs1,480 per kW in the fifth year.**

The SIGHT programme for green hydrogen production (Mode-I) provides incentives for green hydrogen production, which are capped at Rs**50/kg, Rs 40/kg and Rs 30/kg** for the first, second and third year, respectively.

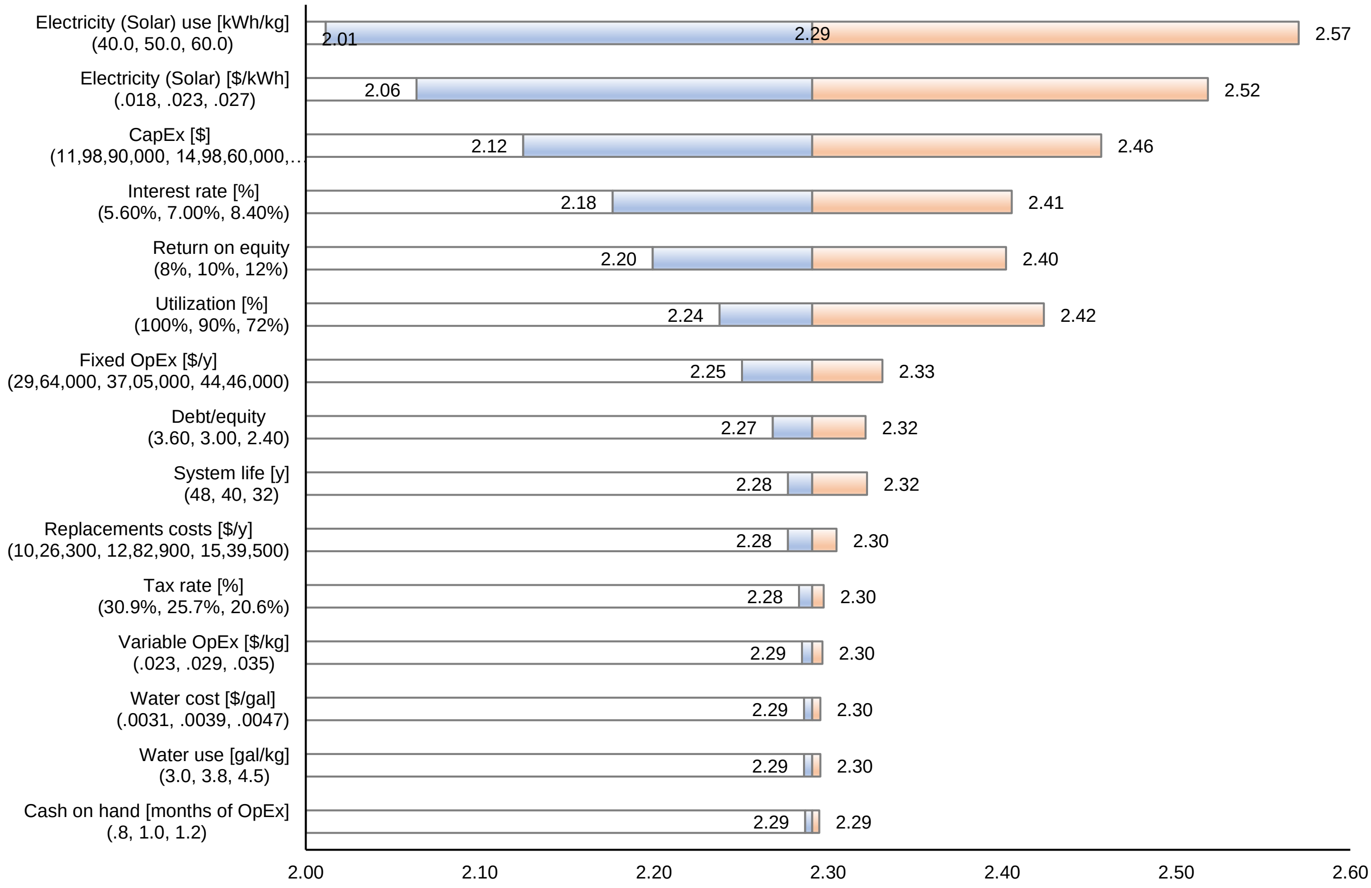
Taking both the incentives into account and if a plant can operate at 90% capacity utilization, we arrive at a H_2 production cost of US$2.1/kg. A cost below US$2/kg will require significant cost reduction in basic electrolyser economics or power consumption requirement per kg of H_2.

Figure 19: The levelized cost of hydrogen using the incentives available in electrolyser manufacturing as well as on hydrogen production comes out to US$2.29/kg



SOURCE: INCRED RESEARCH, COMPANY REPORTS

Figure 20: There can be savings on the on the plant size and cost of power because in a higher plant size, the operational leverage can bring down the cost to below US$2/ kg, but US$1-1.5/kg still looks very difficult



SOURCE: INCRED RESEARCH, COMPANY REPORTS

The companies that are relevant from a green H_2 and electrolyser perspective

Multiple companies are trying their hands in green hydrogen and electrolyser manufacturing. With the government's incentive plan and with the economies of scale, it is possible to make hydrogen at even below US$2/kg in India. The incentive structure makes India competitive in the global H2 space. We can even think of converting H2 into ammonia and exporting it. We have the following companies in this space:

1. Adani Enterprises (UNRATED)
2. Reliance Industries (ADD)
3. Thermax (ADD)
4. John Cockerill India (UNRATED)

John Cockerill India (UNRATED) ➤

John Cockerill India is a leader in alkaline electrolysers. While alkaline electrolysers consume more power, they have a lower capital cost (we have pointed this out in Fig. 8). The way India is focusing on green hydrogen projects, it's natural that the company can garner a significant market share in India. The company has a long history of operations in India and hence, understands Indian customers well. However, to be really cost competitive, the company may have to set up an electrolyser plant in the country.

Thermax (ADD) ➤

Thermax is exploring various alternative strategies for hydrogen, which includes:

1. Manufacturing capacity for electrolyser.
2. Biomass to hydrogen.
3. EPC for hydrogen plants.
4. Supply of hydrogen to industrial users.

Memorandum of Understanding with Fortescue Future Industries

Recently, Thermax has signed a Memorandum of Understanding or MoU with Fortescue Future Industries (FFI) to explore green hydrogen projects, including the setting up of new manufacturing facilities in India. FFI is on a mission to replace fossil fuels by producing green electrons from renewable energy and then convert these green electrons into green hydrogen. With its National Green Hydrogen Mission, the Indian government is committed to developing the green hydrogen industry to help decarbonization.

We believe Thermax's foray into the green hydrogen market will offer more opportunities in the coming years, with its strong execution and technological capabilities in green energy. The joint venture (JV) with FFI is looking to explore green hydrogen projects for commercial and industrial customers, including new manufacturing facilities for electrolysers and sub-systems in India. It is looking to set up electrolyser capacity of 2GW per annum under Phase-I to leverage the productivity-linked incentive or PLI scheme under the National Green Hydrogen Mission. Under the first phase, it is constructing electrolysers with a capacity of 2GW per annum. This project is a JV with an American hydrogen fuel cell developer, Plug Power Inc. FFI, an Australia-based global green energy company, committed to producing green hydrogen, containing zero carbon, from 100% renewable sources. Green hydrogen is a zero-carbon fuel, that when used produces primarily water.

Adani Enterprises (UNRATED)

1. Adani Enterprises is building three giga factories to develop green hydrogen. The company's subsidiary, Adani New Industries (ANIL), has spent US$2.5bn on a green hydrogen project. The first phase of the project is expected to be completed by 2027F, with an annual capacity of 1mt.
2. Adani Enterprises plans to build 10GW solar panels, 10GW wind turbines, and 5GW hydrogen electrolysers. The company has also started producing India's largest wind turbine, which is of 5.3MW.
3. In Jun 2023, Adani Enterprises and France's Total Energies SE announced a plan to invest US$5bn to produce green hydrogen and related products in India.
4. The Adani group believes that India has the potential to become one of the world's largest green hydrogen producers. India hopes to become a globally competitive producer and consumer of green hydrogen by 2030F.

Reliance Industries (ADD)

Reliance Industries is investing Rs600bn (approx. US$7.2bn*) to construct world-scale, state-of-the-art facilities to manufacture and integrate critical components of the new energy ecosystem:

1. Fully integrated solar photovoltaic manufacturing complex.
2. Advanced energy storage systems for integrated cells, battery packs, and control manufacturing.
3. Electrolyser manufacturing facility.
4. Power electronics and semiconductor development.
5. Basic raw material and auxiliary materials manufacturing.
6. Research and development facilities for all new energy technologies.

The company will also invest in glass and polyolefin encapsulant (POE) film manufacturing, both of which have natural synergies with its chemical and materials business.

Reliance Industries is investing Rs150bn (approx. US$1.8bn*) in value-chain, partnerships, and future technologies, including upstream and downstream industries, to create a fully integrated, end-to-end renewable energy ecosystem.

Further, it is developing an ecosystem for assisting small and medium enterprises (SMEs) and entrepreneurs to embrace new technologies and innovations, leading to captive use of renewable energy and green hydrogen.

Reliance Industries is also planning to invest Rs5.95tr (approx. US$72 bn*) in Gujarat for green energy and other projects. It will also set up a 10GW renewable energy capacity in Uttar Pradesh - the largest in the state.

DISCLAIMER

This report (including the views and opinions expressed therein, and the information comprised therein) has been prepared by InCred Research Services Private Ltd.(formerly known as Earnest Innovation Partners Private Limited) (hereinafter referred to as "IRSPL"). IRSPL is registered with SEBI as a Research Analyst vide Registration No. INH000011024. Pursuant to a trademark agreement, IRSPL has adopted "InCred Equities" as its trademark for use in this report.

The term "IRSPL" shall, unless the context otherwise requires, mean IRSPL and its affiliates, subsidiaries and related companies. This report is not directed or intended for distribution to or use by any person or entity resident in a state, country or any jurisdiction, where such distribution, publication, availability or use would be contrary to law, regulation or which would subject IRSPL and its affiliates/group companies to registration or licensing requirements within such jurisdictions.

This report is being supplied to you strictly on the basis that it will remain confidential. No part of this report may be (i) copied, photocopied, duplicated, stored or reproduced in any form by any means; or (ii) redistributed or passed on, directly or indirectly, to any other person in whole or in part, for any purpose without the prior written consent of IRSPL.

The information contained in this report is prepared from data believed to be correct and reliable at the time of issue of this report.

IRSPL is not required to issue regular reports on the subject matter of this report at any frequency and it may cease to do so or change the periodicity of reports at any time. IRSPL is not under any obligation to update this report in the event of a material change to the information contained in this report. IRSPL has not any and will not accept any, obligation to (i) check or ensure that the contents of this report remain current, reliable or relevant; (ii) ensure that the content of this report constitutes all the information a prospective investor may require; (iii) ensure the adequacy, accuracy, completeness, reliability or fairness of any views, opinions and information, and accordingly, IRSPL and its affiliates/group companies (and their respective directors, associates, connected persons and/or employees) shall not be liable in any manner whatsoever for any consequences (including but not limited to any direct, indirect or consequential losses, loss of profits and damages) of any reliance thereon or usage thereof.

Unless otherwise specified, this report is based upon reasonable sources. Such sources will, unless otherwise specified, for market data, be market data and prices available from the main stock exchange or market where the relevant security is listed, or, where appropriate, any other market. Information on the accounts and business of company(ies) will generally be based on published statements of the company(ies), information disseminated by regulatory information services, other publicly available information and information resulting from our research. Whilst every effort is made to ensure that statements of facts made in this report are accurate, all estimates, projections, forecasts, expressions of opinion and other subjective judgments contained in this report are based on assumptions considered to be reasonable as of the date of the document in which they are contained and must not be construed as a representation that the matters referred to therein will occur. Past performance is not a reliable indicator of future performance. The value of investments may go down as well as up and those investing may, depending on the investments in question, lose more than the initial investment. No report shall constitute an offer or an invitation by or on behalf of IRSPL and its affiliates/group companies to any person to buy or sell any investments.

The opinions expressed are based on information which are believed to be accurate and complete and obtained through reliable public or other non-confidential sources at the time made. (Information barriers and other arrangements may be established where necessary to prevent conflicts of interests arising. However, the analyst(s) may receive compensation that is based on his/their coverage of company(ies) in the performance of his/their duties or the performance of his/their recommendations. In reviewing this report, an investor should be aware that any or all of the foregoing, among other things, may give rise to real or potential conflicts of interest. Additional information is, subject to the duties of confidentiality, available on request.

The report is not a "prospectus" as defined under Indian Law, including the Companies Act, 2013, and is not, and shall not be, approved by, or filed or registered with, any Indian regulator, including any Registrar of Companies in India, SEBI, any Indian stock exchange, or the Reserve Bank of India. No offer, or invitation to offer, or solicitation of subscription with respect to any such securities listed or proposed to be listed in India is being made, or intended to be made, to the public, or to any member or section of the public in India, through or pursuant to this report.

The research analysts, strategists or economists principally responsible for the preparation of this research report are segregated from the other activities of IRSPL. Information barriers and other arrangements have been established, as required, to prevent any conflicts of interests.

The research analysts, strategists or economists principally responsible for the preparation of this research report are segregated from the other activities of IRSPL. Information barriers and other arrangements have been established, as required, to prevent any conflicts of interests.

IRSPL may have issued other reports (based on technical analysis, event specific, short term views etc.) that are inconsistent with and reach different conclusion from the information presented in this report.

Holding of Analysts/Relatives of Analysts, IRSPL and Associates of IRSPL in the covered securities, as on the date of publishing of this report

	Analyst/ Relative	Entity/ Associates
any financial interests in the company covered in this report (subject company) and nature of such financial interest	NO	NO
actual/beneficial ownership of 1% or more in securities of the subject company at the end of the month immediately preceding the date of publication of the research report or date of the public appearance;	NO	NO
any other material conflict of interest at the time of publication of the research report or at the time of public appearance	NO	NO
received any compensation from the subject company in the past twelve months for investment banking or merchant banking or brokerage services or investment advisory or depository or distribution from the subject company in the last twelve months for products/services other than investment banking or merchant banking or broker- age services or investment advisory or depository or distribution from the subject company in the last twelve months	NO	NO
managed or co-managed public offering of securities for the subject company in the last twelve months	NO	NO
received any compensation or other benefits from the subject company or third party in connection with the research report	NO	NO
served as an officer, director or employee of the subject company	NO	NO
been engaged in market making activity for the subject company	NO	NO

Analyst declaration

- The analyst responsible for the production of this report hereby certifies that the views expressed herein accurately and exclusively reflect his or her personal views and opinions about any and all of the issuers or securities analysed in this report and were prepared independently and autonomously in an unbiased manner.
- No part of the compensation of the analyst(s) was, is, or will be directly or indirectly related to the inclusion of specific recommendations(s) or view(s) in this report or based any specific investment banking transaction.
- The analyst(s) has(have) not had any serious disciplinary action taken against him/her(them).
- The analyst, strategist, or economist does not have any material conflict of interest at the time of publication of this report.
- The analyst(s) has(have) received compensation based upon various factors, including quality, accuracy and value of research, overall firm performance, client feedback and competitive factors.

IRSPL and/or its affiliates and/or its Directors/employees may own or have positions in securities of the company(ies) covered in this report or any securities related thereto and may from time to time add to or dispose of, or may be materially interested in, any such securities.

IRSPL and/or its affiliates and/or its Directors/employees may do and seek to do business with the company(ies) covered in this research report and may from time to time (a) buy/sell the securities covered in this report, from time to time and/or (b) act as market maker or have assumed an underwriting commitment in securities of such company(ies), and/or (c) may sell them to or buy them from customers on a principal basis and/or (d) may also perform or seek to perform significant investment banking, advisory, underwriting or placement services for or relating to such company(ies) and/or (e) solicit such investment, advisory or other services from any entity mentioned in thisreport and/or (f) act as a lender/borrower to such company and may earn brokerage or other compensation. However, Analysts are forbidden to acquire, on their own account or hold securities (physical or uncertificated, including derivatives) of companies in respect of which they are compiling and producing financial recommendations or in the result of which they play a key part.