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India's $2.1bn Leap Towards its Green Hydrogen Vision

The Strategic Interventions for Green Hydrogen Transition (SIGHT) programme, the country's bold plan to make it a global hub for electrolyser manufacturing and green hydrogen production, can go further

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Glossary

Abbreviation	Definition
BOP	Balance of Plant
CBG	Compressed Biogas
EU	European Union
GHP	Green Hydrogen Producer
GW	Gigawatt
G2G	Government to Government
IPR	Intellectual Property Rights
IRA	The Inflation Reduction Act (US)
ISTS	Interstate Transmission System
KTPA	Kilo Tonne per Annum
LCOH	Levellised Cost of Hydrogen
LOA	Letter of Award
LVA	Local Value Addition
LCOA	Levellised Cost of Ammonia
MT	Metric Tonne
MTPA	Metric Tonnes per Annum
MMTPA	Million Metric Tonnes per Annum
MNRE	Ministry of New and Renewable Energy
MSME	Micro, Small and Medium Enterprises
MW	Megawatts
NGHM	National Green Hydrogen Mission
OEM	Original Equipment Manufacturers
PEM	Proton Exchange Membrane
PSU	Public Sector Undertaking
RFS	Request for Selection
SIGHT	Strategic Interventions for Green Hydrogen Transition
SEC	Specific Energy Consumption
SECI	Solar Energy Corporation of India

Key Findings

The levellised cost of green hydrogen in India will likely fall by up to 40% to Rs260-310/kg (US$3-3.75/kg) with the support of incentives, cheap renewable electricity, waiver of ISTS open access charges, distribution and transmission charges and lowering the GST rate for hydrogen to 5%.

Electrolyser manufacturers are projected to achieve a 7-10% reduction in total system costs for the first five years with Rs2,960/kW (US$36/kW) being the average annual realisable base incentive.

While the green hydrogen scheme is an important step for India, refinements are needed to promote long-term investment and project viability.

The green hydrogen definition framework needs enhancement with globally accepted definitions for critical aspects such as how green hydrogen is produced (additionality), its origin (deliverability) and timing (temporal matching) to make a global impact.

Executive Summary

The US$2.1 billion Strategic Interventions for Green Hydrogen Transition (SIGHT) programme is the foundation of India’s grand plan to become a green hydrogen powerhouse by leveraging the nation’s access to cheap renewable energy. Enthusiastically received by industry, the scheme needs finetuning to attract start-ups, be competitive for global players and create a supply-chain and secure demand to ensure the long-term viability of the industry. If successful, it could help build India’s green hydrogen industry with benefits for a range of sectors including agriculture, transport and manufacturing.

India’s Green Hydrogen Mission aspires to position the nation as a global hub for green hydrogen production, utilisation and export, contributing significantly to energy independence and the decarbonisation of key economic sectors. The mission targets a green hydrogen production capacity of 5 million metric tonnes a year (MMTPA) and the addition of 125 gigawatts (GW) of renewable energy capacity by 2030, with the aim of abating 50MMTPA of greenhouse gas (GHG) emissions.

At the core of the National Green Hydrogen Mission (NGHM) is the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme, which introduces two distinct financial incentive mechanisms. These mechanisms target incentivising domestic manufacturing of electrolysers and green hydrogen production. By leveraging India’s advantage in low-cost renewable electricity, the programme aims to achieve competitive domestic electrolyser manufacturing and reduce the costs of green hydrogen production.

In July 2023, the Solar Energy Corporation of India (SECI) issued a Request for Selection (RFS) as part of Component-I of the SIGHT programme, targeting the establishment of 1,500 megawatts (MW) of electrolyser manufacturing capacity in India.

While the base incentives for electrolyser manufacturers were predetermined, bidders emphasising lower specific energy consumption and higher local value addition were encouraged. Bidders could choose from any stack technology or indigenously developed stack technology, categorised as Bucket 1 and Bucket 2, respectively. The total outlay for this incentive scheme is Rs44.4 billion (US$541 million).

Against the 1,500MW capacity, SECI received bids totalling 3,328.5MW from 21 participants. Ultimately, eight were selected in Bucket 1, including Reliance Electrolyser Manufacturing, John Cockerill Green Hydrogen Solutions and Jindal India, each securing 300MW capacity with a maximum incentive allocation of Rs4.44 billion (US$54.1 million). The others included Ohmium Operations, Advait Infratech and Larsen &Toubro (L&T) Electrolysers.

In Bucket 2, HomiHydrogen won 101.5MW capacity and Adani New Industries secured 198.5MW. Most of the winning participants had prior tie-ups with electrolyser technology companies, some even securing technology license agreements before bid submission, showcasing proactive strategies that contributed to their success.

SECI initiated another RFS in July 2023 to select green hydrogen producers under Component-II of the SIGHT scheme. The total outlay for this component is Rs130.5 billion (US$1.59 billion). Here, winners were selected based on the least incentives quoted for their production capacity. The green hydrogen production capacity was distributed with 410,000 metric tonnes a year (MTPA) under Bucket 1 and 40,000MTPA under Bucket 2. Bucket 1 pertains to technology-agnostic pathways for green hydrogen production, while Bucket 2 focuses on biomass-based pathways. Bid submissions exceeded the available capacity of 450,000MTPA, reaching 551,500MTPA from 13 bidders. Winners in Bucket 1 included Reliance, Greenko and ACME, securing 90,000MTPA of capacity each, with respective average incentives of Rs18.9/kg (US¢23/kg), Rs30/kg (US¢36/kg) and Rs30/kg (US¢36/kg).

HHP Two (Hygenco), with a winning capacity of 75,000MTPA, received an average incentive of Rs25.04/kg (US¢30/kg). Other winners included Torrent Power, CESC Projects, Welspun, UPL and JSW Neo Energy. Bharat Petroleum Corporation Limited secured 2,000MTPA capacity under Bucket 2, with 38,000MTPA unallocated.

Most winners are strategically venturing into green hydrogen production, leveraging their positions in the renewable energy sector. Despite this enthusiasm, using green hydrogen to decarbonise domestic end-use industries remains uncertain due to challenges such as infrastructure limitations, regulatory ambiguities and the absence of clear mandates for its use. The winners focus on export markets due to challenges and price concerns in the domestic market. The sector grapples with stringent safety regulations, technology changes, project delays, policy uncertainties and a need for robust hydrogen supply chain infrastructure.

While ambitious and well-intentioned, the scheme has some shortcomings, which we highlight in this report along with solutions proposed to benefit all stakeholders. Possible barriers to long-term investment in domestic green hydrogen production include the scheme's short tenure (five years) and comparatively low subsidies.

Political, technological and global market uncertainties can affect optimism for a future decline in green hydrogen costs. Government intervention in establishing standards, policies and regulations and streamlining offtake for demand creation is crucial for developing the green hydrogen market in India. Without such measures, India will likely remain a marginal player in the global green hydrogen market.

Policy Framework and Initiatives

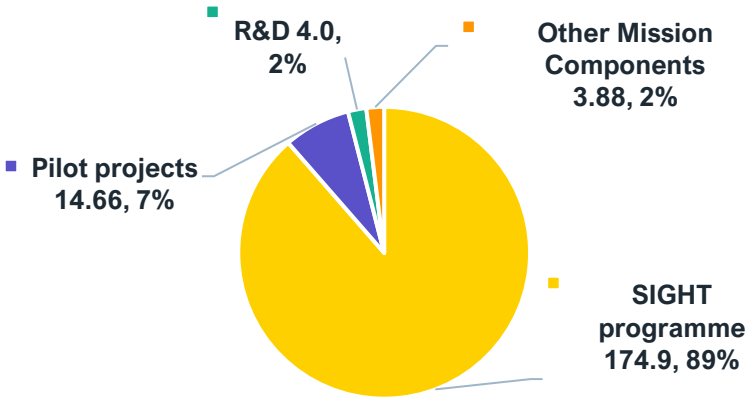
The main objective of the National Green Hydrogen Mission (NGHM) is to make India the global hub for the production, usage and export of green hydrogen and its derivatives. Foremost among them is the establishment of capabilities to generate a minimum of 5 million metric tonnes per annum (MMTPA) of green hydrogen by 2030.[1] There is potential to reach 10MMTPA, but this depends on export market growth.

It is estimated that about 5MTPA[2] of hydrogen is consumed in India for petroleum refining, manufacturing ammonia for fertilisers, methanol production, treatment and production of metals. Most of this hydrogen is sourced from fossil fuels through the steam reformation of natural gas and naphtha and is commonly known as "grey hydrogen".

The NGHM's key initiatives are the substitution of grey hydrogen in critical sectors such as ammonia production and petroleum refining, infusion of green hydrogen into City Gas Distribution systems, integration of green hydrogen in steel production, and the utilisation of green hydrogen-derived synthetic fuels (such as green ammonia and green methanol) to replace fossil fuels across diverse sectors including transportation, shipping and aviation.

The mission's initial outlay of Rs197.44 billion[3] (US$2.41 billion) has the following allocation: Rs174.9 billion (US$2.13 billion) for the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme, Rs14.66 billion (US$178.8 million) for pilot projects, Rs4 billion (US$48.8 million) for R&D and Rs3.88 billion (US$47.3 million) for other mission components.

Figure 1: Capital outlay allocation in National Green Hydrogen Mission (Rs billion)



Source: MNRE National Green Hydrogen Mission

[1] Ministry of New and Renewable Energy. National Green Hydrogen Mission. January 2023. Page 12.
[2] Ibid. Page 23.
[3] MNRE. National Green Hydrogen Mission. January 2023. Page 24.

The SIGHT programme has a total outlay of Rs174.9 billion (US$2.13 billion), dedicated to two financial incentive mechanisms to support the domestic manufacturing of electrolysers and the production of green hydrogen. These incentives aim to enable rapid scale-up, technology development and cost reduction.

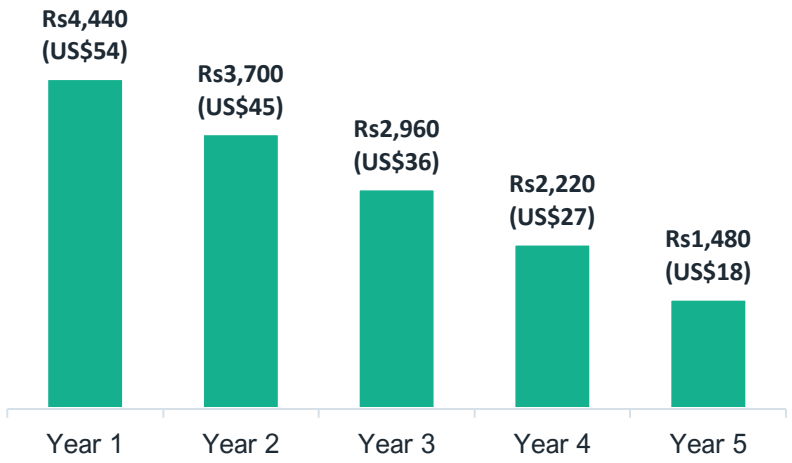
- **Component-I** is an incentive scheme for electrolyser manufacturing with a total outlay of Rs44.4 billion (US$541 million).
- **Component-II** is an incentive scheme for green hydrogen production with a total outlay of Rs130.5 billion (US$1.59 billion).

SIGHT Component-I for Electrolyser Manufacturing

Overseen by the Solar Energy Corporation of India (SECI), the NGHM proposes interventions to boost domestic manufacturing to ensure the production of electrolysers in India at significantly lower costs. India relies on the global market to source electrolyser systems for large-scale green hydrogen projects. Recognising this dependence and in alignment with Ministry of New and Renewable Energy (MNRE) guidelines, in July 2023, SECI issued a Request for Selection (RFS) for electrolyser manufacturers to set up 1.5 gigawatts (GW) of capacity under Component-I of the SIGHT programme. This initiative aims to incentivise manufacturers interested in establishing electrolyser manufacturing capacity, strategically emphasising domestic value addition.

The RFS supports electrolyser manufacturing in terms of Rs/kilowatt (kW) corresponding to the manufacturing capacity, with the base incentive starting at Rs4,440/kW (US$54/kW) in the first year. This incentive tapers over five years (Figure 2).

Figure 2: Base incentives available for electrolyser manufacturers (Rs/kW)



Source: SECI RFS

To promote indigenously developed electrolyser technologies, the RFS invited bids in two buckets:

- **Bucket 1** is solely for electrolyser manufacturing capacity based on any stack technology, with a total offered capacity of 1,200 megawatts (MW). The minimum bid capacity for Bucket 1 is 100MW, with a maximum of 300MW, and;

- **Bucket 2** focuses on electrolyser manufacturing capacity utilising indigenously developed stack technology, offering a total capacity of 300MW. Bucket 2 has no specified minimum bid capacity, and the maximum bid capacity is 300MW.

Indigenously developed stack technology must have a patent/Intellectual property rights (IPR) registered with the Government of India. Further, the patent holding agency must be registered in India.

The maximum capacity that a single bidder can get is 300MW. Bidders competing for electrolyser manufacturing capacity are assessed on two critical parameters:

- **Specific Energy Consumption** (SEC) must be less than or equal to 56 kilowatt-hour (kWh)/kg[4] of hydrogen production. Bidders quoting the lowest values stand a better chance, with achieving these quoted values post-production crucial for incentive realisation.

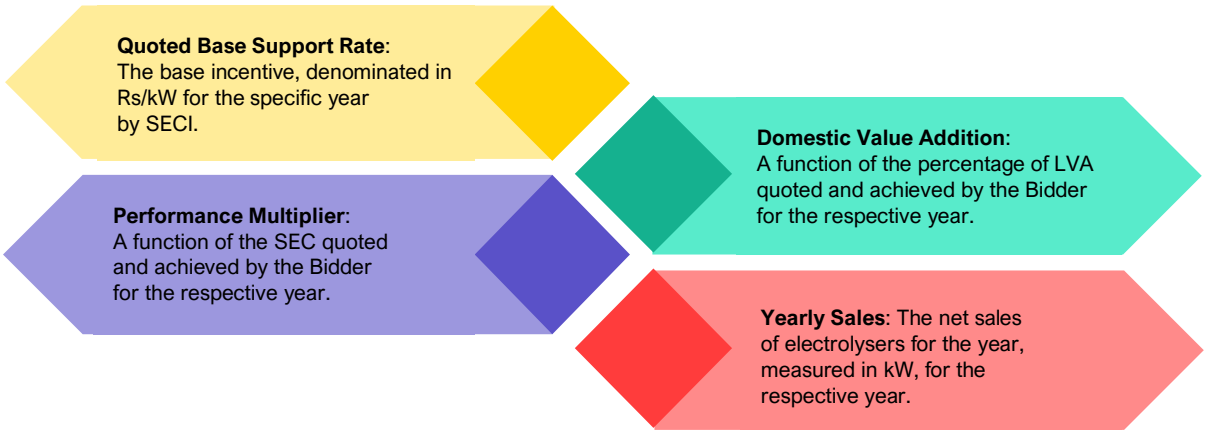
- **Local Value Addition** (LVA) ranges from 30-40% in the first year to 70-80% in the fifth year,[5] based on technology. Achieving these values post-production is essential to secure incentives.

The annual incentives for successful bidders are based on four key components specified in the RFS, as follows:

Incentive = (Base Incentive) x (Domestic Value Addition) x (Performance Multiplier) x (Yearly Sales)

[4] SECI. RFS for selection of electrolyser manufacturers. July 2023. Page 9.
[5] SECI. RFS for selection of electrolyser manufacturers. July 2023. Page 9.

Figure 3: Components determining annual incentives to electrolyser manufacturers



Source: SECI; JMK Research

Successful bidders can obtain full incentives if they meet their allocated manufacturing capacity and the benchmarks they set for domestic value addition and specific energy consumption. Other features of the RFS include:

- **Verification Arrangements**: SECI will arrange quarterly verifications for electrolyser performance and annual assessments for local value addition.
- **Commissioning Timeline**: Electrolyser manufacturers have two years from issuing the letter of award (LOA) to commission the total manufacturing capacity.
- **Responsibility for Clearances**: Bidders are accountable for obtaining the necessary clearances and approvals from various government departments and local bodies for the construction and operation of the facility.

SIGHT Component-II for Green Hydrogen Production (Mode 1)

Another objective of the SIGHT programme is to promote sustainable and large-scale green hydrogen production in India. In line with SIGHT guidelines, SECI also issued the RFS in July 2023 to select green hydrogen producers (GHPs), targeting the establishment of production facilities capable of producing 450,000 metric tonnes per annum (MTPA)[6] of green hydrogen. The goal is to maximise green hydrogen production in India, facilitating rapid scale-up, technology development and cost reduction.

[6] SECI. RFS for selection of Green hydrogen producers. July 2023. Page 9.

To encourage large-scale utilisation and enhance cost-competitiveness, bidders had the option to participate in either or both of the following pathways:

- **Bucket 1:** Technology agnostic
- **Bucket 2:** Biomass-based

The incentive for the quoted bid capacity is determined annually by multiplying two submitted components from the bidder (Table 1):

- Incentive quoted (in Rs/kg) for the specific year. The incentive quoted in a particular year must be equal to or less than the previous year's, and;
- Allocated capacity or production (in kg) – whichever is lower – for the specific year.

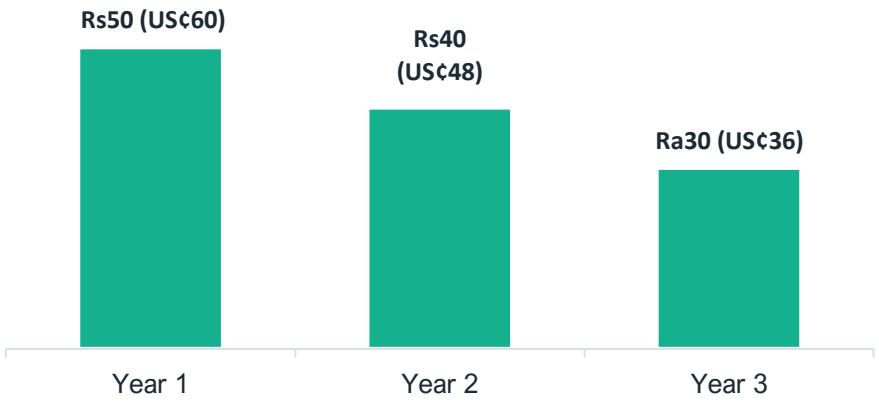
Table 1: Capacity offered in Buckets 1 and 2 – Green hydrogen RFS

Bucket	Pathway	Total capacity offered (MTPA)	Minimum bid capacity per bidder (MTPA)	Maximum bid capacity per bidder (MTPA)
1	Technology Agnostic	410,000	10,000	90,000
2	Biomass-Based	40,000	500	4,000

Source: SECI

In each bucket, the bidder with the lowest average incentive will be given preference when allocating bid capacity. The average incentive is determined by calculating the simple average of the incentives requested (in Rs/kg) for each of the three years. This ensures that bidders quoting a lower average incentive across the specified years are prioritised in the allocation process (Figure 4).

Figure 4: Maximum incentive available for green hydrogen producers (Rs/kg)



Source: SECI RFS for selection of green hydrogen producers

Other features of the green hydrogen RFS include:

- Any unallocated capacity under this tranche is carried over to the next tranche
- The maximum allocation to a single bidder under this tranche is 90,000MTPA
- GHPs have three years from the issue of the LOA to commission the total manufacturing capacity
- Producers of green hydrogen and its derivatives are eligible for credits under the Carbon Credit Trading Scheme (CCTS) 2023, subject to the fulfilment of stipulated criteria

SIGHT Component-II for Green Hydrogen Production (Mode 2)

Mode 1 requires interested GHPs to bid competitively, aiming for the least incentive demanded over three years. In contrast, Mode 2 takes a different approach by aggregating demand and seeking bids for green hydrogen and its derivatives at the lowest cost through a competitive selection process. Bidders quoting the lowest price will be allocated capacity in descending order until the total available capacity is allocated.

Mode 2 consists of two parts, 2A[7] and 2B,[8] focusing on aggregating demand and calling for bids for the production and supply of green ammonia and green hydrogen, respectively. Table 2 shows the total bid capacity available and incentives provided under Mode 2.

[7] MNRE. Guidelines and Incentive scheme for procurement of green ammonia production. January 2024. Page 3.
[8] Ibid.

Table 2: Mode 2 incentives and capacity

Mode	Focus	Implementing agencies	Total bidding capacity – Tranche I Kilo tonne per annum (KTPA)	Year 1	Year 2	Year 3
				Incentives (Rs/kg)		
2A	Green ammonia	SECI of MNRE	550	8.82	7.06	5.30
2B	Green hydrogen	Centre for High Technology (CHT) of MoPNG	200	50	40	30

Source: MNRE
Note: Mode 2 guidelines were released in January 2024. The RFS or Notice inviting Bid documents with further details are expected in the coming months.

Players Show Interest in Electrolyser Manufacturing

SECI's RFS for electrolyser manufacturing has generated substantial interest, attracting bids totalling 3328.5MW[9] from 21 participants, far surpassing the proposed 1500MW capacity. The competitive landscape includes prominent Indian energy companies, subsidiaries/joint ventures of international firms and start-ups.

The bids came from all over India. However, the final decision on where these companies will establish their manufacturing units depends mainly on the incentives and subsidies provided by the state governments. Simply put, the companies will choose locations that offer the best support and benefits for their operations.

Most bids are concentrated in Bucket 1, with key players such as Adani, Reliance Industries, Avaada, L&T, Greenko, Waaree and Jindal India each vying for 300MW despite the bucket's 1,200MW limit. Bids from technology start-ups and mid-size mechanical equipment manufacturers primarily occupy Bucket 2.

Bucket 1 and 2 participants represent a diverse spectrum of industry players. They include established companies with extensive experience in project development and operations and mid-sized and smaller companies venturing into the hydrogen sector. The mix encompasses solar project developers, module manufacturers and entities with a substantial presence in the clean energy sector.

[9] SECI. Result of Electrolyser Manufacturing tender. January 2024.

Figure 5: Participant snapshot – electrolyser manufacturing RFS

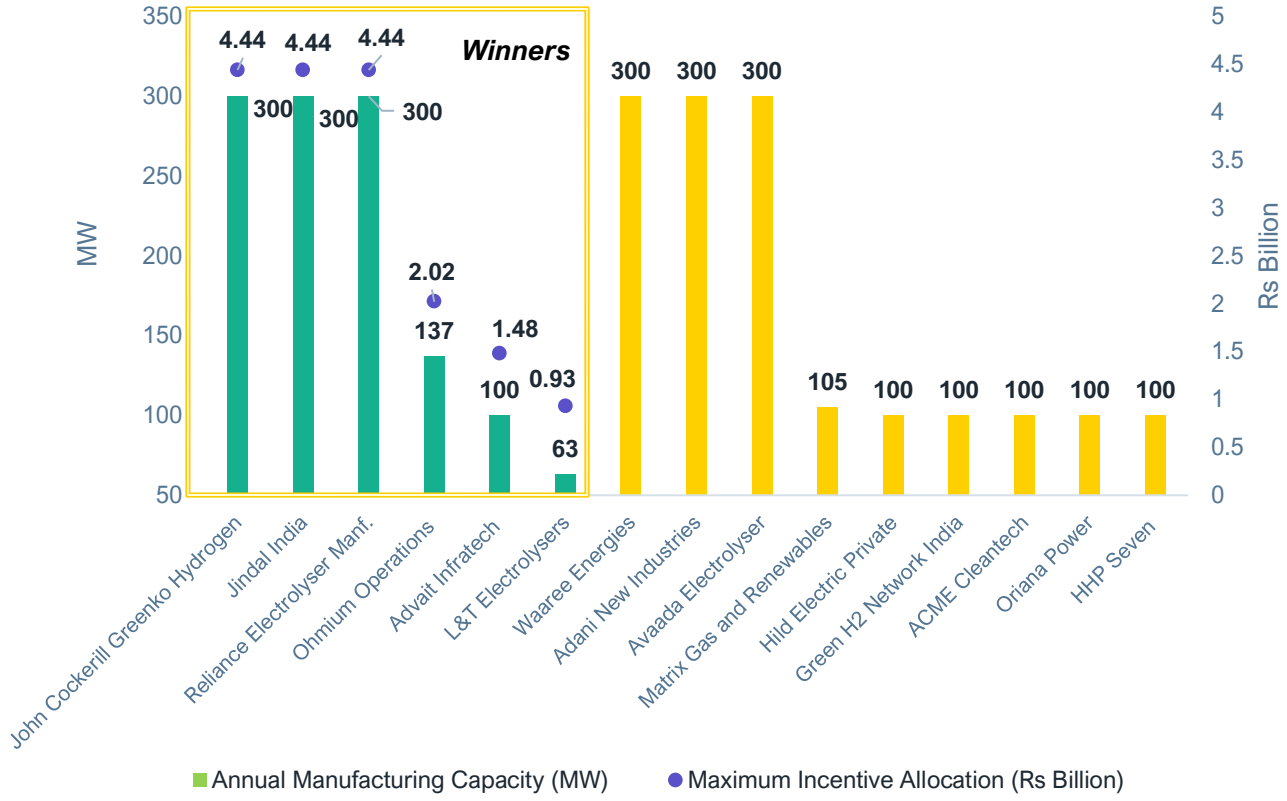
Category	Bidders for Electrolyser Manufacturing Incentives
Players with significant presence in energy value chain	Reliance Industries Limited; adani; L&T; Jindal; BHEL
Players with significant presence in clean energy business	greenko John Cockerill; AVAADA; WAAREE One with the Sun; ACME Leading Through Innovation
Mid-size clean energy companies	Hild. Electric; TrueRE ORIANA POWER LIMITED
Hydrogen Companies/ Startups	ohmium; ADVAIT INFRATECH; MATRIX Gas & Renewables; HomiHydrogen Pvt. Ltd.; newtrace
New entrants	Green H2 Network Pvt. Ltd.; HHP Seven Private Limited; LiveHy Energy Private Limited; C. Doctor India Pvt. Ltd.; Pratishna Engineers Limited Plastic Injection Moulding Machine

Source: JMK Research

Bucket 1 and 2 participants for electrolyser manufacturing capacity were evaluated on two key parameters: SEC and LVA. SEC must be less than or equal to 56kWh/kg of hydrogen production, with lower values favoured. LVA should range from 30-40% in the first year to 70-80% based on technology, with higher LVA preferred. Achieving these values post-production is crucial for securing incentives.

Figure 6 shows the winning companies in the electrolyser manufacturing RFS and the maximum capacity and incentives allocated to them.

Figure 6: Bucket 1 winners of electrolyser manufacturing incentives



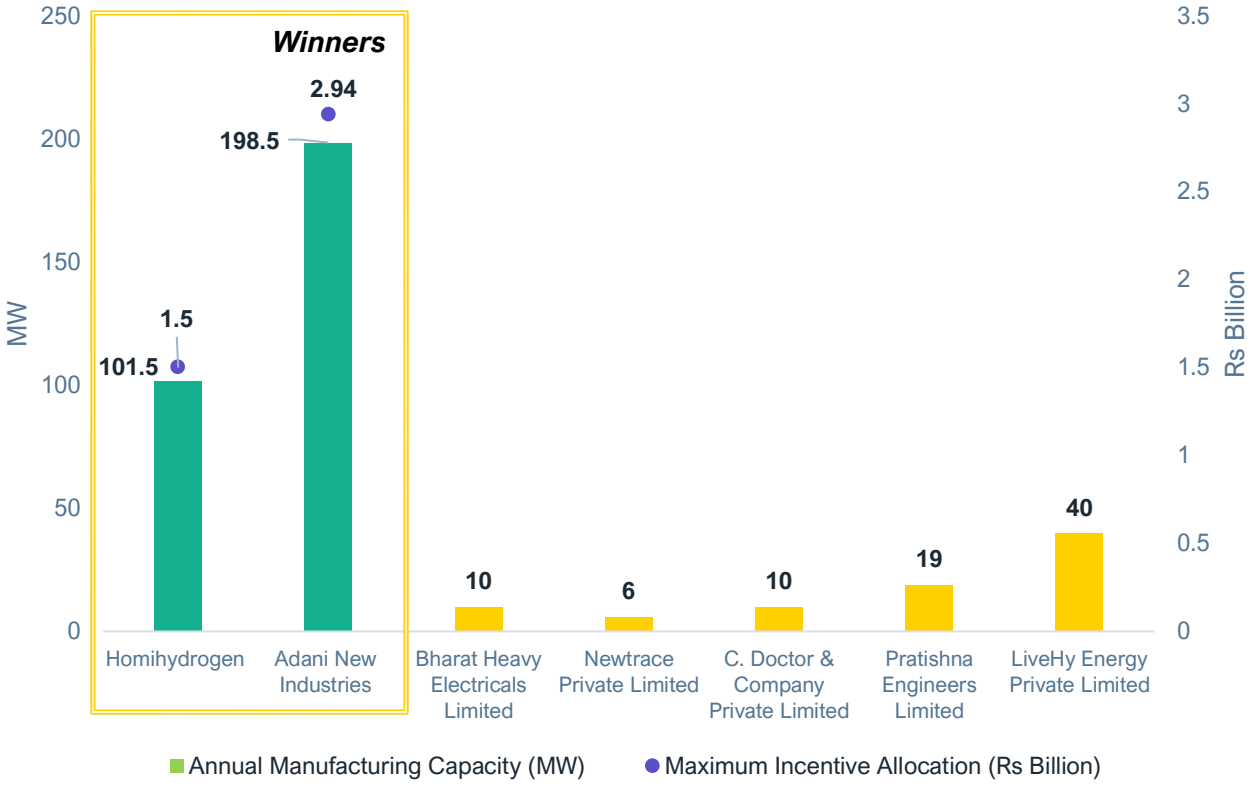
Source: SECI; JMK Research

Greenko succeeded by partnering with John Cockerill, a global leader in electrolyser manufacturing. The recent placement of India’s largest 140MW electrolysers order for its first green ammonia plant, set for operation in 2024, underscores their successful collaboration. Additionally, their joint efforts extend to developing a substantial 2GW-a-year electrolyser manufacturing plant.

Reliance Industries Limited's (RIL) success can be largely attributed to the feasibility study conducted for the Jamnagar gigafactory. In addition, RIL’s strong understanding of state-level incentives and logistics, coupled with its recent partnership with the Danish company Stiesdal for the development and manufacturing of hydrogen electrolysers, has further solidified its position.

Ohmium’s success is grounded in its track record of operating an electrolyser manufacturing plant since 2021. The company’s global outreach is evident through its exports to international markets. Additionally, recent tie-ups with entities such as Hero Future Energies, Shell and Amp Energy India have further strengthened Ohmium’s competitive edge.

Figure 7: Bucket 2 winners of electrolyser manufacturing incentives



Source: SECI; JMK Research

HomiHydrogen and Adani New Industries have the required indigenous technology, and their competitive bids on SEC and LVA played a pivotal role in securing capacities under Bucket 2. HomiHydrogen is a JV between h2e Power Systems, BlueBasic AMA Engineering (H2energy, Italy) and Greenstat Hydrogen India.

SECI has determined the incentives for electrolyser manufacturers for each year. The average of the maximum annual realisable incentive for the manufacturer is calculated to be Rs2,960/kW[10] (US$36/kW). The winners were chosen based on their quoted SEC and LVA figures. The cost of the electrolyser system (comprising only the stack and balance of plant (BOP), excluding installation costs) averages Rs30,000/kW (US$366/kW) for Alkaline and Rs42,000/kW (US$512/kW) for Proton Exchange Membrane (PEM) for a 1MW system at a production rate of 300MW a year.[11] At Rs2,960/kW (US$36/kW), manufacturers are projected to achieve a 7-10% reduction in total system costs for the first five years.

[10] SECI. RFS for selection of Electrolyser Manufacturers. July 2023. Page 35.
[11] National Renewable Energy Laboratory (NREL). Manufacturing Cost Analysis for Proton Exchange Membrane Water Electrolysers. August 2019. Page 46.

However, it needs further support from the government by reducing the goods and services tax (GST) rate for electrolyser manufacturing from 18% to a competitive rate, e.g., 5%.[12]

Players Show Interest in Green Hydrogen Production

In the RFS for incentives for green hydrogen production, bids exceeded the available capacity of 450,000MTPA, exceeding 551,500MTPA,[13] from 13 bidders.

Most GHP bidders have a proven track record of developing and operating renewable power assets. These companies are strategically venturing into green hydrogen production, leveraging their established positions in the renewable energy sector.

In Bucket 1, Reliance Green Hydrogen and Green Chemicals Limited, Avaada GreenH2, Greenko ZeroC and ACME Cleantech Solutions have submitted the largest capacities, each at 90,000MT. Other major bidders include Welspun New Energy (20,000MT), JSW Neo Energy (10,000MT), CESC Projects Limited (10,500MT), Sembcorp Green Hydrogen India (36,000MT) and Torrent Power (10,100MT).

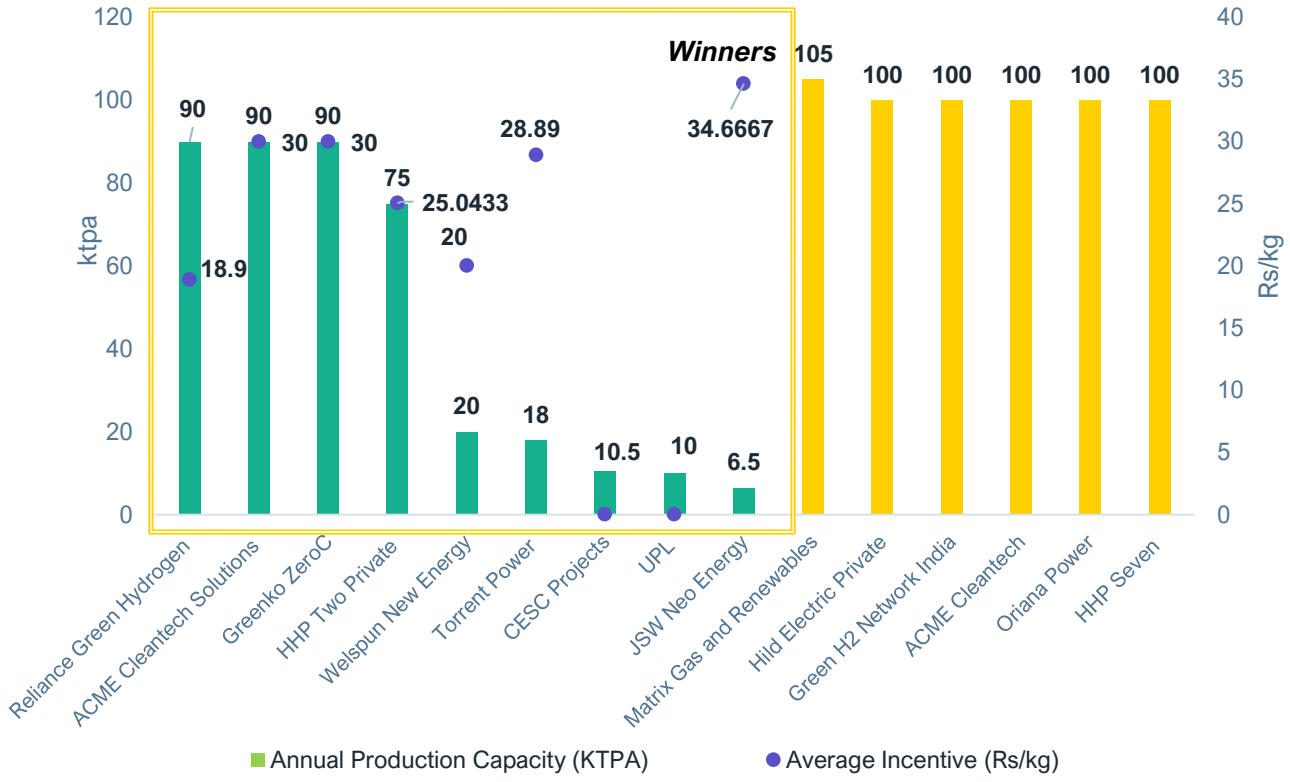
Figure 8: Participants snapshot – green hydrogen producers RFS

Category	Bidders for Green Hydrogen Production Incentives
Players with significant presence in energy value chain	JSW Energy, CESC, Reliance Industries Limited, sembcorp, Bharat Petroleum, torrent POWER
Players with significant presence in clean energy business	AVAADA, ACME Leading Through Innovation, WELSPUN, greenko, UPL
New entrants	HHP Two Private, GH4 India Pvt. Ltd.

Source: JMK Research

[12] Mint. Green energy sector pitches for GST cut. January 2024.
[13] SECI. Result for selection of green hydrogen producer. January 2024.

Figure 9: Bucket 1 winners of green hydrogen production incentives



Source: SECI; JMK Research

Most GHP project winners focus on export markets, especially in South Korea and Japan. This strategic choice stems from the understanding that utilising green hydrogen for captive consumption or selling it in the domestic market could significantly raise the prices of end products such as steel, oil and gas or fertiliser unless purchased by a public sector undertaking (PSU).

In addition to the export markets, the following winners have undertaken initiatives that could enhance the uptake of green hydrogen produced through this RFS.

RIL is committed to replacing grey hydrogen with green hydrogen in its refineries. The company has announced a target to produce green hydrogen at US$1/kg[14] by 2030.

Torrent Power plans to integrate approximately 2.5%[15] of green hydrogen into its City Gas Distribution (CGD) network. In addition, the company is targeting commercial and industrial customers for green hydrogen supply.

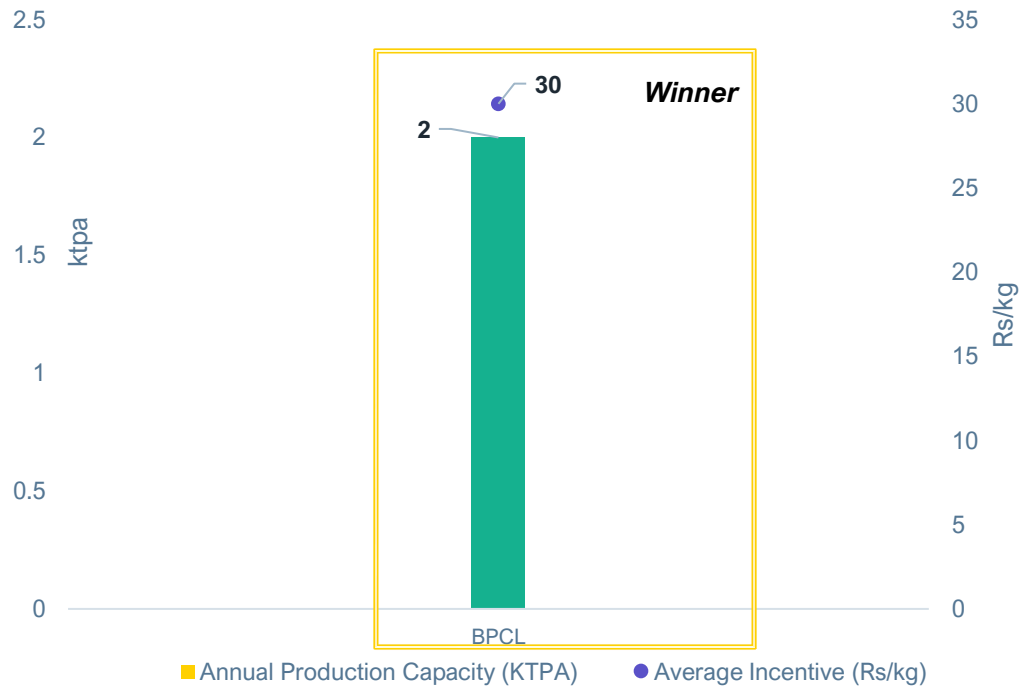
[14] Times of India. Reliance industries eyes green hydrogen in 2 years. August 2023.
[15] Business line. Torrent gas starts blending green hydrogen for CGD network. July 2023.

ACME Group agreed with Tata Steel Special Economic Zone Ltd to set up a green hydrogen and ammonia project at the Gopalpur Industrial Park in Odisha.[16] ACME is already operating an integrated pilot project for a green hydrogen and green ammonia plant in Bikaner, Rajasthan, sourcing power from a 5MW solar plant.

Similarly, JSW's bid submission could be strategically linked to supplying green hydrogen to the Direct Reduced Iron (DRI) unit in JSW's Vijayanagar steel plant.[17] The company has already obtained approval from the Government of Karnataka to establish a 200,000MTPA green hydrogen plant and a 1MMTPA green ammonia plant.

United Phosphorus Limited (UPL) and CESC secured capacities without quoting any incentives. However, their strategy remains to be seen as they do not possess established end-use capacities for green hydrogen or connections to third parties.

Figure 10: Bucket 2 winners of green hydrogen production incentives



Source: SECI; JMK Research

Bharat Petroleum (BPCL) is the sole participant expressing interest in the biomass-based pathway (Bucket 2) for green hydrogen production. The company has secured the quoted capacity of 2,000MTPA, with an average three-year incentive of Rs30/kg (US¢36/kg). BPCL is actively sourcing

[16] ACME. ACME sign land agreement for green hydrogen in Odisha. August 2023.
[17] PV Magazine. JSW steel to use green hydrogen for steelmaking at Vijayanagar plant. July 2023.

Compressed Biogas (CBG) from private players and is establishing greenfield CBG production facilities close to its refineries. Leveraging biogas for green hydrogen production represents a cost-effective and promising technology.

The weighted average incentive demanded by various successful bidders is about Rs24/kg (US$0.29/kg). The incentives are expected to reduce the cost of green hydrogen production but with the support of other waivers.

As per a NITI Aayog report, the levellised cost of green hydrogen (LCOH) in India will most likely reduce to Rs260-310/kg[18] (US$3.17-3.78/kg) from the current price of Rs380-520/kg (US$4.63-6.34/kg), assuming following scenarios:

- Renewable energy makes up 60-70%[19] of the production cost of green hydrogen. The levellised cost of electricity needs to be consistent and cheap for the rest of the project's lifetime, assuming, in this case, the cost of round-the-clock renewable electricity is delivered at Rs3.6/kWh (US$0.04/kWh).
- Complete waiver of interstate transmission system (ISTS) open access charges, such as cross subsidy surcharge and additional surcharges
- Complete waiver of distribution and transmission charges
- Lowering the GST rate for hydrogen. For instance, 5%[20] makes it more affordable for sectors such as transportation and industry.

With these incentives applied in the first three years, the LCOH for successful GHPs is anticipated to decline, contributing to a competitive cost in parity with grey hydrogen, especially for international markets.

Issues and Challenges

Major Concerns Foreseen by Electrolyser Manufacturers

Bankability and Anchor Demand Concerns

In line with the RFS provisions, electrolyser manufacturers are responsible for marketing their electrolyser and securing anchor customers for their facility. Failure to secure anchor demand affects the project's bankability and hampers the ability to secure attractive financing. Additionally, the electrolyser manufacturer must maintain at least half of sales for domestic customers, including

[18] NITI Aayog. Harnessing Green Hydrogen. June 2022. Page 29.
[19] EnergyWorld. How India can unlock the potential of Green Hydrogen. August 2023.
[20] Mint. Green energy sector pitches for GST cut. January 2024.

affiliates or group companies establishing green hydrogen production projects. The challenge lies in finalising sale agreements and securing orders within the stipulated time, particularly during the project construction. Failure to achieve sales equivalent to the awarded manufacturing capacity will reduce the final incentives applicable for that year.

Technology Selection

A significant concern is the need for a distinct category for other technologies in the bid evaluation process. With high localisation content being a critical selection factor, the favourability towards alkaline technology, which is comparatively easier to localise, may result in India missing out on establishing a manufacturing base for other competitive technologies.

> **With high localisation content being a critical selection factor, the favourability towards alkaline technology, which is comparatively easier to localise, may result in India missing out on establishing a manufacturing base for other competitive technologies.**

For example, on 7 February 2024, BPCL introduced India's first indigenous alkaline electrolyser prototype, developed in collaboration with Bhabha Atomic Research Centre (BARC).

Impact of Net Worth and Financial Guarantees on Smaller Companies

The RFS stipulates a minimum net worth requirement of Rs10 million/MW (US$120,000) and a performance guarantee of Rs1.48 million/MW (US$18,048/MW). With a minimum bid capacity of 100MW under Bucket 1, bidders must demonstrate a net worth and performance bank guarantee of Rs1 billion (US$12 million) and Rs148 million (US$1.8 million), respectively.

This poses a significant obstacle for micro, small and medium enterprises (MSMEs); the criteria caps their investment in plant and machinery at Rs500 million (US$6 million). This stringent requirement is a deterrent for many manufacturing enterprises and start-ups looking to enter the electrolyser manufacturing sector. Additionally, the financial burden imposed by the bank guarantee requirement, especially for entities without established credit lines, further complicates their participation in the bidding process.

Technology Collaboration Missing from RFS

A notable gap in the RFS document is the absence of specifications regarding mandatory technology collaboration for selected bidders in Bucket 1 before the issuance of the LOA. This omission may allow participants lacking an understanding of the international market to enter, creating an uneven playing field. Such a scenario significantly disadvantages serious players who have established technology tie-ups with international partners.

Case for Overachievement by the Bidder

Under the RFS, bidders must submit their optimal LVA and SEC figures, which are crucial for bid evaluation. Incentives are structured around these quoted LVA and SEC values, with a provision stipulating that if a bidder or manufacturer falls short of the quoted benchmarks, SECI will reduce the incentives for that year. However, the RFS needs a provision that motivates manufacturers to exceed the quoted LVA and SEC values, thus creating the potential for overachievement.

Electrolyser Sales to Affiliate Companies

Some bidders have raised concerns regarding manufacturers selling electrolysers to affiliated companies. Larger entities selling electrolysers to their own group or affiliate companies involved in green hydrogen projects might use notional purchase orders to claim incentives. There may also be a risk of resale of electrolysers from one company to another within the same group. Furthermore, when selling to affiliate companies, manufacturers might have the opportunity to inflate the sales value of electrolysers, potentially aiding them in meeting the LVA requirements outlined in the RFS provisions.

Major Concerns Foreseen by Green Hydrogen Producers

Bankability

Some bidders have expressed concerns that SECI should have played a bigger role in aggregating green hydrogen demand, particularly from PSUs, similar to practices in solar and wind auctions. The bidders believe facilitating anchor demand from PSUs would enhance project bankability, expedite the FID process, and improve project financing.

Inadequate Incentives

Levellised cost of Hydrogen (LCOH) in India ranges between Rs380-520/kg (US$4.5-6.3/kg).[21] The average of the incentives for the initial three years amount to Rs40/kg (US¢48/kg). While these incentives are a positive step, they are considered insufficient compared with overall production costs and incentives offered in other countries. For example, the Inflation Reduction Act (IRA) in the US offers production tax credits for up to US$3/kg[22] (~Rs250/kg) of hydrogen produced over 10 years for clean hydrogen projects. Similarly, the European Hydrogen Bank proposes a fixed premium per kilogram of renewable hydrogen produced, capped at €4.5/kg[23] (~Rs400/kg) for a 10-year contract duration.

[21] NITI Aayog. Harnessing Green Hydrogen. June 2022.
[22] US Department of Energy. Financial Incentives for Hydrogen and Fuel Cell Projects. 2022.
[23] European Commission. Commission launches first European Hydrogen Bank auction. November 2023.

This premium/incentive is intended to offset the difference between production costs and consumer prices, especially in a market where grey hydrogen remains less expensive to produce. Considering the nascent stage of green hydrogen in India, bidders believe that higher incentives are essential to establish larger plants, benefit from economies of scale and gain a competitive edge, especially against global producers enjoying substantial incentives.

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Aggressive Timeline for Green Hydrogen Derivative Projects

Establishing green hydrogen production facilities involves multiple stakeholders and risks, potentially causing project delays. The bidders urge flexibility in changing the commissioning date after due diligence by SECI/MNRE. Additionally, derivative projects will have different commissioning dates due to associated complexities, and bidders have requested SECI consider requests for extension on a case-by-case basis.

Capacity Constraints for Different End-use Segments

The stipulated minimum bid capacity of 10,000 tonnes a year (TPA) poses challenges for smaller end-use projects with hydrogen requirements ranging from 800-1,500TPA, especially in steel, refinery and fertiliser industries. Bidders propose that a single large project with a substantial award capacity may not be a viable business case if the total capacity is commissioned at one location. Therefore, GHPs prefer setting up production plants (of different capacities) for multiple end products, such as green ammonia, green methanol, sustainable aviation fuel, or other derivatives, with cumulative capacities equal to those awarded under LOA.

Regulatory Uncertainties

Issues around Green Hydrogen Definition

European Parliament Research Service (EPRS) EU rules for Renewable Hydrogen whitepaper says that electricity sourced from the grid can be deemed fully renewable if it fulfils specific criteria, including being generated by dedicated new renewable energy capacity (additionality), is in the same location as hydrogen production (deliverability), and ensuring temporal alignment between renewable electricity generation and hydrogen production (temporal matching). Indian regulations lack clear guidelines on these criteria. Internationally, the EU has established some requirements, with the US also contemplating similar measures. Any regulation disparities will hinder global comparisons of Indian projects and affect market access (exports) for Indian hydrogen not meeting these criteria.

Safety Compliance and Technological Adaptation

As safety regulations become more stringent to address potential risks in hydrogen production, storage and transportation, bidders (electrolyser manufacturers and GHPs) face increased pressure to invest in advanced safety measures and technologies. Simultaneously, the industry's evolving standards and technological advancements necessitate continuous adaptation. This ongoing adjustment to meet updated specifications may incur additional costs, challenging bidders to balance compliance and maintaining competitiveness in the dynamic market.

Changes in International Trade Policies

Changes in international trade policies, geopolitical shifts, and trade tensions pose significant risks to electrolyser manufacturing and GHPs' supply chain. These uncertainties may impact the import/export of crucial raw materials, components, and final products, leading to fluctuations in availability and costs. Electrolyser manufacturers must navigate this complex global trade landscape to ensure supply chain resilience and cost-effectiveness.

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Recently, electrolyser manufacturers in overseas markets have scaled back their ambitions due to difficulties securing definite orders for them. Although they've received several purchase orders, these commitments appear less certain than initially indicated. The root cause lies in persistent delays affecting green hydrogen projects, with policy uncertainties in Europe and the US and sluggish demand in China contributing to the challenges.

Likewise, global buyers, particularly those in the EU and South East Asia, view India as a critical market for sourcing Green Ammonia. To cater to their requirements, Indian producers must ensure competitive pricing compared to international counterparts from regions like the Middle East, Australia, North Africa, or South America. The success of Indian GHPs is sensitive to shifts in international policies or subsidies in other markets, influencing their competitiveness and market position.

Hydrogen Infrastructure and Supply Chain Bottlenecks

The need for robust facilities for hydrogen production, storage, transportation and last-leg distribution networks presents a formidable obstacle to the integration of hydrogen energy into mainstream use. This, in turn, will affect the sales of electrolysers and green hydrogen in the domestic market. Bridging the hydrogen investment gap requires a dual focus: substantial investment in research and development to lower production costs and a parallel emphasis on addressing infrastructure development.

The hydrogen supply chain, covering production, transport, storage and use, demands specialised facilities located strategically with access to water, renewable electricity and local transportation networks. Distribution channels, such as shipping and pipelines, require significant infrastructure investment. Shipping hydrogen requires ports, vessels and trucks equipped to transport the highly volatile gas. Blending hydrogen beyond a certain percentage into the fossil gas network presents a challenge due to the need to modify existing infrastructure. Fossil gas facilities, including pipelines and storage, are designed for methane, and hydrogen’s distinct physical properties require adjustments for safe and efficient blending.

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Establishing hydrogen fuelling stations in high-demand strategic areas is crucial for utilisation. Hydrogen transmission and distribution infrastructure development encounters hurdles related to high-pressure handling, cost implications, technology readiness and apprehensions about leaking and durability.

The demanding high-pressure requirements, especially for hydrogen transportation exceeding 700bar (10,153psi), entail specialised compressors and substantial storage containers, adding complexity and cost considerations.

Barriers to International Markets

When juxtaposed with products from Chinese and European manufacturers, the competitiveness of domestically manufactured electrolysers from India poses a critical challenge, both in technical capabilities and economic viability. Concerns arise regarding India’s ability to access global markets, particularly among overseas developers accustomed to sourcing equipment from established and reliable foreign Original Equipment Manufacturers (OEMs). Strategic international collaboration and enhanced market access are imperative to ensure the successful positioning and acceptance of Indian electrolysers globally.

Globally, there is an optimistic outlook for a significant reduction in the cost of green hydrogen in the future, replicating the trajectory seen in the solar industry over the past decade. This anticipated decline is attributed to the scaling of electrolyser manufacturing and the decreasing costs of renewable electricity. However, according to a few electrolyser manufacturers, the short-term reality may not align with these optimistic projections. The gap between the costs of green hydrogen and conventional grey hydrogen might limit the widespread adoption of green hydrogen. Consequently, this gap could restrict the global market size for electrolysers in the short term.

Recommendations

SECI and MNRE should be commended for taking the initial steps to establish this new sector and introducing financially feasible interventions. Nevertheless, there is a long way to go to ensure India's green hydrogen's competitiveness and substantial advantages. Policymakers must address specific interventions to propel progress in this direction.

Bidders (electrolyser manufacturers and GHPs) have shared their inputs with SECI on the validating commissioning of the capacity, verification methodology, testing and commissioning procedures. A quick response and action from SECI are critical to bring technical clarity to the bidders. This will help the winning bidder prepare and ensure they meet the conditions to receive timely incentives.

Strengthening Regulatory Framework for the Industry

A clear set of emission standards is essential to provide a robust foundation for the growth of India’s green hydrogen industry while aligning with global efforts to mitigate climate change. A detailed methodology needs to be included, which is essential to streamline processes, instil confidence and promote accountability within the green hydrogen sector.

> **A clear set of emission standards is essential to provide a robust foundation for the growth of India’s green hydrogen industry while aligning with global efforts to mitigate climate change.**

To this end, on 18 August 2023, the MNRE issued a memorandum explicitly defining green hydrogen. It establishes specific criteria for acceptable greenhouse gas (GHG) emissions throughout production.

The MNRE’s definition of green hydrogen underscores that GHG emissions from various production stages, including water treatment, electrolysis, gas purification and drying, and hydrogen compression, must not exceed 2kg of carbon dioxide equivalent per kilogram of hydrogen (2kg CO_2e/kg hydrogen).[24]

This definition framework needs enhancement with globally accepted definitions for critical aspects such as how green hydrogen is produced (additionality), its origin (deliverability) and timing (temporal matching).

The improved regulations after incorporating these criteria, along with the guidelines for permissible limits and timelines for implementation, will certify Indian hydrogen to global standards. This will attract financing for Indian projects and create export opportunities for green hydrogen and its derivatives.

[24] MNRE. Office memorandum Green hydrogen standard for India. August 2023.

Enhanced Funding for Research and Development

The US Inflation Reduction Act (IRA) offers significant incentives for green hydrogen projects, providing 10-year production tax credits of up to US$3/kg of hydrogen produced, with no limit on the number of eligible projects. However, the Congressional Budget Office estimates the 10-year cost of the IRA hydrogen production subsidies to be US$13.2 billion[25] by 2031. In the EU, the inaugural auction under the European Hydrogen Bank (EHB) programme allocates a total of €800 million (US$866 million), forming part of the larger €3 billion[26] (US$3.25 billion) initiative.

> **We strongly recommended that another tranche of funding for 2026-2030 be announced, extending support to encourage sustainable growth and innovation in the sector.**

The National Green Hydrogen Mission has proposed an outlay of Rs14.66 billion (US$179 million) for green hydrogen pilot projects and an additional Rs4billion (US$49 million) for R&D projects. Of the funds allocated for pilot projects and R&D, Rs10.11 billion (US$123 million) is earmarked for the period up to the fiscal year (FY) 2025-26. This outlay is relatively modest given the nascent stage of the industry in India and comparable initiatives in the EU, US, and Australia. Therefore, we strongly recommended that another tranche of funding for 2026-2030 be announced, extending support to encourage sustainable growth and innovation in the sector.

It is to be noted that the recent Union Budget for 2024-25 has allocated Rs6 billion[27] (US$72 million) for the NGHM, more than double the previous year's allocation of Rs2.97 billion (US$35 million).

Adopting International Standards for Hydrogen Ecosystem

India's ambitious green hydrogen mission, aiming for substantial production by 2030, demands a conducive ecosystem and harmonised standards. Urgent, targeted actions are imperative to adopt necessary standards, particularly in critical areas such as hydrogen production, storage, transport, applications and refuelling. The ultimate goal of integrating India into the global hydrogen market can be achieved by establishing comprehensive and internationally aligned safety standards.

[25] US Congressional Budget Office. Estimated Budgetary Effects of H.R. 5376, the Inflation Reduction Act of 2022. August 2022. Page 8.
[26] European Parliament Research Service. European hydrogen bank. December 2023. Page 1.
[27] India Budget. Notes on Demands for Grants, 2024-2025. February 2024. Page 252.

Facilitating Global Collaboration for Technology Transfer

Green hydrogen and its derivatives from India may possess a competitive edge on the global stage, thanks to the country’s cost advantages associated with renewable electricity generation. Indian entities have actively engaged in international tenders, particularly in European markets, to export green hydrogen and its derivatives.

To further enhance this global presence, the Indian government is encouraged to identify key markets with significant import requirements for green hydrogen. Initiating government-to-government (G2G) discussions with these nations can pave the way for adopting cutting-edge electrolyser manufacturing, storage and distribution technologies. Indian policymakers and bureaucrats need capacity building and training from international players to accelerate progress in the green hydrogen industry. This strategic collaboration aims to capitalise on India’s strengths and contribute to the global green energy landscape.

Annexure

Table 3: Participants in the SECI RFS for electrolyser manufacturing

S. No.	Bidder	Manufacturing Capacity (MWpa)		Company HQ Location	Company Background/ Business Interests
		Bucket 1	Bucket 2		
1	Hild Electric Private Limited	100	-	Chennai	Mid-size solar engineering, procurement and construction (EPC) company with diversified business interests.
2	Ohmium Operations Private Limited	137	-	Bangalore	US-based technology company backed by Indian R&D centres and foreign investors.
3	John Cockerill Greenko Hydrogen Solutions Private Limited	300	-	Hyderabad	JV of Greenko Group, a leading Indian cleantech company, and John Cockerill, a Belgium-based leading designer and manufacturer of high-capacity alkaline electrolysers.
4	Waaree Energies Limited	300	-	Mumbai	One of the largest manufacturers of solar photovoltaic (PV) modules in India, with 12GW PV manufacturing capacity.
5	Jindal India Limited	300	-	Kolkata	One of the largest galvanised steel sheet and coil manufacturers.
6	Adani New Industries Limited	300	300	Ahmedabad	A subsidiary of Adani Enterprises that undertakes green hydrogen projects, manufacturing wind turbines, solar module batteries and other components.
7	L&T Electrolysers Limited	300	-	Mumbai	In 2023, L&T signed an electrolyser manufacturing agreement with French tech firm McPhy Energy for a long-term partnership.
8	Avaada Electrolyser Private Limited	300	-	Noida	A subsidiary of Avaada and a leading solar module manufacturer and developer of clean energy projects.
9	Green H2 Network India Private Limited	100	-	Mumbai	Diversified company in electronics, software solutions and transport.
10	Reliance Electrolyser Manufacturing Limited	300	-	Mumbai	RIL group company. RIL has also partnered with Stiesdal of Denmark to manufacture hydrogen electrolysers.
11	Advait Infratech Limited	100	-	Ahmedabad	Turnkey EPC in telecoms, transmission and green energy project developer. Awarded a project by THDC in March 2023 to set up a 300KW electrolyser and 70KW fuel cell.

12	ACME Cleantech Solutions Private Limited	100	-	Gurugram	Leader in developing, constructing and operating large-scale solar power projects. It also operates an integrated Green H2 project in Rajasthan, powered by 5MW solar power.
13	Oriana Power Limited	100	-	New Delhi	Solar and BESS project EPC and developer.
14	Matrix Gas and Renewables Limited	105	-	Ahmedabad	Gas marketing company, promoted by Gensol Engineering, which specialises in solar EPC, operations and maintenance (O&M) services, and electric mobility sectors.
15	HHP Seven Private Limited	100	-	Gurugram	A subsidiary of Hygenco established in 2023.
16	HomiHydrogen Private Limited	-	101.5	Pune	JV between h2e Power Systems Private Limited, BlueBasic AMA Engineering (H2energy, Italy) and Greenstat Hydrogen India.
17	Bharat Heavy Electricals Limited	-	10	New Delhi	Largest government-owned power generation equipment manufacturer.
18	Newtrace Private Limited	-	6	Bangalore	A start-up founded by technologists in 2020.
19	C. Doctor & Company Private Limited	-	10	Ahmedabad	Mechanical heat-exchanging equipment and vessel manufacturer.
20	Pratishna Engineers Limited	-	19	Mumbai	Manufacturer and supplier of injection moulding machines.
21	LiveHy Energy Private Limited	-	40	Bangalore	Start-up established in 2023.
	Total capacity	**2942**	**486.5**		

Source: SECI; Company Websites; JMK Research

Table 4: Participants in the SECI RFS for green hydrogen production

S. No.	Bidder	Production Capacity (MTPA)	Company HQ Location	Company Background/ Business Interests
1	UPL Limited	10,000	Mumbai	Agro-chemicals company. In 2022, it acquired a 26% stake in Clean Max Kratos Pvt Ltd.
2	CESC Projects Limited	10,500	Kolkata	Independent power producer (IPP) and power distribution utility with aggressive plans to expand its renewable energy portfolio.
3	Reliance Green Hydrogen and Green Chemicals Limited	90,000	Mumbai	RIL subsidiary was established in 2023. Plans to set up renewable energy and green hydrogen plants in Tamil Nadu.
4	Welspun New Energy Limited	20,000	New Delhi	IPP and Infrastructure developer. Plans to export green hydrogen from Gujarat.
5	HHP Two Private Limited	75,000	New Delhi	A subsidiary of Hygenco established in 2023.
6	Torrent Power Limited	18,000	Ahmedabad	Wide presence in the electricity value chain. In 2023, it announced plans to blend ~2.5% green hydrogen into its CGD network.
7	ACME Cleantech Solutions Private Limited	90,000	Bengaluru	Renewable energy developer and operator with multiple MoUs and agreements with state governments and private players to set up green hydrogen production facilities.
8	Greenko ZeroC Private Limited	90,000	Hyderabad	One of the largest renewable energy developers in India. It signed a term sheet with NTPC Green Energy to procure renewable power for Kakinada's upcoming green ammonia plant.
9	JSW Neo Energy Limited	10,000	Mumbai	Subsidiary of JSW Group that plans to set up a 3,800TPA green hydrogen plant in Karnataka.
10	Sembcorp Green Hydrogen India Private Limited	36,000	New Delhi	Incorporated in 2023, Sembcorp is collaborating with two Japanese companies to produce green ammonia for export to Japan.
11	Avaada GreenH2 Private Limited	90,000	Mumbai	Green hydrogen arm of Avaada Group. It signed an agreement with TSSEZL for a 0.5MTPA green hydrogen/ammonia production facility at Gopalpur.
12	GH4India Private Limited	10,000	Mumbai	JV of L&T, ReNew and Indian Oil established in 2023.
13	Bharat Petroleum Corporation Limited	2,000	Mumbai	Oil PSU is working with several entities to develop an electrolyser and green hydrogen production facility.

Source: SECI; Company Websites; JMK Research

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The Institute for Energy Economics and Financial Analysis conducts research and analyses on financial and economic issues related to energy and the environment. The Institute's mission is to accelerate the transition to a diverse, sustainable, and profitable energy economy. www.ieefa.org

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