FUELING THE FUTURE:

IGNITING INDIA'S GREEN HYDROGEN AMBITIONS

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Disclaimer

FOREWORD

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The transition to green hydrogen is not merely an option but a necessity for addressing climate change while advancing our economic development.This insightful ICF publication **Fueling the Future: Igniting India's Green Hydrogen Ambitions**, prepared in collaboration with the Ministry of New and Renewable Energy (MNRE), addresses one of the most pressing challenges in the green hydrogen sector today, the commercial viability of green hydrogen production.

In this publication, ICF aims to provide a detailed analysis of the current landscape of green hydrogen, focusing on the critical price disparity between green hydrogen and grey hydrogen. Through a rigorous green hydrogen cost estimation model, the report offers a comprehensive evaluation of existing incentives and their effectiveness in bridging this gap. By scrutinizing the existing incentives and policies, the report illuminates the path towards making green hydrogen a viable and competitive alternative.

This comprehensive report, a first of its kind for India by ICF, provides a timely and thorough analysis of how green hydrogen could transform our energy landscape, while also addressing the challenges associated with its commercial adoption. The analysis presented underscores the necessity of continued and enhanced government support to drive down costs and accelerate adoption.

The recommendations outlined are pivotal for bolstering the green hydrogen sector. They offer actionable strategies that align with our national energy goals, positioning India to lead in the global transition towards sustainable energy. As we stand at the threshold of this transformative era, it is essential to seize the moment and focus on impactful measures that will drive progress and foster economic growth.

This report will serve as a crucial resource for policymakers, industry stakeholders, and advocates of green hydrogen. Its insights will serve as a foundation for informed decision-making and strategic planning as we work towards realizing our shared vision of a sustainable and economically robust energy future.

Warm regards,

Gurpreet Chugh
Managing Director, ICF Consulting India Private Limited

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LIST OF ABBREVIATIONS

ASC	Additional Surcharge
CCfD	Carbon Contracts for Difference
CCS	Carbon, Capture and Storage
CfD	Contracts for Difference
COP	Conference of Parties
CSS	Cross Subsidy Surcharge
DISCOM	Distribution Company
EC	European Commission
eFCI	Estimated Fixed Capital Investment.
EPF	Employee Provident Fund
ESI	Employees State Insurance
ETS	Emissions Trading System
FCEV	Fuel Cell Electric Vehicle
GEOA	Green Energy Open Access
GOI	Government of India
GW	Gigawatt

LIST OF ABBREVIATIONS

H2	Hydrogen
HRS	Hydrogen Refuelling Station
IRA	Inflation Reduction Act
kTPA	Kilo Tonne Per Annum
MSME	Micro, Small & Medium Enterprises
MT	Metric Tonne
MTPA	Million Tonne Per Annum
MW	Megawatt
NDC	Nationally Determined Contribution
NGHM	National Green Hydrogen Mission
PLI	Production Linked Incentive
R&D	Research and Development
RD&D	Research, Development, and Demonstration
RE	Renewable Energy
RfS	Request for Selection
SGST	State Goods and Services Tax
SIGHT	Strategic Intervention for Green Hydrogen
STU	State Transmission Utilities
TSSEZL	Tata Steel Special Economic Zone Limited
VAT	Value Added Tax


H2

Executive **Summary**

Executive Summary

In January 2023, the Ministry of New and Renewable Energy (MNRE) introduced the National Green Hydrogen Mission, setting a goal of achieving an annual production of 5 million metric tonnes of green hydrogen by 2030. This initiative reflects India's strategic commitment to advancing a low-carbon economy and acknowledges the significant role that green hydrogen can play in this transition.

To support the successful realization of the National Green Hydrogen Mission, it is essential to address the economic challenges currently associated with green hydrogen production. The cost of producing green hydrogen remains a key obstacle to its broader adoption. Under direction from MNRE, ICF has developed a detailed economic model to estimate the cost of green hydrogen production in India and assess the impact of various central and state-level incentives on these costs. The results of the model have been presented in this report.

The report also highlights key factors affecting both capital and operating expenses and identifies the incentives that could be most effective in reducing green hydrogen production costs. During the production of this report, ICF has engaged with key stakeholders in the green hydrogen ecosystem through targeted consultations which helped in identifying practical challenges related to green hydrogen production. These insights were crucial in formulating recommendations presented in this report such that they align with industry needs and support the overall development of a robust green hydrogen ecosystem.

The key conclusions drawn in the report are:

1. **Economies of Scale:** Increasing the scale of green hydrogen production can significantly reduce costs. For instance, expanding production capacity from 10 MW to 100 MW at single location could lower the levelized cost of hydrogen (LCOH) by INR 20/kg. Centralizing production in large-scale units located in industrial hubs can further minimize capital expenditure.

2. **Electricity Costs:** Electricity constitutes approximately 65%-75% of green hydrogen production costs. Incentives to reduce electricity costs, coupled with cost-competitive round-the-clock renewable energy power, can substantially decrease hydrogen production expenses. Optimizing and aligning electrolyzer operation with solar generation hours and evaluating storage solutions will be critical in reducing overall costs for green hydrogen and derivatives.

3. **Investment Incentives:** Loan concessions, such as reduced interest rates and flexible repayment terms, can attract investment and reduce green hydrogen costs. For example, a 2% concession on commercial loans can reduce the cost of green hydrogen by approximately INR 16-18 per kg.

4. **State-Level Incentives:** States like Uttar Pradesh and Maharashtra offer capital subsidies that incentivize early adoption. Odisha's power incentives, including INR 3/kWh rebates and 20-year exemptions from electricity duty, have brought green hydrogen costs at close to parity with grey hydrogen costs.

5. **Carbon Pricing:** Implementing carbon pricing and enabling green hydrogen projects to monetize carbon credits could narrow the cost gap between green and grey hydrogen. Potential reductions in costs range from INR 7-80/kg depending on carbon price scenarios.

Recommendations: The report provides certain key recommendations to reduce the production costs for green hydrogen and increase adoption

1. **Detailed Assessment at National Level:** A comprehensive national level analysis is crucial for optimizing green hydrogen production costs and enhancing efficiency. Key focus of this analysis may include evaluation of banking mechanisms, optimizing electrolyzer use along with solar hours, integrating energy storage, and integrating solar-wind systems.

2. **Development of Green Hydrogen Production Cost Tool:** A real-time cost assessment tool will help investors by providing insights into regional cost variations and incentives. It will aid in designing targeted incentives and accelerating green hydrogen adoption.

3. **Green hydrogen demand creation via sector-specific targets / Green Procurement:** Hydrogen blending mandates in sectors like refining and ammonia can boost green hydrogen demand. Green procurement policies across industries can further drive demand and support sustainability.

4. **Demonstration Projects:** Green hydrogen demonstration projects can showcase new technology, business models and other benefits and encourage wider adoption.

5. **Ensuring Large-scale Green Hydrogen Production:** Establishing large-scale green hydrogen plants can significantly reduce costs through economies of scale and advanced

technologies. Scaling up electrolyzer capacity from 10 MW to 100 MW and then 1 GW can lower production costs substantially.

6. **Hydrogen Hubs to hydrogen distribution zones:** Hydrogen hubs centralize production and distribution, improving supply chain efficiency. Aggregating additional local demand from industries in the region of hydrogen hub and developing local hydrogen distribution zones connecting supply with demand will foster further growth.
7. **Relaxation on Import Taxes:** Reducing import duties on essential components like electrolyzers can lower production costs and foster investment in green hydrogen. This policy will make green hydrogen more viable and support innovation.
8. **Carbon Markets:** Activating a robust carbon market in India can provide additional monetization options for green hydrogen projects thereby improving viability for developers. Flexibility in carbon credit retention can create additional revenue streams and attract investment.
9. **Financing Support:** A comprehensive financing framework, including low-interest loans and green bonds, will ease funding for green hydrogen projects. This support will drive innovation and growth in the sector.
10. **Development of Port Infrastructure:** Upgrading ports for green hydrogen export is essential for handling safe storage and transportation. Enhancing strategic ports like Kandla, Paradip, and Visakhapatnam will strengthen India's position in the global market.

Preface

Preface

The looming climate crisis poses a serious threat to humanity. The mounting evidence about the perils of climate change has led to a global rise in commitment to cut greenhouse gas emissions and embrace cleaner energy sources. Hydrogen is now considered an essential fuel for achieving net-zero emissions through decarbonization. Various governments have announced policies and incentives to foster a robust hydrogen-based economy. As a result, the global clean hydrogen market size is projected to potentially expand to USD 112 billion by 2030[1].

In India, according to the latest reports, the demand for hydrogen driven by captive consumption within refineries and fertilizer units amounts to approximately 6 MTPA[2]. Since black / brown hydrogen is cheaper than green hydrogen, 95 per cent of this total demand is met by fossil fuel-derived hydrogen[3]. The National Green Hydrogen Mission, approved by the Indian cabinet in 2023, aims to increase the country's green hydrogen production capacity to at least 5 MTPA by 2030 and has the potential to increase production to 10 MMT per year, if export markets grow. Cost reductions in key technologies, accompanied by the growing imperative to decarbonize in the energy sector, may further drive the demand up to around 28 MTPA by 2050[4]. Achieving net-zero target by 2070 could require around **40 MTPA of green hydrogen, a multi-fold increase over today's production capacity**.[5]

However, achieving these targets necessitates a significant reduction in the cost of green hydrogen to make it commercially viable. While the existing incentives from the SIGHT program under the National Green Hydrogen Mission and various state-level initiatives have bolstered production, there remains an urgent need to explore and assess specific ideas for cost reduction, to make green hydrogen economically competitive.

This report presents a comprehensive analysis of the current production costs of green hydrogen, highlighting the key components that contribute to these costs. It involves evaluating the existing incentives and determining which cost elements can be reduced through targeted incentives and support.

Green hydrogen focus in India

1

1 Green hydrogen focus in India

1.1 Focus of Indian government on Green H2

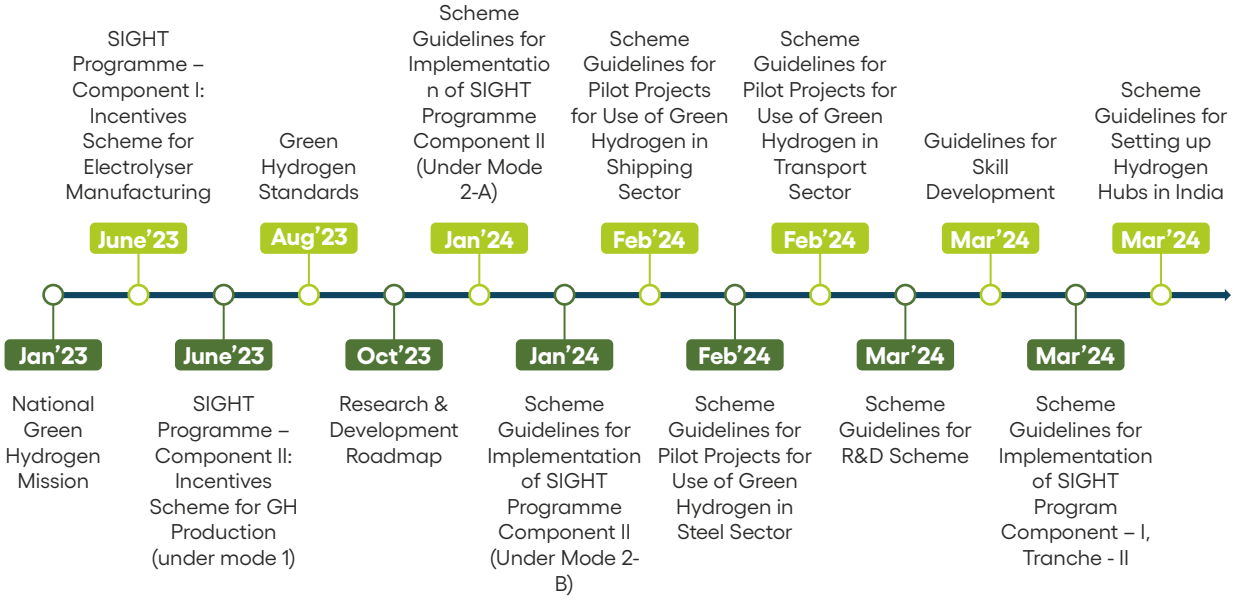
India signed the Paris Agreement in 2016 and announced its first Nationally Determined Contribution (NDC) targets to reduce overall GHG emissions. Subsequently, at the 26th Conference of Parties (COP-26) at Glasgow in 2022, updated NDCs were announced, targeting a 45% reduction emissions intensity of India's GDP by 2030. India also committed to reach net zero by 2070 and increase its non-fossil energy capacity to 500 GW by 2030, meeting 50% of the energy demand with renewable energy. Further, it also committed to reduce 1 billion tonnes of projected emissions from 2022 to 2030. The key elements of India's revised NDCs are illustrated in Figure 1.1.

Figure 1.1 : India's NDCs

National statement at COP26 and 2022 NDC	
Renewable Energy Generation Capacity	50% energy requirement by 2030 (~500 GW)
Emission intensity wrt GDP relative to 2005	45% by 2030
Additional carbon sink through forestry	2.5-3 billion metric tons of Co_2 equivalent
Reduced total projected Carbon emissions	1 billion tons from 2022 till 2030
Net- zero goal	Net zero by 2070

The government of India (GOI), aware of escalating climate concerns, is keen to ensure sustainable development. India's commitment towards a sustainable future is evident from its NDC (Nationally Determined Contribution) goals, and its inclination to adopt green hydrogen as a fuel for the next generation. Green Hydrogen, by reducing emissions in hard-to abate sectors such as steel, fertilizers, refinery, cement & mobility, is the key to fulfilling India's energy security needs while simultaneously working towards Net-Zero. Some of the major advancements by the government of India in the green hydrogen sector are discussed in the following section.

Figure 1.2: Major Green Hydrogen Sector Announcements



The National Green Hydrogen Mission, announced by the government, has significantly advanced the green hydrogen sector in India. This, along with several other government initiatives elaborated below, demonstrates government's commitment to promote and boost this growing sector:

- The Ministry of New and Renewable Energy (MNRE) has clearly defined green hydrogen as hydrogen produced from renewable energy sources, including but not limited to, electrolysis or biomass conversion, with stringent emission limits. Specifically, carbon emissions associated with the production process must not exceed 2 kilograms of carbon dioxide equivalent per kilogram of hydrogen produced. This emissions cap is calculated as an average over the preceding 12 months to ensure continuous compliance with environmental standards.
- To support the growth of the green hydrogen ecosystem, comprehensive standards and regulations have been implemented, with additional guidelines under development. These regulations ensure the quality and safety of green hydrogen, while also streamlining production, storage, and usage processes. Under the supervision of the MNRE, central and state government entities are cooperating to implement the objectives outlined in the Green Hydrogen Mission.
- To further encourage industry participation, several pilot project schemes have been introduced, particularly in sectors such as shipping, steel, and mobility. Additionally, the Production Linked Incentive (PLI) schemes, included in the Make in India initiative, aim to ramp up the production of electrolyzers and green hydrogen. By January 2024, contracts were awarded to eight companies to establish a total electrolyzer manufacturing capacity of 1,500 MW per annum and to ten companies to produce 412,000 metric tonnes per annum of green hydrogen.

- India's strategic advantage in the green hydrogen sector is further supported by its extensive coastline, abundant water resources, and numerous ports. These regions are being developed into Green Hydrogen Hubs, which will facilitate large-scale hydrogen production and utilization. To begin with, three ports at Deendayal (Kandla, Gujarat), Paradip (Odisha), and V.O. Chidambaranar (Tuticorin, Tamil Nadu), are being considered for the development of these Green Hydrogen Hubs.

1.2 Benefits of green hydrogen economy in India

India stands at the cusp of a significant energy transformation with the advent of the green hydrogen economy. This shift promises to revolutionize the nation's energy landscape by harnessing the power of renewable resources to produce hydrogen. Moreover, green hydrogen offers a multitude of benefits that extend beyond environmental sustainability. It has the potential to enhance India's energy security by reducing dependence on imported fossil fuel, while stimulating economic growth through new industries and job creation. This section delves into the multifaceted advantages of adopting a green hydrogen economy in India

Enhancing Energy Security and fuel import substitution

India imported around 232.5 million tonnes of crude oil in financial year 2024[6]. By producing green hydrogen domestically, India can reduce its crude oil imports to become more self-reliant, and potentially saving billions in foreign exchange. Domestically produced green hydrogen ensures a stable and sustainable energy supply by reducing reliance on volatile international markets, which is crucial for economic stability and growth.

By adopting green hydrogen, India can significantly reduce imports of ammonia, crude oil, and natural gas. The National Green Hydrogen Mission is targeting a production of 5 million tonnes of green hydrogen annually by 2030. If this target is achieved, it could result in significant import substitution, potentially worth over ₹1 lakh crore (approximately $12 billion) by 2030[7]. Domestically produced green hydrogen can translate to a net energy import savings of $246-$358 billion cumulatively between 2020 and 2050 ($3-$5 billion between 2020 and 2030 alone)[8].

Export Economy - Ammonia

India has the potential to become a leading exporter of green ammonia, by leveraging its vast renewable energy resources. India's growing importance in the global green energy market is demonstrated by its recent agreement to export green ammonia to Japan.[9] This venture can open new markets and boost the economy.

Jobs Creation and Social Upliftment

The green hydrogen sector is expected to create numerous jobs across various skill levels. The National Green Hydrogen Mission aims to create over 600,000 jobs by 2030[10], thus contributing to social upliftment and economic growth. Moreover, the green hydrogen sector will require a diverse range of skills, from engineering and technical expertise to project management and logistics. This necessity to upskill and reskill will facilitate unique opportunities for professional

growth of the existing workforce. Some of the examples of projected job creation from green hydrogen projects are -

1. **NTPC's Green Hydrogen Mobility Project:** The pilot project launched by NTPC in Leh, Ladakh, to produce green hydrogen for fuel cell electric buses, is expected to create around 500 direct and indirect jobs in hydrogen production, transportation, and vehicle maintenance.[11]
2. **GAIL's Green Hydrogen Production Plant:** GAIL (India) Limited is setting up one of India's largest green hydrogen production plants in Madhya Pradesh. It is estimated that the project will generate over 1,000 jobs during the construction phase and around 200 permanent jobs once operational.[12]
3. **Reliance Industries' Green Hydrogen Initiative:** Reliance Industries plans to produce 100 GW of renewable energy, emphasizing on green hydrogen by 2030, thus creating thousands of jobs in renewable energy infrastructure, hydrogen production, and supply chains.[13]

To understand the potential impact in job creation, we can draw parallels with the IT boom in India. The IT sector has been a significant driver of job creation and economic development. For instance, in FY22 alone, the Indian IT services sector created over 500,000 new jobs . This growth was driven by the expansion of IT services and the establishment of global capability centers (GCCs). The IT boom not only created direct employment but also spurred the growth of ancillary industries such as transportation, real estate, and catering. The sector's contribution to India's GDP has been substantial, amounting to 7.5% of GDP in the financial year 2023 . Similarly, the green hydrogen sector is poised to create a ripple effect, generating employment in related industries such as renewable energy, manufacturing, and logistics.

Transition After Coal

Replacing coal with green hydrogen can potentially reduce annual CO2 emissions in India by 50 million tonnes by 2030. While coal-fired power plants emit approximately 820 grams of CO2 per kilowatt-hour of electricity produced, green hydrogen production generates zero emissions when powered by renewable energy sources. Additionally, the National Green Hydrogen Mission in India aims to produce 5 million tonnes of green hydrogen per year by 2030, which could replace nearly 13% of India's total coal based energy production.


H2
H2 HYDROGEN
ZERO EMISSION
CLEAN ENERGY OF THE FUTURE

Centre & State level incentives in India

2

2 Centre & State level incentives in India

2.1 Centre-level Incentives in India

As India has recognized the potential of green hydrogen as an alternative energy source, it has launched several initiatives to promote green hydrogen as a clean energy source, including the National Green Hydrogen Mission. These initiatives aim to promote hydrogen production and utilization across various end-use sectors. Some of these incentives for green hydrogen production have been outlined:

National Green Hydrogen Mission and support mechanisms:

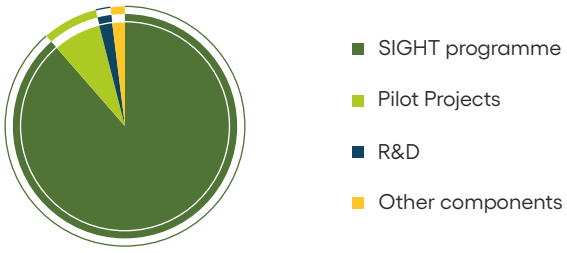
National Green Hydrogen Mission (NGHM)

Government of India notified the National Green Hydrogen Mission on 4th January 2023 with an aim to produce 5 million metric tons of green hydrogen by 2030. To support this vision the government has allocated a budget of INR 19,744 crore for a 6-year period from financial year 2023-24 to financial year 2029-30. The aim of the National Green Hydrogen Mission is to make India a global hub for production, usage and export of green hydrogen and its derivatives. The mission seeks to achieve the following targets.

Figure 2.1: Objectives of NGHM

The Government of India is eager to expand its renewable energy capacity, which is necessary to increase green hydrogen production. This initiative is expected to have a significant impact on the economy by generating millions of jobs, attracting substantial investment, and reducing reliance on imported fossil fuels. A comprehensive approach is required to finance green hydrogen and renewable energy projects. While traditional financing methods remain important, innovative strategies and favorable policies are the key to unlocking the full potential of clean energy investments. In addition to conventional debt and equity options, green financing tools like Green Bonds and Sovereign Loans need to be explored. Collaboration between the public and private sectors is essential to bridge financing gaps and accelerate the shift towards a sustainable future.

Figure 2.2: Outlay of NGHM



The initial outlay for the Mission is Rs. 19,744 crore, including an outlay of Rs. 17,490 crore for the SIGHT programme, Rs. 1,466 crore for pilot projects, Rs. 400 crore for R&D, and Rs. 388 crore towards other Mission components. The following section presents the details of the major component of this mission i.e. SIGHT programme, focusing on its current status.

Strategic Intervention for Green Hydrogen (SIGHT) Program

The SIGHT program is a component of the National Green Hydrogen Mission. It focuses on advancing research and development to drive technological innovations in green hydrogen production. It promotes pilot projects, large-scale demonstrations, and collaborative research efforts. In June 2023, the SIGHT program[14] earmarked ₹17,490 crore for this purpose, of which, ₹13,050 crore was dedicated to incentivizing the production of green hydrogen, while another ₹4,440 crore was allocated specifically for electrolyzer production. These incentives reflect the government's commitment to fostering the growth of green hydrogen technologies. The current status of the scheme is shown in the Figure 2.3.

Figure 2.3: Current Status of NGHM

Electrolyser Manufacturing
Proposed Outlay: Rs. 4440 crores
Scheme guidelines for electrolyzer manufacturing Tranche-I launched on 28th June 2023 and Tranche- II was on 16th March 2024.
Request for Selection (RfS) for electrolyzer manufacturers to establish 1.5 GW annual capacity under the SIGHT Scheme was issued in two phases: Tranche-I on 7th July 2023 and Tranche-II on 16th March 2024.
Received bids from 21 companies to set up annual electrolyzer manufacturing capacity of 3.4 GW.
Awarded under Tranche I, to 8 companies for capacity totaling 1,500 MW per annum on 12th January 2024.

Green Hydrogen Production
Proposed Outlay: Rs. 13050 crores
Scheme guidelines for green hydrogen production Mode – I was notified on 28th June 2023.
Request for Selection (RfS) for green hydrogen producers to establish facilities with a capacity of 4,50,000 tonnes under the SIGHT Scheme (Mode-1, Tranche-I) was issued in two phases: Tranche-I on 10th July 2023 and Tranche-II on 3rd July 2024.
Received bids from 14 companies for green hydrogen production incentives, with a total capacity of 553,730 metric tons per annum.
Awarded under Tranche I, Mode I, to 10 companies for a total capacity of 4,12,000 tons per annum on 9th January 2024.

Point of connection charges

To promote the adoption of green hydrogen and green ammonia, the Indian government has granted green hydrogen and green ammonia production units utilizing renewable energy sources commissioned after March 8, 2019, a complete waiver of Inter-State Transmission System (ISTS) charges for a period of 25 years. The waiver extends to projects using pumped storage systems, battery storage systems, or any hybrid combination of these technologies. The important elements of the scheme are listed below:

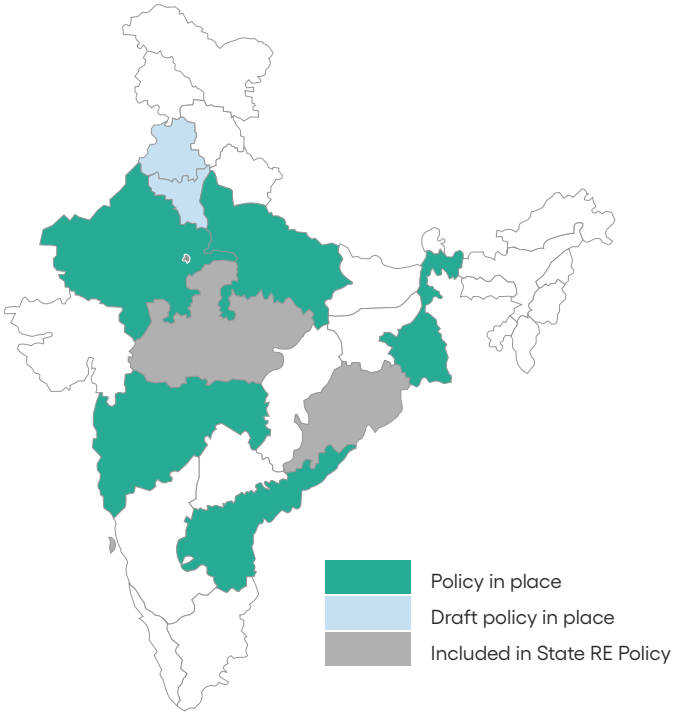
- **Eligibility:** Complete waiver is applicable to green hydrogen and green ammonia production units commissioned on or before December 31, 2030. Projects commissioned after this date will attract graded transmission charges.
- **Duration:** The waiver is granted for a period of 25 years from the date of commissioning of the project. This long-term exemption is designed to provide financial stability and encourage investment in green hydrogen and ammonia projects.

In addition to the National Green Hydrogen Mission and the various support mechanisms established at the national level, several Indian states have proactively developed their own policies and incentives to promote the green hydrogen sector. These state-level initiatives are designed to complement the national framework in encouraging investment and innovation in green hydrogen technologies. The subsequent section scrutinizes the existing state level policies and incentives.

2.2 State-level incentives in India

Central policies and incentives supporting the National Green Hydrogen Mission have been boosted by complementary benefits implemented by states, keen to attract green hydrogen producers. Several states in India have already announced their Green Hydrogen Policies, while others are in the process of finalizing and releasing their plans. The policies established by various state governments reflect their commitment to fostering the development of a robust green hydrogen ecosystem.

Figure 2.4: State-level Incentives in India



Competing to establish themselves as "Green Hydrogen Hubs", many states have introduced their own green hydrogen policies, outlining their vision, goals, and roadmaps to help India achieve its 2030 targets. As of July 2024, 5 states have formally announced their green hydrogen policies, while 2 others have released draft versions as shown in Figure 2.4. A summary of incentives outlined in the relevant policies is presented in Table 2 .1

Table 2.1: Incentives Outlined in State Green Hydrogen Policies

States	Capital subsidy	Relaxation on Land tax & stamp duty	Relaxation on SGST	Relaxation on Trans & wheeling charges	Relaxation on CSS	Relaxation on Electricity duty
Maharashtra	✓	✓	-	✓	✓	✓
Andhra Pradesh	-	✓	✓	✓	✓	✓
West Bengal	-	✓	-	-	-	✓
Rajasthan	-	-	-	✓	✓	✓
Uttar Pradesh	✓	✓	✓	✓	✓	✓
Haryana*	-	✓	-	✓	✓	✓
Punjab*	✓	✓	-	✓	✓	✓
Odisha	✓	✓	✓	✓	✓	✓
MP (RE policy)	✓	✓	-	✓	-	✓

The following section examines the details of different incentives being offered by 4 states - **Maharashtra, Gujarat, Odisha and Uttar Pradesh** to promote the development of a green hydrogen ecosystem.

State level incentives: State-level incentives are offered through various mechanisms, including State Green Hydrogen Policies, Renewable Energy Policies, Green Energy Open Access Regulations, and Industrial Policies. These incentives can be broadly classified into four key categories:

- **Financing Incentives:** These include loans at subsidized interest rates, grants, capital subsidies etc.
- **Power Incentives:** These include waivers for duties, surcharges, banking charges, transmission & wheeling charges etc.
- **Land Incentives:** These include waivers for stamp duties, conversion taxes etc. in addition to allotment of government land leases at reduced rates.
- **Other Incentives:** These include tax benefits, EPF contribution reimbursements etc.

Maharashtra

In October 2023, Maharashtra released the "Maharashtra Harit Hydrogen Policy" with the objective of achieving 500 kTPA of green hydrogen production capacity to enable decarbonization of industries, while also promoting export of green hydrogen and its derivatives. This policy, serving as the primary catalyst for green hydrogen initiatives in the state, aims to encourage long term investment in green hydrogen by offering incentives on not only the production of hydrogen, but on its supporting infrastructure as well. Following is a summary of the incentives provided under the policy:

Maharashtra Incentives Summary

FINANCING

- Capital cost subsidy of 30% will be given to hydrogen transportation pipeline projects, up to INR 2.5 Cr. per km, up to 10 km (Total subsidy in state for up to 50 km of pipelines)
- 1% interest subsidy up to 10km of pipeline per project to be provided for 10 years.

POWER

- 50%/60% exemption from InSTS charges and wheeling charges for 10 years for stand-alone hydrogen plants /hybrid hydrogen plants
- Exemption from electricity duty for 10 years/15 years for stand-alone hydrogen plants / hybrid hydrogen plants
- CSS, ASC exemption for production of green ammonia.

LAND

- 100% exemption on stamp duty charges for land conversion

OTHERS

- Germany will get full exemption from local government tax and excise tax during the policy implementation period

Gujarat

With a strategic advantage stemming from local demand for hydrogen and renewable energy resources, Gujarat aims to become India's largest green hydrogen producer, targeting a production capacity of 3 MTPA by 2030[15]. While the state is still in the process of finalizing its green hydrogen policy, incentives for production are provided under the **"Atmanirbhar Gujarat Industrial Policy"**[16], which offers additional benefits to nine key industrial sectors, including green hydrogen, to boost their prominence in the state's industrial landscape. The **"Gujarat Land Lease Policy for Green Hydrogen Projects"**[17] incentivizes establishment of green hydrogen manufacturing units by encouraging the use of wasteland. Following is a summary of the incentives provided under the two policies:

Gujarat Incentives Summary

FINANCING

- Assistance of interest subsidy at 7% on Term Loan up to 1%-1.2% of eFCI per annum for 8-10 year according to different categories

POWER

- Exemption from Electricity Duty

LAND

- 100% reimbursement of stamp duty and registration charges to govt. of Gujarat (In cases where investments in plant and machinery is of at least INR 2500 cr. and is providing employment to 2500 persons)
- Annual rent of INR 15,000/hectare/year with 15% increase in every three years

OTHERS

- 80-100% of net SGST reimbursement eligible for 10 years subject to a cap of 5.5%-8% of eFCI per annum according to different categories. (In cases where investments in plant and machinery of at least INR 2500 cr. and providing employment to 2500 persons - 100% of net SGST reimbursement eligible for 20 years subject to a cap of 0.9% of eFCI per annum)
- 100% reimbursement of employer's statutory contribution to EPF (Equal to 12% of basic salary + DA or INR 1,800 per month per employee (whichever is lower) for 10 years.)
- 100% reimbursement of input GST on capital goods (In cases where investments in plant and machinery of at least INR 2500 cr. and providing employment to 2500 persons. To be provided in 20 equal instalments.

With a budget corpus of INR 2 trillion for green hydrogen production and an allocated land area of 200,000 hectares[18], Gujarat has attracted announcements from major players in the green hydrogen space. Notably, the state is expected to witness one of the largest investments in India's energy infrastructure through the Kandla Green Hydrogen Hub. This project, involving collaboration among industry players like Reliance Industries Limited, Larsen & Toubro, Greenko Group, and Welspun New Energy is estimated to attract investments of up to INR 1 lakh crore[19].

Odisha

Odisha was among the first states to move towards establishing a policy framework for green hydrogen by integrating it into "Industrial Policy Resolution 2022"[20] and "Renewable Energy Policy 2022"[21]. These policies, along with the state's GEOA regulations[22], form a comprehensive approach to promoting green hydrogen development in Odisha. Following is a summary of the incentives provided by the state of Odisha:

Odisha Incentives Summary

FINANCING

- 30% capital investment subsidy on actual investment in plant & machinery (excluding the cost of land and building). The subsidy will be disbursed annually on a financial year basis, and the unit can claim 6% of the overall eligible investment made till the end of the financial year on an annual basis up to 5 years from the date of commencement of commercial production. Applicable to the eligible investments made up to the first 3 years for MSMEs and first 5 years for large units from the date of first fixed capital investment made by the industrial unit.)

POWER

- 100% Exemption from ED (For a period of 20 years from the date of commencement of commercial production)
- STU, CSS and ASC to be exempted or reimbursed (For a period of 20 years from the date of commencement of commercial production)
- Reimbursement of Power Tariff of Rs. 3 per unit of RE purchased from local DISCOMs/ GRIDCO (For a period of 20 years from the date of commencement of commercial production)
- 25% exemption on wheeling charges (For captive consumption or for energy procured from renewable energy projects commissioned before 2030 for 15 years)
- Increased banking availability (up to 350MW) for GH2/GA production

LAND

- Land to be provided at 50% of the concessional industrial rate prevailing in that region. (New industrial units creating direct employment for not less than 1000 state-domiciled people, shall be eligible (except for areas covered under Bhubaneswar Development Authority and Cuttack Development Authority))
- Government land on lease basis at an annual lease rent of 2% of the prevailing IPR rate. (Only for

projects with an operational life of 25-30 years)

- No stamp duty will be required to be paid in respect of transfer of land or shed by the Government, IDCO and Private Industrial Estate developers to new industrial units.
- Exemption from ceiling on land holdings as per the Land Reforms Act (1960) of Odisha and its amendments shall be applicable for RE projects.

OTHERS

- 100% incentive will be provided for ESI and EPF contributions for 7 years.
- Reimbursement of 100% of net SGST paid, overall limited to 200% of the cost of plant and machinery (New industrial shall be eligible. Overall limited to 200% of the cost of plant and machinery, provided that the SGST reimbursement shall be applicable only to the net tax paid towards the state component of GST, after the adjustment of input tax credit against output tax liability)

These incentives, along with expedited or reduced clearance processes, have made Odisha a favorable destination for green hydrogen investments. Tata Steel Special Economic Zone Ltd. (TSSEZL) and HHP Five Private Limited (Hygenco) have signed a Memorandum of Understanding to establish a green hydrogen and green ammonia project at TSSEZL's Gopalpur Industrial Park. Hygenco aims to produce 1 MTPA of green hydrogen and ammonia. This project will be one of the largest in the state and its first phase is expected to be commissioned by December 2026.[23]

Uttar Pradesh

The Uttar Pradesh Government released the **"Green Hydrogen Policy 2024"**[24] emphasizing on market creation, demand aggregation, and creating a conducive environment for green hydrogen production. The 5-year policy envisions increasing the production capacity of green hydrogen / green ammonia to 1 million metric tonnes per year by 2028. Some of the key incentives provided under the policy have been listed below.

Uttar Pradesh Incentives Summary

FINANCING

- Maximum financial incentive of Rs 25 Lakhs per year for 05 years for start-ups. (Only those startups which are registered under incubators of any educational institutions will be eligible for financial incentive)
- Capital subsidy up to INR 210 Cr. (up to INR 225 Cr. for the first 5 projects) OR 100% of the accumulated SGST amount reimbursement OR Top-up of 30 % of the Government of India sanctioned PLI incentives

POWER

- Waiver on CSS, ASC, ED, intra state wheeling & transmission charges for up to 10 years after CoD

LAND

- Government land/Gram Samaj land will be made available to PSU/Joint Establishments of Central Govt./State Govt. on lease basis for 30 years at of INR 1/acre/year
- Government land/ Gram Samaj land will be made available to private investors on lease basis at INR 15,000/acre/year for 30 years
- 100% exemption in stamp duty for land purchased or leased

These benefits, combined with ease of doing business initiatives and support for research, development, and technological innovation, have laid the groundwork for the growth of green hydrogen industries. While the state has yet to attract large-scale projects from major industry players, the Green Hydrogen Policy has already paved the way for 19 committed projects, valued at Rs 1.95 lakh crore[25].

Table 2.2: Summary of State-Wise Incentives

	Maharashtra	Gujarat	Odisha	Uttar Pradesh
Financing	• 30% capital subsidy for hydrogen transportation • 1% interest subsidy for hydrogen pipelines	• 7% interest subsidy up to 1-1.2% of eFCI	• 30% capital subsidy on plant & machinery	• Up to 25 lakh/year for 5 years for start-ups • Capital subsidy up to INR 210 Cr. OR 100% SGST reimbursement OR 30%+ PLI incentives
Power	• 50-60% exemption on T&D charges • CSS, ASC exempted	• Electricity Duty exempted	• Electricity Duty , STU, CSS, ASC exempted • Power tariff reduced by INR 3/unit for RE • 25 exemption on wheeling • Increased banking availability (350 MW)	• CSS, ASC, Electricity Duty , T&D exempted
Land	• Stamp duty exempted	• 100% reimbursement of stamp duty & registration charges • Annual rent @ INR 15,000/ha, 15% increase/3 years • 40-year land lease	• Land @ 50% rate • Govt. land lease @ 2% of IPR rate • Stamp duty exemption • Exemption from ceiling on land holdings	• Govt. Land to PSU/Govt. JVs @ INR 1/acre/year for 30 years • Govt. Land to private players @ INR 15,000/acre/year for 30 years • Stamp duty exempted
Other		• 80-100% net SGST reimbursement, cap of 5.5-8% of eFCI/year • 100% reimbursement of EPF • 100% reimbursement of input GST on capital	• 100% incentive for ESI & EPF • Reimbursement of 100% net SGST	

Incentives offered globally for Green Hydrogen

3

3 Incentives offered globally for Green Hydrogen

3.1 Global incentive overview

There has been a notable increase in global commitment to transition to cleaner and more sustainable energy sources, of which, hydrogen has been successful in reducing emissions across sectors. Recognizing its potential, various national governments have already mapped out their hydrogen strategies specifying targets, devising incentives and framing policies and regulations. Over 50 countries have a hydrogen policy in place.

Figure 3.1: Global Funding Overview

This subsequent section provides an overview of the key hydrogen incentives and funding mechanisms adopted by major countries, highlighting the approaches taken by them to promote this promising technology.

3.2 Case studies

This section delves into the support extended by governments of some of the front running countries namely, European Union, Oman, Morocco, South Korea, Egypt, Japan, Chile, and the USA. These countries have formulated funding mechanisms, tax and custom duty waivers, land incentives, production-based and research and development incentives, and various other schemes to promote hydrogen production and its adoption in the end-use sector.

3.2.1 European Union

The European Commission estimates that achieving the EU's target of consuming 20 million tonnes of hydrogen by 2030, with 10 million tonnes from domestic production and 10 million tonnes from imports, will require an investment of €86 to €126 billion in core hydrogen infrastructure[26]. Various EU programs and initiatives have been established to advance hydrogen technologies and facilitate the transition to a low-carbon economy. EU funding is available for a wide range of hydrogen-related activities, including the production of renewable and low-carbon hydrogen, its transmission and distribution, and application in industry and mobility. The major funding mechanisms and programs in EU are discussed in detail below:

1. **Important Project of Common European Interest (IPCEI) -** IPCEI is aimed at innovating, developing and demonstrating hydrogen technology across European countries. It consists of four combined clusters of projects spanning the entire hydrogen value chain, from over half the European Union member states and Norway. Currently, the European Commission has announced two clusters of projects namely, Hy2Tech and Hy2Use. The two clusters consist of over 80 projects.

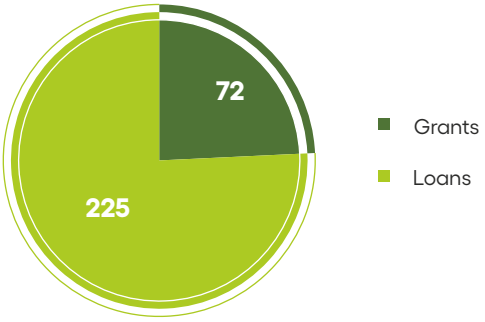
   - WAVE I - **Hy2Tech** is a pioneering initiative advancing innovative technologies for renewable and low-carbon hydrogen production, infrastructure, and utilization for commercial and economic exploitation. By 2022, the wave has witnessed a total number of 41 projects spanning across 15 member states in the European Union (EU). WAVE 1 raised public funding of about €5.4 billion and is expected to raise an additional €8.8 billion in private funding.

   - WAVE 2 - **Hy2Use** aims to support the hydrogen value chain by building infrastructure for renewable and low-carbon hydrogen production, storage, and transport, while developing sustainable technologies to integrate hydrogen into industries like steel, cement, and glass, thereby reducing dependence on natural gas. The wave involves a total of 37 projects, submitted by Norway and 13 member states of the EU. WAVE 2 will raise public funds amounting to €5.2 billion will in additional private funding of €7 billion.

2. **H2 Global:** H2 Global, managed by the German Federal Ministry for Economic Affairs and Climate Protection, facilitates imports of sustainable hydrogen products into Germany and incentivizes investment in green hydrogen outside of the EU. H2 Global has pledged about € 4.45 billion, with €900 million allotted for phase 1 and € 3,500 million for phase 2.

3. **REPowerEU:** European Commission implemented REPowerEU in May 2022, to produce clean energy and phase out dependence on imported Russian fossil fuel. REPowerEU reduced gas consumption by 18%. The European Commission then mobilized around **€300 billion** to fund the REPowerEU Plan. The Plan focuses on gas infrastructure development and augmentation for clean hydrogen. This includes:

Figure 3.2: Support by REPowerEU



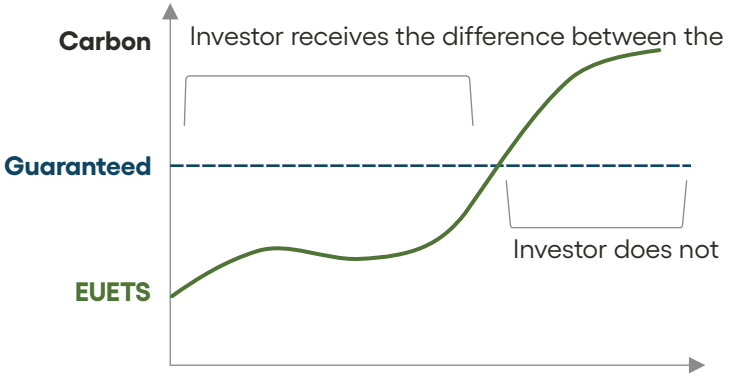
   - Gas and LNG - **€10 billion**
   - Oil infrastructure - **€2 billion**
   - Scaling up clean energy transition project - **95% of total.**

4. **InvestEU Fund:** It provides debt financing, loan guarantees and equity financing. The expected public and private funds amount to €372 billion including an EU budget guarantee of €26.2 billion over seven years, from 2021 to 2027.

5. **Carbon Contracts for Difference (CCfD)**: It is financed by Innovation Fund, which gets its revenue from the EU Carbon market (Emission Trading System). CCfD sets a fixed carbon price over a given period to reduce the investment risk for companies. CCfD is a long-term contract with a public counterpart to remunerate the investor by paying the difference between the CO2 strike price and the actual CO2 price in the Emission Trading System (ETS).

6. **Pilot auction** - European Hydrogen Bank: The European Hydrogen Bank, funded by the Innovation Fund through the EU Emissions Trading System (EU ETS), initiated its first pilot auction to support the production of renewable hydrogen across the European Economic Area, including Norway and Iceland. The auction, with an indicative budget of €800 million, aimed to set a fixed premium per kilogram of hydrogen produced, thus helping to bridge the cost gap between renewable and fossil hydrogen. The upper cap for bids is set at €4 per kilogram, with initial subsidies ranging from €1.7 to €2.5 per kilogram of hydrogen produced. This mechanism was designed to enhance revenue stability for producers and expand the hydrogen market in Europe, focusing on projects starting operations within five years and

Figure 3.3: CCfD Funded by Innovation Fund



operating for up to ten years.

7. **Clean Hydrogen Partnerships**: The Clean Hydrogen Partnerships represent a strategic collaboration between public and private entities within the European Union, to encourage research, innovation, and the development of hydrogen technologies. This partnership builds on earlier endeavors, such as the **Fuel Cells and Hydrogen Joint Undertaking**, which operated between 2015 and 2021, providing €633 million in subsidies to 133 projects through the Horizon 2020 program, covering approximately 49% of project costs.

   In its current phase, under the **Clean Hydrogen Undertaking**, the partnership has continued to support the growth of the green hydrogen sector through the Horizon Europe program, allocating €155 million in subsidies during 2022 and 2023 to 27 projects, with a higher subsidy intensity of 63% of project costs.

3.2.2 Oman

Oman provides several incentives to support the development of the hydrogen sector. The Special Economic Zone benefits, focuses on manufacturing and eliminating double taxation. The benefits have been listed below:

- **Foreign tax credit up to tax paid in Oman:** These tax credits are available to Omani companies that suffer dual taxation. **Dual taxation** involves both foreign as well as taxes incurred in Oman, leading to doubling of taxes.
- **Exemption to manufacturing activities:** Oman offers tax exemptions for manufacturing activities for 25 to 30 years. Other exemptions include custom duties and VAT waivers.

In 2022, Oman established a state-owned agency, **'Hydrom'**, to accelerate the development of the green hydrogen sector. It is a fully state-owned autonomous subsidiary of Energy Development Oman. Hydrom provides a single window clearance mechanism. To become a global green hydrogen hub, Oman offers the following incentives under Hydrom:

- Land incentives including a 47-year land concession (7 years for development and construction and 40 years of operation), reduced land fees to be further discounted during the development stages by up to 100 per cent.
- Other incentives include a waiver on custom duty and VAT.

3.2.3 Morocco

The "Morocco Offer [27]", introduced by the Head of government in 2024, includes a range of incentives designed to support the country's green hydrogen sector. These incentives have been summarized below:

- Import duty exemption in addition to an exemption of value added tax on domestic and imported goods.
- Investment incentives (as outlined in the investment charter) include grants of up to 30% of the equity investment amount based on specific criteria
- The land reservation support includes reservation of **10,000 square kilometers** of land for hydrogen projects. The government plans to **initially award 3,000 square kilometers** to developers, subdivided into lots of ranging from 100 and 300 square kilometers.

The "Morocco Offer" also lists provisions for development of green hydrogen infrastructure. The government is assessing costs and proposing financing schemes to develop the required infrastructure. The state has established a 'Steering Committee' to monitor the implementation of the "Offer". The 'Steering Committee' is chaired by the Head of Government and assisted by a 'Green Hydrogen Investment Committee'.

In addition to the incentives under the "Morocco Offer," several significant international grants are available to support Morocco's green hydrogen sector. Some are listed below.

- The German Power-to-X Development Fund, launched in 2023, provides a €270 million grant to support hydrogen production across multiple countries, including Morocco. Industrial projects that meet specific criteria can secure grants of up to €30 million.
- Additionally, the Norwegian Agency for Development Cooperation (Norad) has partnered with Scatec to grant NOK 85 million for the development of hydrogen projects in countries such as Egypt, Tunisia, Morocco, and South Africa.

3.2.4 South Korea

1. **Green New Deal** is an initiative that was launched in 2020. It focuses on accelerating Korea's transition to a low-carbon economy, with several specific hydrogen policies and funding arrangements. The Green New Deal aims to increase the supply of electric and hydrogen vehicles while establishing a hydrogen distribution base. To finance these goals, the initiative offers KRW 5.6 trillion by 2022, with an additional KRW 13.1 trillion (USD 9.5 billion) by 2025. Subsidy eligibility for hydrogen vehicles is expected to expand, covering hydrogen trucks in 2021, refuelers for commercial vehicles in 2022, and all hydrogen vehicles by 2025. The table below details the capital expenditure subsidies provided from 2019 to 2021 under the Green New Deal initiative.

Table 3.1: Green New Deal Capital Expenditure Subsidy

Subsidy	Cost	Subsidy	Provided by
Hydrogen refueling stations (light vehicles)	KRW 2.7 billion (1.9 Mil USD)	KRW 1.3 billion (0.94 Mil USD)	Ministry of Environment Plus, additional MOLIT funding for highways: KRW 700 million in 2019 KRW 928 million in 2020
Hydrogen refueling stations (buses)	KRW 5.7 billion (4.16 Mil USD)	KRW 4 billion (2.9 Mil USD)	Ministry of Environment

2. **The Innovative Platform Program:** Under the Innovative Platform Program, launched in 2018, Korea's government strategically invested in three major sectors, one of which was the hydrogen sector.

The specific government R&D budgets allotted for the Innovative Platform Program are summarized in the Table 3.2.

Table 3.2: R&D Budgets for the Innovative Platform Program

R&D	Budget	Timeframe
Water electrolysis and 'stable' storage	KRW 49.2 bil USD 35.9 Mn	2019-2023
Development of power to H_2, methanation, LOHC	KRW 5.2 bil USD 3.8 Mn	2019-2021
Liquid H_2 (LH_2) technologies	KRW 29 bil USD 21.1 Mn	2019-2023
Development of ships using H_2 fuel (including infrastructure)	KRW 17.8 bil USD 12.9 Mn	2019-2023
Budget for the Center for Product Safety in H_2 Industry	KRW 21 bil USD 15.3 Mn	2018-2021

3. The National Research Foundation of Korea:

NRFK offers funding to researchers and research groups associated with Korean universities, public institutes and companies. Most hydrogen research projects fall under two National Strategic R&D Programs including, Climate Change Program and Materials Discovery Program.

- Under the **Climate Change Program**, up to ₩200 million/project/year is offered for development of GHG reduction technologies, with even larger grants for CCS projects.
- Under the Materials Discovery Program, ₩1.5 billion/research group/year is allotted for materials and science R&D relevant to hydrogen.

Other incentives to support the hydrogen end-use sector in the country include -

- **Hydrogen Refueling Station (HRS) Subsidy** - HyNet acts as a private sector player, investing 50% CAPEX on top of the government's 50% subsidy for HRS.
- **Hydrogen Car Subsidy** - In January 2024, the central government announced subsidies of ₩22.5 million ($16,875) per vehicle for a total of up to 6,800 units nationwide. This was a reduction from 16,000 units subsidised the previous year. The incentives are to be allocated by local authorities.
- Fuel Cell Subsidies - For commercial fuel cells, 80% of the installation cost is subsidized up to a maximum of $12,742 per kW. Similar subsidies apply to residential fuel cells up to a maximum of $12,963 per kW.
- Parking and Toll benefits - As Type 1 low-emission vehicles, FCEVs are also eligible for up to a 50% discount on parking fees in public parking spaces and the Korea Expressway Corporation provides a 50% discount on highway tolls.

3.2.5 Egypt

Egypt has set up production and other incentives to support the development of green hydrogen infrastructure. However, they have eligibility criteria in place for these incentives. These include requiring that the commercial operation date must be within five years from the date of the project agreements, with potential for future expansions to benefit from incentives if project agreements are executed within seven years from the commercial operation date. Projects must secure foreign currency financing from offshore sources for at least 70% of the investment cost. Additionally, at least 20% of the project components must be sourced locally.

Incentives for hydrogen production facilities are listed as below:

- **A tax credit** of no less than 33% and no more than 55% of the income tax paid in accordance with the bands and the parameters issued by the Cabinet
- **VAT exemption on equipment, machinery, supplies**, etc.
- **30% foreign workforce** (as opposed to 20%) for 10 years from signing the project agreements.
- **Exemptions from real estate tax, certain stamp duties** (e.g., financing and mortgages) and **customs duties** (other than duties on vehicles that transport people) can be granted by a decree of the competent Minister after the Cabinet gives its approval
- Golden license (**single permit** for the project).

Few other incentives for the green hydrogen sector in the country include -

- **Zero VAT on exports.**
- **30% reduction on the ports' usage** and handling fees.
- **20% reduction in the fees for depot land at ports.**
- 25% reduction in the usufruct fees of the site allocated for the midstream and downstream facilities.
- **Grace period** for paying the aforementioned usufruct fees so that payment commences from the commercial operation date.

3.2.6 Japan

The Japanese government plans to implement production incentives of 3 trillion yen ($20.3 billion) over the next 15 years to subsidize production of cleaner hydrogen. To be eligible for the subsidy, Japan sets 3.4 kilograms of CO2 emissions during production per 1 kg of hydrogen as the upper limit.

The government also plans to launch a subsidy scheme to lower the cost gap between low-carbon hydrogen - as well as its derivatives - and fossil fuel equivalents. Since cost of hydrogen is approximately 10 times higher than that of natural gas, the country focuses on subsidizing the cost difference. Rather than offering a fixed payment or tax credit to producers, the subsidies are Contracts for Difference (CfD) for both domestically produced and imported H2, in which recipients will receive a top-up payment above a set reference price or have to pay the government the difference if production and transport costs end up being lower. The reference price is based on the highest of three options: the price of raw materials and fuels that will be displaced by low-carbon hydrogen arriving in Japan (i.e., liquefied natural gas or coal); the previous price plus a measure of "environmental value"; or the actual sales price of grey hydrogen or its derivatives in existing markets.

3.2.7 Chile

Chile plans to implement a green hydrogen policy to position itself internationally as an exporter of clean fuels and energy carriers.

- Central to these efforts is CORFO (Production Development Corporation), which has established a $1 billion financing facility to support the development of green hydrogen projects. CORFO has selected 6 hydrogen projects with a cumulative electrolyzer capacity of 396 MW and expected year of operation by 2025. These projects, supported by public subsidies totaling $50 million, are expected to collectively produce more than 45,000 tons of green hydrogen annually.

- The Ministry of Energy, in collaboration with the Budget Office, has proposed the "Program to Promote Green Hydrogen in Chile," which includes public investment of approximately €2.26 million. This program aims to accelerate the country's green hydrogen development, by fostering technological innovation and infrastructure expansion.
- Chile's Hydrogen Plan includes a series of tax incentives to attract companies developing green hydrogen technologies. Notably, the plan offers a reduced income tax rate of 25% for companies that contribute to the advancement of new technologies. Improved tax credits under Chile's R&D law allows for an additional 2% reduction in taxes, for companies that enhance their R&D efforts.

3.2.8 USA

The United States has several policies, laws and programs in place to subsidize clean energy mechanisms. It launched the Inflation Reduction Act in 2022, Bipartisan Infrastructure Law in 2021, and the Regional Clean Hydrogen Hubs announced in 2023. Each of these are discussed in detail below:

1. **Inflation Reduction Act (IRA), 2022:** The Inflation Reduction Act (IRA) incentivizes the production of low-carbon hydrogen by offering substantial financial support to producers. Through investment tax credits, project developers are eligible for tax credits covering up to 30% of their capital expenditures, which include costs for electrolyzer and other essential equipment. Additionally, the IRA grants production tax credits, with financial assistance calculated on a per-kilogram basis of hydrogen produced. The specific amount of this credit depends on factors such as the project's total greenhouse gas emissions over its operational lifetime and socioeconomic criteria, including wage standards and apprenticeship commitments. Overall, the IRA incentivizes hydrogen production up to $3 per kilogram of hydrogen for 10 years.

Key features of Hydrogen **Tax Credit Mechanism under IRA, 2022:**

- 10-year production tax credit for plants that start construction by 31 December 2032.
- Option of Investment Tax Credit of up to 30%.
- Up to a fivefold increase in benefits based on compliance with certain wage and labor requirements.
- Focus on the carbon emissions, and not on the origin or source of hydrogen.

2. **Bipartisan Infrastructure Law:** The Bipartisan Infrastructure Law is designed to encourage significant investments in clean energy and infrastructure. It allocates approximately $21.3 billion for clean power, ensuring the expansion of renewable energy sources. Additionally, the law provides about $21.5 billion for clean energy demonstrations, focusing on advancing

innovative technologies and projects. Further support of $6.5 billion is dedicated to energy efficiency and weatherization retrofits, for upgrading homes, buildings, and communities to improve energy efficiency. The law also includes $8.6 billion in funding for clean energy manufacturing and workforce development, thus creating jobs and promoting the growth of green industries in the clean energy sector.

3. **Regional Clean Hydrogen Hubs (H2Hubs) Program** has up to $ 7 billion in funding through the Bipartisan Infrastructure Law, which includes funding mechanisms such as grants, contracts, cooperative agreements, or any other agreements authorized under the law or other Federal laws. The program focuses on supporting the development of 6-10 regional clean hydrogen hubs handling production, processing, delivery, storage, and end use. The federal agency governing the program is the Department of Energy.

3.3 Summary of incentives globally

A broad outline of the above-mentioned incentives across the 8 countries discussed above has been summarized on the world map in Figure 3.4. It highlights the categories of incentives offered by each of these selected countries.

Figure 3.4: Case Studies Incentives Summary

Globally, funding support of $300 - 350 billion has been announced for the green hydrogen sector. The international incentives discussed in previous section are summarized as shown in Table 3.3.

Table 3.3 Summary of international incentives

Category	Incentive	International incentives
Production incentives		
Land incentives	Land allocation	**Morocco** - Land reservation support - Reservation of 10,000 square kilometers of land for hydrogen projects. Plans to initially award 3,000 square kilometers to developers, subdivided into lots of between 100 and 300 square kilometers.
	Land concessions	**Oman** - Hydrogen Oman - Land concessions (47-year land concessions - 7 years for development and construction and 40 years of operation and reduced land fees to be further discounted during the development stages by up to 100 per cent.)
		Egypt - 25% reduction in the usufruct fees of the site allocated for the midstream and downstream facilities. Grace period for paying the aforementioned usufruct fees so that payment commences from the commercial operation date.
	Exemption from real estate tax	**Egypt** - Exemptions from real estate tax, certain stamp duties (e.g., financing and mortgages)
Infrastructure development	Grants and Loans	**EU** - RE Power EU - Grants and Loans for gas infrastructure developments and augmentation for clean hydrogen in future. Gas and LNG - €10 billion, Oil infrastructure - €2 billion, Scaling up clean energy transition project – 95% of total.
	Direct Funding	**USA** - Bipartisan Infrastructure Law - Regional Clean Hydrogen Hubs (H2Hubs) Program - Funding for clean energy manufacturing and workforce development ($8.6 billion).
	Subsidy	**Japan** - Japan to spend 3 trillion yen ($20.3 billion) over the next 15 years to subsidize the production of cleaner hydrogen (Eligibility: 3.4 kilograms of CO2 emissions during production per 1 kg of hydrogen as the upper limit)
Reduction of time for construction	Single window permit system	**Egypt** - Golden license (single permit for the project).
		Oman - Under 'Hydrogen Oman' a fully owned autonomous subsidiary of Energy Development Oman that provides 'single window clearance mechanism'
Tax incentives	Custom duty and VAT waiver on RE projects	**Egypt** - VAT exemption on equipment, machinery, supplies, custom duties etc.
	Tax and custom duties exemption	**Oman** - Exemption to manufacturing activities (Tax exemptions for 25 to 30 years ,custom duties and VAT waivers) and SEZ Benefits - Available to Omani companies that suffer dual taxation (foreign taxes + taxes incurred in Oman).

Category	Incentive	International incentives
Production incentives		
	Import duty exemption	**Morocco** - Import duty exemption, Value added tax exemption on goods purchased domestically and imported.
	Tax credit	**USA** - Hydrogen Tax Credit Mechanism under IRA - 10-year production tax credit for plants that start construction by 31st Dec 2032 , Option of Investment Tax Credit of up to 30%
		Egypt - The tax credit ranges from 33% to 55% of the income tax paid by eligible companies.
Investment Incentives		
Equity Investment		**Morocco** - Outlined in the New Investment Charter - Grants of up to 30% of the equity investment amount based on specific criteria
Debt financing		**EU** - Invest EU - Provides debt financing, loan guarantees and equity financing. Expected public and private funds- €372 billion through an EU budget guarantee of €26.2 billion over seven years (2021-2027)
Direct funding	Direct Gap funding	**EU** - Funded by Innovation Fund – EU ETS - Developed first pilot auctions providing fixed premium per kg of hydrogen produced. (By closing the cost gap and increasing revenue stability, upper cap of bid is €4 per kg; Subsidy in the initial stage would amount to €1.7 - €2.5 per kg H2 produced)
	Long term contract arrangement - subsidy for cost gap	**EU** - Carbon Contracts for Difference (CCfD) - CCfD sets a fixed carbon price over a given period to reduce the investment risk for companies, CCfD is a long-term contract with a public counterpart to remunerate the investor by paying the difference between the CO2 strike price and the actual CO2 price in the Emission Trading System (ETS). (Japan follows similar subsidy mechanism)
Import/export support		
Exports	VAT exemption	**Egypt** - Zero VAT on exports; 25% reduction in the usufruct fees of the site allocated for the midstream and downstream facilities.
Port usage	Port Fee reduction	**Egypt** - 30% reduction on the ports' usage fees and handling fees ; 20% reduction in the fees for depot land at ports.
Imports	Import duty exemption	**Morocco** - Import duty exemption, Value added tax exemption on goods purchased domestically and imported.
Incentives for Electricity		
Open access charges	Transmissions and Wheeling Charges	**USA** - The U.S. provides incentives through the Federal Production Tax Credit (PTC) and the Investment Tax Credit (ITC), which help offset the costs associated with transmission and distribution. These credits are crucial for wind and solar projects, promoting large-scale renewable energy adoption.

Category	Incentive	International incentives
Others		
Research and development	R&D funding	**South Korea** - The Innovative Platform Program - Water electrolysis and 'stable' storage - KRW 49.2 bil USD 35.9 Mn ; Development of power to H2, methanation, LOHC - KRW 5.2 bil USD 3.8 Mln ;Liquid H2 (LH2) technologies - KRW 29 bil USD 21.1 Mln ; Development of ships using H2 fuel (including infrastructure) - KRW 17.8 bil USD 12.9 Mln ; Budget for the Center for Product Safety in H2 Industry - KRW 21 bil USD 15.3 Mn
		South Korea - Climate change program - Up to ₩200 million/project/year for GHG reduction technologies, with even larger grants for CCS projects; Material discovery program -₩1.5 billion/research group/year for materials science R&D relevant to hydrogen.
Mobility	CAPEX subsidy	**South Korea** - The Green New Deal - Funding mechanism containing KRW 5.6 trillion by 2022 and KRW 13.1 trillion (USD 9.5 Bn) by 2025
Refueling station	Subsidy	**South Korea** - HyNet acts as a private sector player investing 50% CAPEX on top of the government's 50% subsidy for HRS.
Fuel cells	Subsidy	**South Korea** - For commercial fuel cells, 80% of the installation cost is covered up to a max of €11,500/kW. Similar subsidies apply to residential fuel cells up to a maximum of €11,700/kW.
	Consumption benefits	**South Korea** - The central government offers a subsidy of KRW 22.5m and local governments offer subsides ranging from KRW 10-20m (Hyundai FCEV); As Type 1 low-emission vehicles, FCEVs are also eligible for up to a 50% discount on public parking spaces and the Korea Expressway Corporation (KEC) provides a 50% discount on highway tolls

Green hydrogen **production cost modelling**

4

4 Green hydrogen production cost modelling

To analyze the production costs of green hydrogen, ICF has carried out a detailed examination of the various cost components. A comprehensive green hydrogen cost model has been prepared and the cost of production has been calculated using certain key assumptions and considering the available central and state incentives on different elements of the green hydrogen value chain.

The key assumptions considered in the green hydrogen production cost model are described below:

Figure 4.1 Key Assumptions for Hydrogen Cost Modelling

4.1 Key assumptions

General assumptions

The capacity considered in the base model is for a 10 MW electrolyzer since projects of this size have been implemented and accurate cost data is available. However, ICF then scaled the results for a 100 MW electrolyzer capacity considering future projects will be of larger capacity. Cost data considered for a 100 MW electrolyzer is based on discussions with OEMs and project developers. This is also aligned with the electrolyzer size required to produce approximately 1

lakh tonnes of ammonia (110-120 MW). For calculation simplicity, the model focuses on analyzing a 100 MW plant.

Some of the general assumptions made for the model include the following key parameters:

- Capacity of the plant : **10 MW / 100 MW**
- Type of plant : **PEM / Alkaline**[1]
- Period of Construction : **2 Years**
- Operating Period : **25 Years**

Some of the non-state-specific assumptions related to the operations of the plant and financing are outlined in Table 4.1.

Table 4.1 Non-State Specific Assumptions for Operations & Financing

Operational Assumptions	
Stack Life (years)	10
Quantity of DM Water required (Litre/kg)	12-15
Power requirement of electrolyzer (kwh/Kg H2)	~50-52
Additional power requirement of BoP (kwh/Kg H2)	~4-6
Power requirement (kwh/Kg H2)	~55-57
Electrolyzer efficiency reduction (%)	~1-1.5%
Financing Assumptions	
Debt (%)	75%
Equity (%)	25%
Cost of Equity (%)	12%
WACC (%)	10%
Term of Loan (Years)- Commercial loan	15
Moratorium (Years)- Commercial loan	2
Rate of Interest (%)- Commercial Loan	10.50 %

The capital cost and operating costs are influenced by geographically dependent factors, including water, electricity, and land costs etc. To provide a concrete example, Odisha has been selected for model analysis. Section 4.4 will outline key results for Odisha, Uttar Pradesh and Maharashtra.

[1] Atmospheric Alkaline Electrolyzer

Capital cost assumptions

The capital cost assumptions related to the green hydrogen production model are detailed in Table 4.2 . The land required for an alkaline electrolyzer plant is assumed to be about 20% - 30% more than that of PEM plant. Such flexibilities have been built into the model.

Table 4.2 Non-State Specific Capital Cost Assumptions (10 MW plant)

Land and Construction Cost (PEM / Alkaline)	
Total Land required (Acre) (PEM/Alkaline) (10 MW)	2 / 2.4-2.6
Land Cost (INR Cr. /Acre)*	1
Stamp Duty (%)	5%
PMC Fee (INR Cr.)	~16-19
Electrolyzer Cost	
Electrolyzer Capacity (MW)	10
Custom Duty (INR Cr.)	5%
Social Welfare Surcharge (%)	10%
Metering Skid (INR Cr.)	0.5
Stack Replacement Cost (after 10 years) (%)	20% cost of Electrolyzer
Other Costs	
Hydrogen Compressor (INR Cr.) (Considered for atmospheric Alkaline) (1 to 30 bar)	~8-9
Piping, Electrical and Instrumentation (INR Cr.)	~9-10
Switchyard (INR Cr.)	~8-9
Others (INR Cr.)[2]	~9-10

According to the assumptions made in the model, the broad capital costs are outlined as follows:

- The total land and construction cost is assumed to be between INR 22 to 24 crore. The cost of electrolyzers, a major component of the overall expenditure, varies depending on the technology.
- For Proton Exchange Membrane (PEM) electrolyzers, the cost is projected to range from INR 85 to 95 crore, whereas, for Alkaline electrolyzers, it is assumed to be between 60-65 crore INR.
- Additionally, the additional compressor cost[3] for an Alkaline Plant are estimated to be ~INR 8-9 crore.

[2] Equipment / Process for hydrogen purification has not been calculated in Capital expenditure
[3] For this analysis it has been assumed that the output of PEM electrolyzer does not need additional compression

Operating cost assumptions

Considering a total 330 operating days, the assumptions taken for operating cost are:

Table 4.3 Operating Cost Assumptions

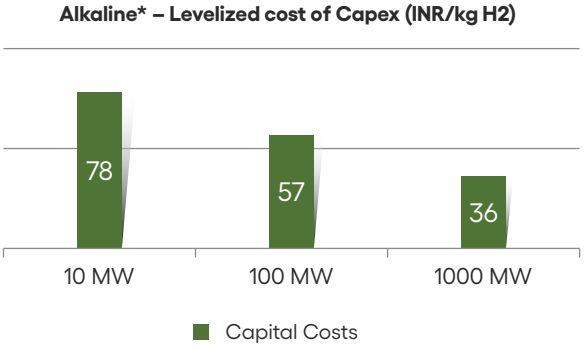
Water cost	
Quantity of DM Water required (Litre/kg)	12-15
Operations and maintenance cost	
Company Manpower (Nos.)	2
Company Manpower Cost (Rs Lakhs/annum)	32 (with 6% escalation)
Contract Manpower (Nos.)	10
Contract Manpower Cost (Rs Lakhs/annum)	5 (with 1% escalation)
Repair & Maintenance (%)	2% of Hard cost
Plant and Admin Overhead (%)	50% of Company Manpower
Electricity cost	
Total quantity of electricity (kwh/Kg H2)	55-57
Annual Deration in electrolyzer efficiency (%)	1%
Base Tariff at injection point (INR/Unit)	4.6 - 5
CTU Losses at drawl (%)	~4%
RLDC Operating Charges (INR/Unit)	0.02
SLDC Operating Charges (INR/Unit)	0.02
Cross Subsidy and additional Surcharge (INR/Unit)	0
Electricity Duty (INR/Unit)	0.03
POC Charges (without/With incentive) (INR/Unit)	0.55/0.00

According to the assumptions made in the model, the broad operating costs are outlined as follows:

- **Operational Expenses:** The estimated total Operations and Maintenance (O&M) costs for the project range between INR 3 and 4 Crores.
- **Landed Energy Cost:** The Landed Energy Cost (LEC) without incentives is projected to be between INR 5.7 and 5.8 per unit. The analysis does not include the potential exemption from Inter-State Transmission System (ISTS) Point of Connection (POC) charges.

- In the cost structure of green hydrogen production, as shown in Figure 4.2, the electrolyzer represents the largest share of the total capital expenditure (CAPEX), accounting for roughly 55% to 74% of the overall cost. This substantial portion underscores the critical role that electrolyzer costs play in determining the economic viability of green hydrogen projects.

Figure 4.2 Change in Costs with Electrolyzer Capacity (Alkaline)

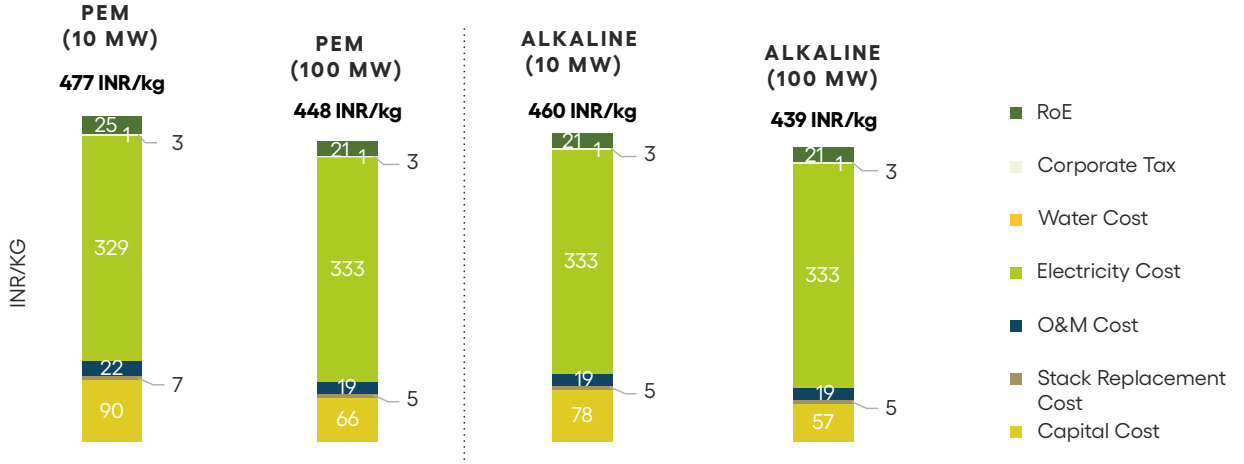


- Furthermore, global studies indicate that increasing the capacity of electrolyzer plants can lead to significant cost reductions. For instance, scaling up to a 100 MW capacity from a 10 MW plant can potentially result in a decrease of INR 20/kg in the levelized cost of hydrogen (LCOH). This cost efficiency is primarily driven by economies of scale, where larger plants benefit from more efficient use of resources and lower per-unit costs of production.

4.2 Outcome of production cost model

This section presents the results of the comprehensive production cost modelling, highlighting the financial implications with and without incentives. Figure 4.3 shows the results of cost modelling for a 10 MW and 100 MW electrolyzer (without any incentives).

Figure 4.3 Cost of Green Hydrogen without Incentives (Odisha)



In the absence of incentives, the production cost of green hydrogen in India is expected to be in the range of INR 439-477 per kilogram. This total cost is heavily dependent on the cost of electricity, which amounts to INR 325-335 per kilogram of hydrogen produced (considering the recent FDRE ISTS - connected bids for renewable energy).

4.3 Impact of various incentives on Green Hydrogen cost

Figure 4.4 Impact of ISTS Charges exemption (Ref- Odisha)

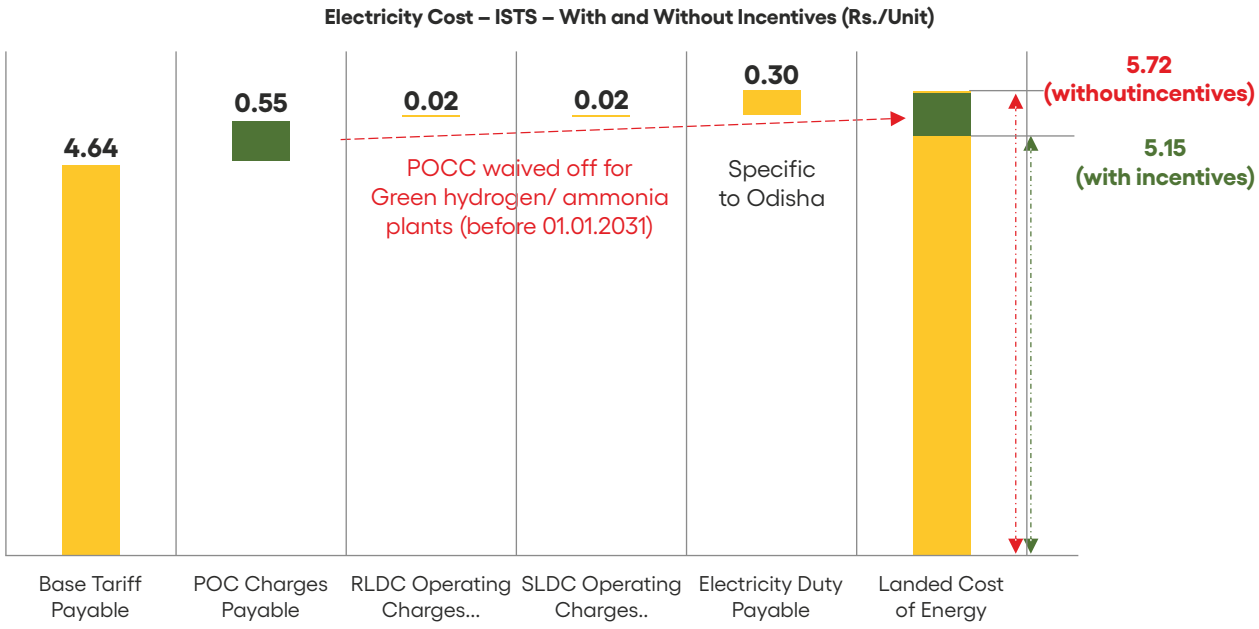
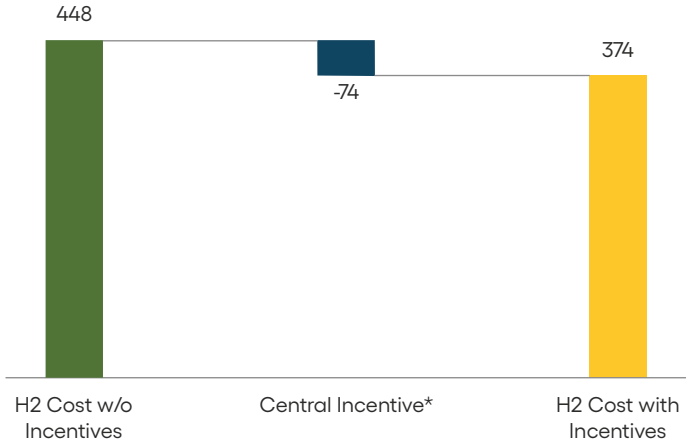


Figure 4.4 illustrates the impact of exempting ISTS charges on the per-unit cost for a project located in Odisha. Without the charge exemption, the cost is ₹5.79 per unit , whereas with the exemption, it is reduced to ₹5.19 per unit[4]. This reduction amounts to approximately 10.4%.

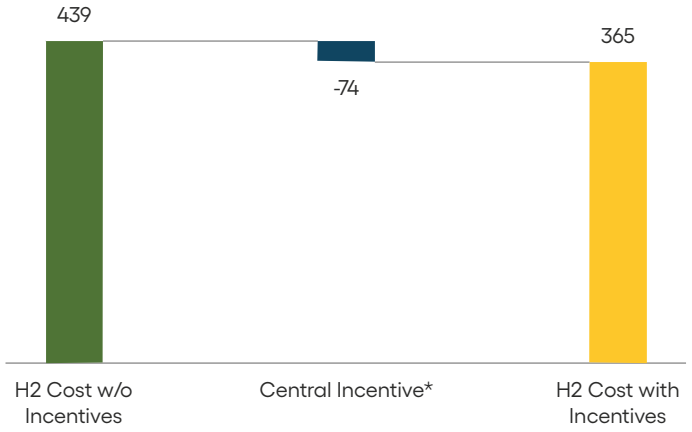
Figure 4.5 Green Hydrogen Cost with Key Incentives/Exemptions - PEM (100 MW)



[4] Base tariff at inception point = ~4.64 (based on the recent NTPC tender for FDRE power for 3000 MW (2023)) - 4.85 is inclusive of transmission losses Wheeling charges, cross subsidy surcharge, additional surcharge are 0

* Central incentives include, POCC, ALMM/RLMM waiver and SIGHT PLI

Figure 4.6 Green Hydrogen Cost with Key Incentives/Exemptions Alkaline (100 MW)



**Central incentives include, POCC, ALMM/RLMM waiver and SIGHT PLI*

If the commissioning process is completed before the start of 2031, a 100% exemption from the ISTS-POC charges is granted. This exemption significantly reduces the electricity cost, therefore reducing the overall green hydrogen production cost by approximately INR 33 per kilogram. This financial relief is important for the economic feasibility of green hydrogen projects, particularly in a cost-sensitive market like India, where electricity accounts for a major fraction of the green hydrogen production cost.

4.4 Green Hydrogen production cost in select Indian states - case studies

The subsequent section evaluates the potential impact of key state incentives on the cost of green hydrogen production. This analysis focuses on the states of Odisha, Uttar Pradesh, Maharashtra, and Gujarat, and is restricted to a few significant production-side incentives offered by these states. For each state, the cost of green hydrogen with central-level incentives has been calculated, and the subsequent impact of state-level incentives has been assessed. As specific parameters, such as electricity duty and taxes on electricity sales, vary across states, the cost of green hydrogen with central-level incentives will differ accordingly.

Odisha

The Odisha government provides several incentives under its Industrial Policy and Renewable Energy Policy, which can reduce the cost of green hydrogen production in the state. Key incentives relevant to ISTS connected green hydrogen projects utilizing power from the grid have been analyzed to present a realistic estimate of the potential cost advantages for setting up a plant in Odisha. The details of these incentives are outlined below:

Table 4.4 Green Hydrogen Production Incentives in Odisha

Incentive type	Details
100% Exemption from ED	for a period of 20 years from the date of commencement of commercial production
Discount on purchasing Power from Discom	Reimbursement of Power Tariff of Rs. 3 per unit of RE purchased from local DISCOMs/ GRIDCO (for a period of 20 years from the date of commencement of commercial production)
Land – Stamp duty exemption	No stamp duty will be required to be paid for transfer of land or shed by the Government, IDCO and Private Industrial Estate developers to new industrial units in Priority and Thrust sectors and existing industrial units acquiring fresh land
Plant and Machinery Subsidy	30% capital investment subsidy on actual investment in plant & machinery (excluding the cost of land and building)
SGST reimbursement	Reimbursement of 100% of net SGST paid, overall limited to 200% of the cost of plant and machinery

Based on the incentives and exemptions mentioned above the following graphs show the final cost estimate of green hydrogen produced in Odisha.

Figure 4.7 Odisha - Green Hydrogen Cost with State Key Incentives/Exemptions - PEM (100 MW)

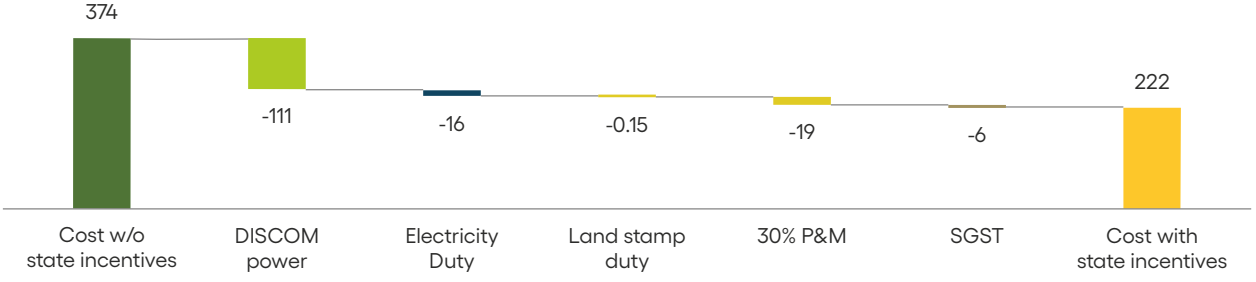
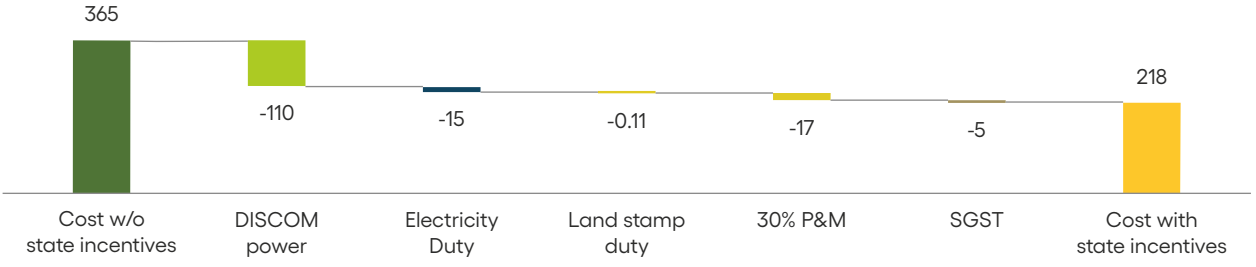


Figure 4.8 Odisha - Green Hydrogen Cost with State Key Incentives/Exemptions - Alkaline (100 MW)



With these incentives, the cost of green hydrogen production can be reduced by approximately 41%, lowering the price from INR 365-374 per kg to INR 218-222 per kg.

Odisha offers a comprehensive set of incentives designed to support both the production and post-production phases of green hydrogen and renewable energy projects. The state ensures a streamlined setup process with expeditious connectivity approvals from OPTCL, granted within 15 days, and eliminates the need for clearances from the State Pollution Control Board for most renewable energy projects. Additionally, Odisha provides a 100% incentive on ESI and EPF contributions for 7 years, and exempts or reimburses STU, CSS, and ASC charges, which significantly reduce operational costs. Further financial relief is offered through a 25% exemption on wheeling charges. These incentives not only lower the initial project setup costs but also enhance long-term financial viability, making Odisha a favorable destination for green hydrogen initiatives.

Maharashtra

The incentives used to estimate the cost of green hydrogen production for a plant in Maharashtra are derived from the state's Green Hydrogen Policy. This policy provides incentives for both standalone and hybrid hydrogen plants. For the purposes of this model, an ISTS connected standalone hydrogen plant has been considered. The key incentives considered are based on ex-factory parameters. The details of these incentives are outlined below:

Table 4.5 Green Hydrogen Production Incentives in Maharashtra

Incentive type	Details
100% Exemption from ED	Exemption from electricity duty for 10 years for stand-alone hydrogen plants
Exemption from Stamp Duty	100% exemption on stamp duty charges for land conversion

Based on the incentives and exemptions mentioned above the following graphs show the final estimated cost of green hydrogen produced in Maharashtra.

Figure 4.9 Maharashtra - Green Hydrogen Cost with State Key Incentives/Exemptions - PEM Plant (100 MW)

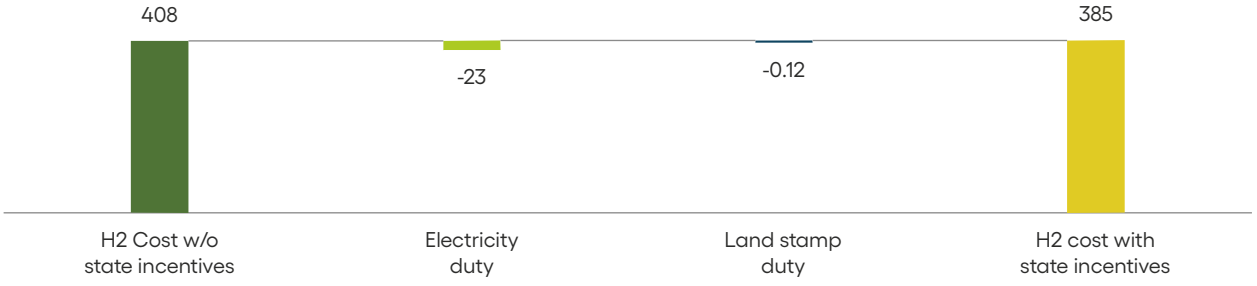
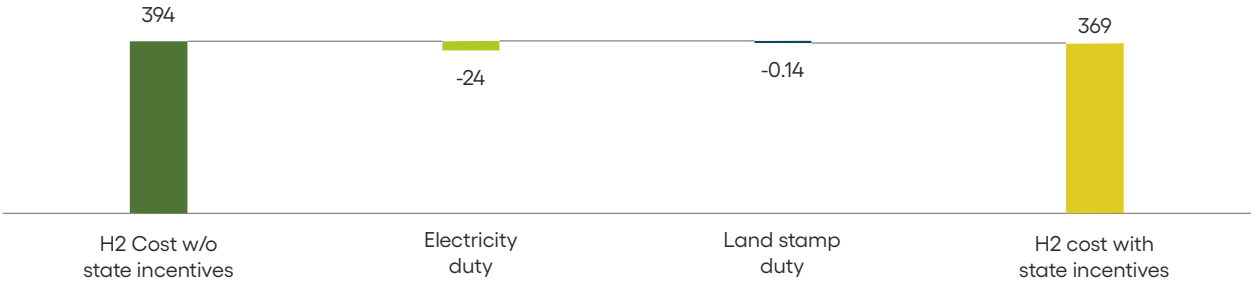


Figure 4.10 Maharashtra - Green Hydrogen Cost with State Key Incentives/Exemptions - Alkaline Plant (100 MW)



The cost of green hydrogen in Maharashtra, under central incentives alone, is projected to be approximately INR 394-409 per kilogram. This cost varies from that of Odisha due to differences in state-specific parameters such as taxes on sales and electricity duty. State-level incentives further reduce the cost of green hydrogen production by approximately 6%, decreasing the price from INR 394-409 per kg to INR 369-385 per kg.

While our cost modeling primarily focuses on ISTS-connected green hydrogen production, it's important to highlight that Maharashtra offers significant incentives for InSTS-connected projects, including a 50% exemption from InSTS charges and wheeling charges for stand-alone hydrogen plants and a 60% exemption for hybrid hydrogen plants. Additionally, the state provides exemptions from CSS and ASC for green ammonia projects, further reducing operational costs. Other post-production incentives, capital subsidies for hydrogen transportation pipelines, and interest subsidies, along with support for anchor projects, while not directly factored into the computed production costs, play a vital role in strengthening the green hydrogen value chain in Maharashtra.

Uttar Pradesh

The incentives considered to estimate the cost of green hydrogen production for a plant in Uttar Pradesh are derived from the state's Green Hydrogen Policy. Under this policy, Uttar Pradesh offers most incentives based on the size of the plant. The calculations presented here are specifically for a large-scale plant. The different types of incentives considered in the model are outlined below:

Table 4.6 Green Hydrogen Production Incentives in Uttar Pradesh

Incentive Type	Details
Capital Subsidy	10-15% capital subsidy for a large plant based on the exact location of the plant.
Electricity Duty Exemption	Waiver on CSS, ED, intra state wheeling/transmission charges and ASC for up to 10 years after CoD
Exemption on stamp Duty	100% exemption on stamp duty for land purchased or leased
Subsidized Land Cost	Government /Gram Samaj land will be made available to PSU/Joint Establishments of Central Govt./State Govt. on lease basis for 30 years at Re 1/acre/year Government / Gram Samaj land will be made available to private investors on a lease basis at Rs. 15,000/acre/year for 30 years

Based on the incentives and exemptions mentioned above the following graphs show the final cost estimate of green hydrogen produced in Uttar Pradesh.

Figure 4.11 UP - Green Hydrogen Cost with State Key Incentives/Exemptions - Alkaline (100 MW)

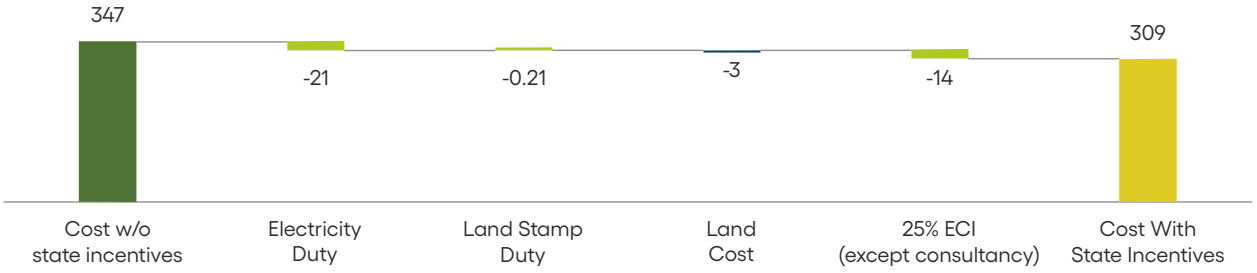
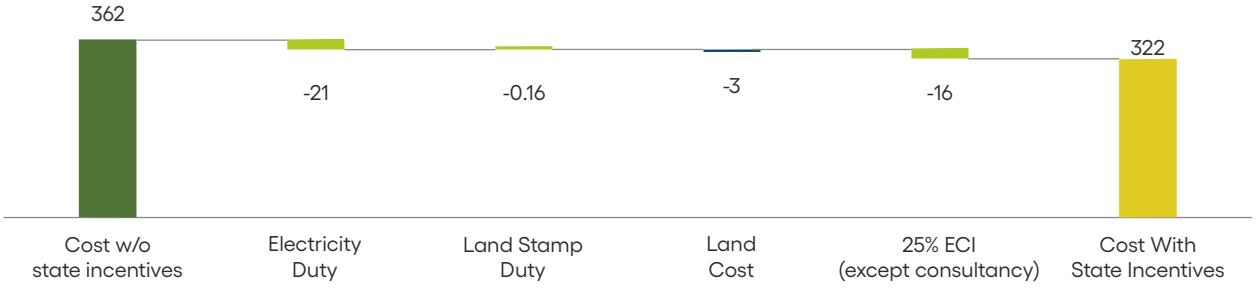


Figure 4.12 UP - Green Hydrogen Cost with State Key Incentives/Exemptions - PEM plant (100 MW)



With these incentives, the cost of green hydrogen production can be reduced by approximately 11%, lowering the price from INR 347-362 per kg to INR 309-322 per kg.

In Uttar Pradesh, the state offers a financial incentive of up to ₹25 lakhs per year for five years specifically for start-ups. However, eligibility for this incentive is limited to those start-ups registered under incubators affiliated with educational institutions. This incentive, while not directly computable in the model, provides support for fostering innovation and growth within the state's green hydrogen sector.

Gujarat

The incentives considered to estimate the cost of green hydrogen production for a plant in Gujarat are derived from the state's Green Hydrogen Policy and the Atmanirbhar Gujarat Industry Policy. The different types of incentives considered in the model are outlined below:

Table 4.7 Various Types of Incentives considered in the Model

Incentive Type	Details
Financing	Assistance of interest subsidy at 7% on Term Loan up to 1%-1.2% of eFCI per annum for 8-10 year according to different categories
Electricity Duty Exemption	100% Exemption from Electricity Duty
Subsidized land Cost	Annual rent of INR 15,000 per hectare per year with 15% increase in every three years
SGST reimbursement	80-100% of net SGST reimbursement eligible for 10 years subject to a cap of 5.5%-8% of eFCI per annum according to different categories (as per document in comments)

Based on the incentives and exemptions mentioned above the following graphs show the final cost estimate of green hydrogen produced in Gujarat.

Figure 4.13 Gujarat - Green Hydrogen Cost with State Key Incentives/Exemptions - Alkaline (100MW)

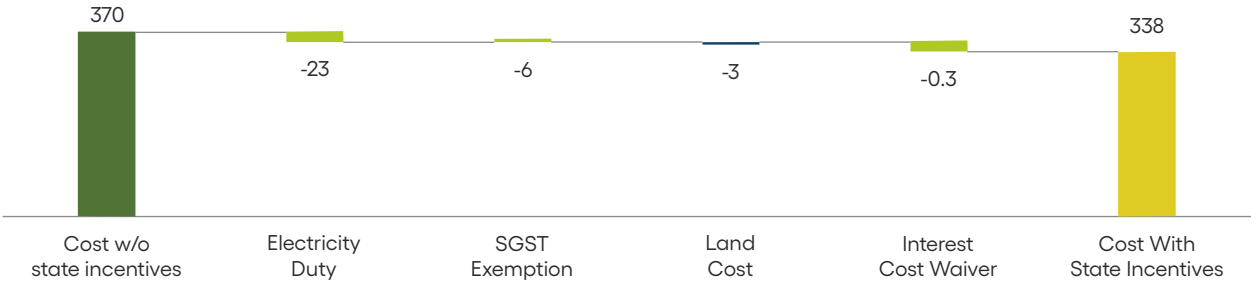
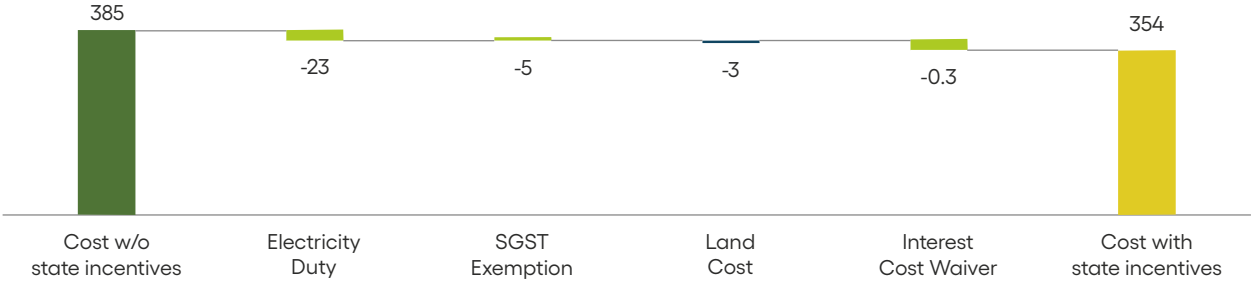


Figure 4.14 Gujarat - Green Hydrogen Cost with State Key Incentives/Exemptions - PEM (100MW)

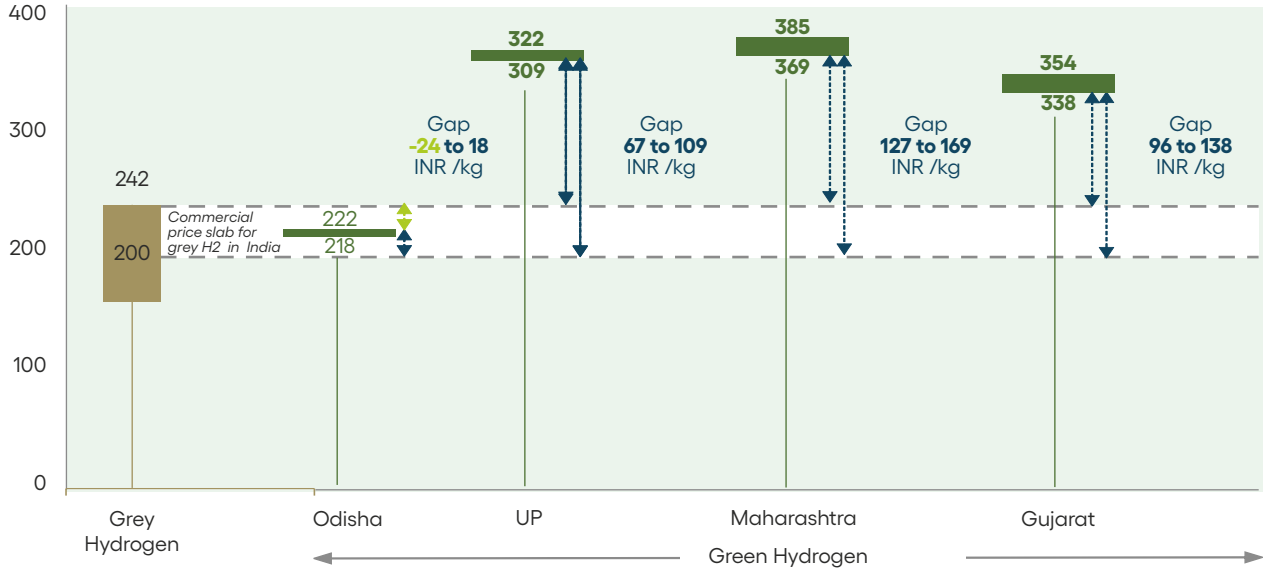


With these incentives, the cost of green hydrogen production can be reduced by approximately 9%, lowering the price from INR 370-385 per kg to INR 338-354 per kg.

In addition to the directly computable incentives, the state offers several other benefits that support green hydrogen production. These include a 7% interest subsidy on term loans, capped at 1.2% of eFCI per annum for 10 years, 100% reimbursement of the employer's statutory contribution to EPF, full reimbursement of input GST on capital goods, complete reimbursement of stamp duty and registration charges to the Government of Gujarat, and a 40-year land lease for renewable energy plants dedicated to green hydrogen production. These incentives, while not directly computable in the model, play a crucial role in enhancing the overall feasibility of green hydrogen projects in the state.

4.5 Comparison of grey hydrogen and green hydrogen prices

Figure 4.15 Comparison of Grey Hydrogen and Green Hydrogen Price



Comparing the prices of green and grey hydrogen reveals significant differences, driven by various factors such as production costs, government incentives, and potential carbon taxes. The base price for green hydrogen ranges from **427 to 444 INR/kg** (calculated for PEM and alkaline, using the cost estimation model with POCC incentive). The figure showcases green hydrogen prices across different states for both alkaline and PEM plants, structured in a slab format for each state, incorporating the state-specific incentives discussed in earlier sections. The grey hydrogen's cost, without accounting for carbon credits, lies between approximately **200 to 242 INR/kg** (for natural gas delivered prices of $12/MMBTU - $15/MMBTU).

The calculation of price gap is done with the price of green hydrogen from an alkaline plant. In some states like Odisha, green hydrogen is already cost-competitive with grey hydrogen due to the national and state incentives. For instance, in Odisha, the price of green hydrogen is **218 INR/kg**, which is **24 INR/kg** lower than the grey hydrogen price of **242 INR/kg** (for natural gas delivered prices of $15/MMBTU). However, in other regions such as Maharashtra, the price of green hydrogen is **369 INR/kg**, which is **143 INR/kg** higher than the grey hydrogen price. This gap can be addressed via additional incentives, carbon credits or other market based mechanisms. Considering carbon price scenarios with carbon prices at $10, $50 & $100 per tonne, the potential benefit to green hydrogen is likely to be ~INR 7-8/kg, INR 37-40/kg, INR 74-80/kg respectively for these three scenarios.

4.6 Conclusion

Basis the analysis conducted, the following conclusions may be drawn:

1. Increase in scale of green hydrogen production is expected to have a significant impact on the cost of green hydrogen production. As per available reports, the increase in the capacity of a green hydrogen production plant by a factor of 10 (e.g. 10 MW to 100 MW) is expected to potentially result in a decrease of INR 20/kg in the levelized cost of hydrogen (LCOH). So, encouraging development of centralized large-scale production units within industrial hubs, where demand is concentrated and transportation requirements are minimal, could lead to a substantial reduction in capital expenditure.
2. In the absence of incentives, electricity cost accounts approximately 65% - 75% of the cost of green hydrogen. Hence, incentives to reduce the electricity cost are expected to considerably decrease the cost of green hydrogen. Further, the availability of cost competitive round-the-clock RE power would have a notable impact on the costs because of the substantial difference in RE RTC power (INR 4.6-5 per kWh)[5] and solar power costs (INR 2.8-3.5 per kWh[6]). This can be achieved by providing reliable power banking for ISTS projects. The developer can optimize the cost of green hydrogen by aligning the electrolyzer operations to the solar generation hours. Though, a detailed cost benefit analysis would be required to determine the most optimum option from utilizing BESS, Pump storage, green hydrogen storage, aligning operations to solar generation hours etc.
3. To attract investment in green hydrogen projects, offering concessions on loans, such as lower interest rates and flexible repayment terms, can be an effective strategy. For example, a 2% concession on commercial loans can reduce the cost of green hydrogen by approximately ~INR 16-18 per kg.

[5] As per the FDRE tender bid-results in September 2023

[6] Recent SECI bids

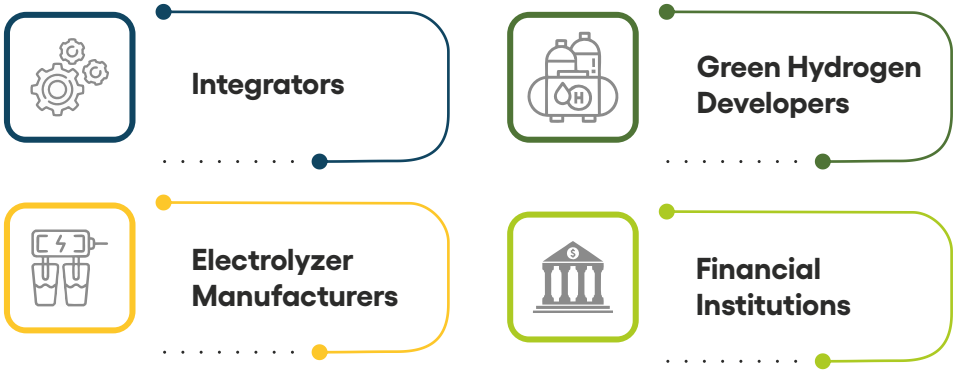
4. The states can incentivize first movers by providing special incentives like the capital subsidy on green hydrogen production plant offered by UP and Maharashtra or a subsidy on capital cost of RE plant installation offered by Maharashtra.
5. The power incentives provided by Odisha i.e. INR. 3/kWh rebate on power procured through grid and ED exemption for 20 years has the most significant impact on the cost of green hydrogen amounting to approximately INR 120-130/kg of hydrogen. This along with other incentives provided by the state, puts the green hydrogen cost at close to parity with the grey hydrogen cost at ~$12-$15/MMBTU.
6. Quick implementation of carbon pricing and allowing green hydrogen projects to monetize the carbon credits in the market would help bridge the cost gap between green and grey hydrogen. Considering a carbon credit price scenario of $10, $50 & $100 per tonne of CO2 emission, the potential impact is likely to be ~INR 7-8/kg, INR 37-40/kg, INR 74-80/kg of green hydrogen for these three scenarios.

Feedback & Insights from Stakeholders 5

5 Feedback & Insights from Stakeholders

During this study, ICF engaged with various industry stakeholders including green Hydrogen developers, electrolyzer manufacturers, investors, financiers, DFIs, MFIs to obtain their inputs on the assumptions used in the model. They were also consulted about incentives they consider essential to lower the cost of green hydrogen production in India. These interactions provided valuable insights into the practical challenges and opportunities in the sector.

Figure 5.1 Types of Stakeholders Consulted



The feedback from these stakeholders has been incorporated into the green hydrogen production cost model. Their recommendations regarding the support needed to reduce the cost of green hydrogen in India have been summarized in Table 5.1.

Table 5.1 Recommendations for Reducing Cost of Green Hydrogen in India

	Financing Support
1	**Low-Interest Loans or Grants:** Establish low-interest loans or grants for companies and startups developing or using green hydrogen technologies.
2	**Long-Term Contracts:** Ensure long-term contracts fostering a stable investment environment.
3	**Promote Green Bonds and sustainability bonds:** Promote green bonds and other sustainable financing mechanisms. Attract investment in green hydrogen projects by offering tax benefits on these bonds.

	Demand pull mechanisms
1	**Direct Subsidies:** Provide direct subsidies for the production and use of green hydrogen to narrow the cost gap between green and grey hydrogen.
2	**Emission Reduction Targets:** Set stringent emission reduction targets for industries, incentivizing the transition to green hydrogen. Offer incentives to industries such as steel, ammonia, and chemicals to switch to green hydrogen, thereby creating a demand-pull effect.
3	**Penalize Grey Hydrogen Use:** Impose penalties on the retail cost of petrochemical and refinery outputs that utilize grey hydrogen to discourage its use.
4	**Mandatory Green Hydrogen Offtake:** Mandate the use of green hydrogen for specific sectors, similar to Renewable Purchase Obligations (RPO)
5	**Green Procurement:** Incentivize the implementation of green procurement policies across end-user organizations, such as the steel industry to significantly drive the demand for green hydrogen and support other sustainable energy alternatives.

	Tax incentives
1	**Tax Breaks for Initial Years:** Offer tax breaks for the first five years of operations to enhance the viability of green hydrogen projects. Also, facilitate reduction in electrolyzer cost by encouraging the development of large-scale electrolyzer manufacturing plants, with the support of some tax breaks from the GoI for the initial years.
2	**Tax Incentives for Investments:** Implement tax incentives or rebates for companies investing in green hydrogen technologies and infrastructure.
3	**Subsidies for Electrolyzer Plants:** Provide subsidies for setting up electrolyzer plants and exempt them from taxes like Basic Customs Duty (BCD) and Goods and Services Tax (GST).
4	**Income Tax Benefits for OPEX:** Allow deductions for total operating expenses from total tax liabilities.
5	**Import/export support:** Waive or reduce duties on import of critical minerals. Negotiate trade agreements to enable the export and import of hydrogen across borders at competitive rates.

Viability Gap Funding	
1	**Government Price Guarantees:** Implement schemes where the government guarantees a fixed price for green hydrogen, covering the difference between production cost and market price.
2	**Incentives for Hydrogen Production:** Offer production incentives for green hydrogen, similar to the $3/kg incentive under the United States Inflation Reduction Act.

Standardized regulations for RE support	
1	**Standardized Regulations:** Standardize regulations across regions to facilitate easier and faster deployment of green hydrogen infrastructure and integration, thus ensuring uniformity and reducing administrative hurdles.
2	**Banking Regulations for RE:** Implement banking regulations that allow for longer hours of energy storage, which would reduce the overall cost of renewable energy—RE-RTC power.
3	**Fixed Dispatchable Renewable Electricity (FDRE) Market:** Develop and activate the Fixed Dispatchable Renewable Electricity market to provide cheaper electricity with higher Full Load Hours (FLH) for electrolyzers, ultimately lowering the cost of green hydrogen production.

Other suggestions	
1	**R&D Support:** Support investments in R&D to increase the efficiency of electrolyzers.
2	**Carbon Credits Market:** Establish a robust carbon credits market to enhance the viability of green hydrogen projects. Allowing either the GH2 producer or buyer to retain the credits will promote market flexibility.

Recommendations for **enhancing viability of green hydrogen in India**

6

6 Recommendations for enhancing viability of green hydrogen in India

6.1 Recommendations

1. Detailed Assessment at National Level

A comprehensive national-level analysis is imperative for the large-scale adoption of green hydrogen. This necessitates conducting in-depth feasibility studies to identify potential optimizations that can significantly reduce the cost of power. Such interventions are crucial for enhancing the efficiency and economic viability of hydrogen production and utilization.

Key areas of focus include:

- The development of banking mechanisms and the strategic use of electrolyzers in alignment with solar hours can optimize the hydrogen production processes.
- Additionally, studies on green hydrogen storage, ammonia storage, battery storage, and pumped hydro storage are essential to determine the most effective energy storage and management practices.
- Moreover, exploring the integration of solar-wind hybrid systems, which can provide a balanced and reliable energy supply, will enable continuous and efficient green hydrogen production.

These comprehensive studies will lay the groundwork for a sustainable and economically viable hydrogen economy in India, facilitating the transition to a low-carbon energy future.

2. Development of Green hydrogen Production Cost Tool

A comprehensive and robust dynamic tool for real-time cost assessment of green hydrogen produced across various states in India would enable investors and hydrogen producers to analyze the feasibility of their projects by providing detailed insights into regional cost variations, available incentives, and potential financial benefits.

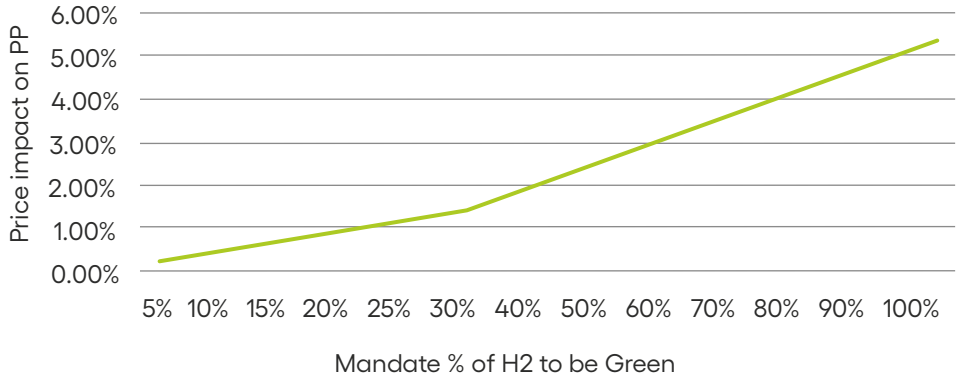
By incorporating factors such as local renewable energy prices, infrastructure costs, and state-specific subsidies, this tool could offer a clear and region-specific picture of the economic landscape for green hydrogen production. Additionally, it could help design tailored incentives to promote investment in regions with the highest potential for cost-effective hydrogen production. This tool would serve as a critical resource for stakeholders, facilitating informed decision-making and accelerating the adoption of green hydrogen technologies across the country.

3. Sector-specific Green Hydrogen targets / Green Procurement:

Implementing sector-specific Green Hydrogen targets for the natural gas, refining, and ammonia sectors—key consumers of hydrogen in India—could significantly drive the demand for green hydrogen. An analysis of the feasibility of such mandates is discussed in brief:

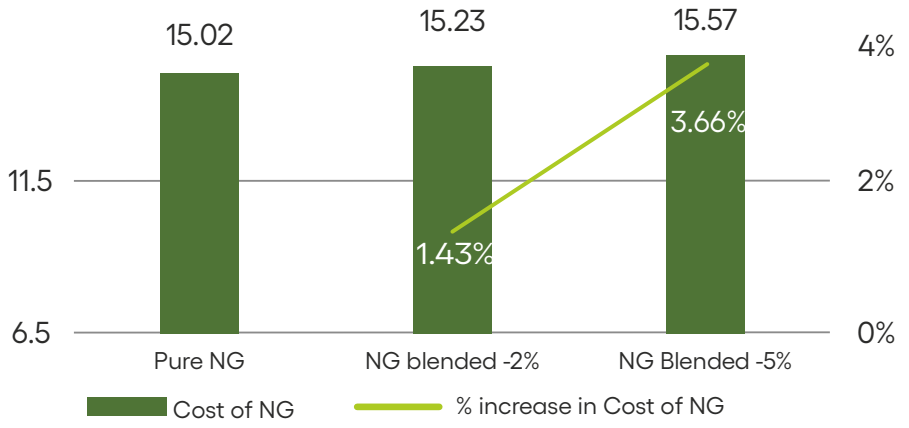
- The **implementation of green hydrogen mandates in refineries**, which will replace grey hydrogen, is expected to result in increased costs for the refineries. While these mandates may lead to a rise in the prices of petroleum products, the impact is projected to be minimal. Specifically, at a 50% green hydrogen mandate, the increase in petroleum product prices is estimated to be around 2.5%.[1]

Figure 6.1 Price Impact of Green Hydrogen Mandates on Petroleum Products



- **Hydrogen blending into natural gas** is a promising approach to reduce carbon emissions while utilizing existing infrastructure. However, blending increases the nominal price of natural gas due to the higher costs associated with producing green hydrogen. For instance, a 5% hydrogen blend by volume results in a 3.66% increase in the nominal price of natural gas, while a 2% blend leads to a 1.43% increase[7]. These figures illustrate that even small percentages of hydrogen blending can have a noticeable impact on the overall price, which is an important consideration for the economic feasibility and market acceptance of such initiatives.
- Incentivizing the of green procurement policies (incl. public procurement policies) across end-user organizations, such as the steel industry, could significantly drive the demand for green hydrogen and support other sustainable energy alternatives.

Figure 6.2 Increase in Natural Gas Cost with Blending of Green Hydrogen ($/MMBTU)



4. Demonstration Projects:

Hydrogen demonstration projects in India, with government backing and sectoral contributions, can significantly benefit various end-use sectors by convincing them of the practical applications and advantages of hydrogen technology. As a result, if green hydrogen is widely adopted, these projects would drive down production costs through economies of scale and technological advancements.

Example - New York Power Authority (NYPA) Hydrogen Blending Demonstration Project

NYPA, in collaboration with GE and the Electric Power Research Institute (EPRI), conducted a hydrogen blending demonstration at the Brentwood Power Station. The project involved blending hydrogen with natural gas to power a gas turbine. The project demonstrated that blending hydrogen with natural gas could reduce carbon emissions by up to 14% with a 35%

[7] ICF Analysis

hydrogen blend. The reduction in emissions could translate to significant cost savings in **carbon credits and compliance with environmental regulations**. Additionally, the project showed that existing power plants could be retrofitted to use hydrogen blends with minimal modifications, **potentially saving millions in infrastructure costs.**[28]

5. Ensuring Large-scale Green Hydrogen Production

The establishment of large-scale green hydrogen plants is strongly recommended. Global studies indicate that increasing the capacity of electrolyzer plants can lead to substantial cost reductions driven by economies of scale. For example, scaling up from a 10 MW plant to a 100 MW plant can potentially result in a decrease of INR 20/kg in the levelized cost of hydrogen (LCOH). Further, larger plants can optimize the procurement of raw materials, streamline operational processes, and leverage advanced technologies, all of which contribute to reduced costs

6. Augmentation of Hydrogen Hubs

Hydrogen hubs are pivotal to centralizing the production and distribution of hydrogen, thereby enhancing both supply chain efficiency and reliability. By concentrating production in larger facilities, significant economies of scale can be realized.

To further this goal, aggregating demand from local hydrogen demand zones near these hubs is essential. Additionally, developing infrastructure to connect these demand zones with the hydrogen hubs will facilitate the growth of green hydrogen demand.

Advancing the development and operation of hydrogen hubs requires a robust network of facilitators and stakeholders. Government agencies, industry consortia, and research institutions must actively collaborate to drive investment and innovation within these hubs.

7. Relaxation on Import Taxes

High import duties on essential components like electrolyzers and renewable energy equipment can inflate the overall cost of green hydrogen production. So, reducing or exempting import taxes on green hydrogen-related equipment can make green hydrogen more economically viable and encourage investments in the sector, thus fostering innovation and accelerating the adoption of green hydrogen technologies. By implementing favorable import taxation policies, India can enhance its green hydrogen production capabilities, and reduce reliance on imported fossil fuel.

8. Carbon Credits Market

Activating and integrating a robust carbon credits market can boost the viability of green hydrogen (GH2) projects. Introducing carbon reduction incentives can significantly enhance the financial attractiveness of GH2 initiatives. Allowing flexibility within the market, either the GH2

producer or the buyer should have the option to retain the carbon credits. This flexibility can create additional revenue streams and improve the overall project economics. A dynamic carbon credits market will not only align with decarbonization goals, but also make GH2 projects more competitive, by attracting greater investment and participation.

9. Financing Support

The adoption of green hydrogen in India can be accelerated through a comprehensive financing support framework. Some of the measures that can be taken include -

- Availability of soft loans at low interest rates makes it easier for both startups and established companies to secure funding.
- Partial guarantee schemes to mitigate risks associated with large-scale investments encourage growth in this emerging sector.
- Green hydrogen sector focused sustainability bonds and green bonds to channel investments in the sector.

These financial instruments can make it more feasible for companies to invest in green hydrogen technologies, fostering innovation and growth of the industry.

10. Development of Port Infrastructure

To effectively position green hydrogen (GH2) as a major export commodity, it is crucial to develop specialized port infrastructure. This includes upgrading and expanding ports to handle the unique requirements of GH2 export, such as safe storage, handling, and transportation facilities for hydrogen. Infrastructure development should align with national initiatives like India's Harit Sagar Guidelines, which promote environmentally sustainable practices in ports, including those necessary for GH2 export. Key Indian ports such as Kandla, Paradip, and Visakhapatnam have been identified as potential hubs for green hydrogen exports. By concentrating on the enhancement of these strategic locations, India can strengthen its position in the international green hydrogen market.

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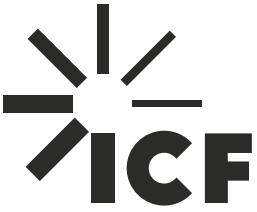

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