INNOVATION CENTRE DENMARK

2024

AN ICDK REPORT

# INDIA'S GREEN HYDROGEN R&D ECOSYSTEM

## Key Stakeholders and Strategic Insights across the Value Chain

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# EXECUTIVE SUMMARY

As of today, India uses only grey hydrogen and the country consumes about 5 million tons of it every year. India aims to generate 5.5 million tons of green hydrogen by 2030, to replace fossil fuels used in heavy industry and generate low-emissions versions of products like ammonia, which is used to make fertiliser.

India's aspiration to become a leading player in the green hydrogen sector hinges on technological innovation. This report aims to capture and identify research and development activities being conducted at various institutions across India in the field of green hydrogen. The primary objective is to identify key stakeholders throughout the value chain of green hydrogen. By doing so, we intend to leverage this information to effectively promote the 2024 bilateral call between India and Denmark on “Cutting-edge Hydrogen Technologies”.

In the short term, ICDK Bangalore’s Innovation Project “Enhancing Collaboration for India’s Green Hydrogen Research Landscape” aims to provide an overview of research and development activities across various institutions across India. It will aid in facilitating knowledge sharing and networking between actors in India and Denmark and support the development of consortia for upcoming research calls and projects. We aim to do this by setting up workshops and seminars for this engagement. In the long term, the project seeks to establish enduring collaborations and projects involving public, private, and academic stakeholders from both countries. Follow-up on potential leads will be ensured through 1:1 meetings, fostering continuous engagement and progress.

Through this report, we have identified academic institutions involved in the Green Hydrogen sector in various capacities. Additionally, we have compiled a detailed document listing key contacts within these institutions. Furthermore, we have summarised India’s Green Hydrogen R&D priorities, including objectives and gaps across its value chain.

# POLICY OVERVIEW

India is actively pursuing green hydrogen as a key component of its low-carbon transition and climate goals. The National Hydrogen Mission, launched in 2021, aims to make India a global hub for green hydrogen production and export by 2030, while reducing fossil fuel dependency. Key policies under this mission include the 2022 Green Hydrogen Policy, which offers incentives like exemptions on inter-state transmission charges, priority grid access, and easier land allocation for renewable energy projects.

The R&D landscape in India is vibrant, focusing on developing efficient electrolyser technologies, innovative storage and distribution solutions, and diverse applications in industries and transportation. Institutions like Indian Institutes of Technology (IITs) and the Council of Scientific and Industrial Research (CSIR) are at the forefront of research, supported by public sector units and international collaborations. With strong governmental support and cross-sector partnerships, India is poised to advance its green hydrogen infrastructure, drive down costs, and become a major player in the global hydrogen economy.

# AN OVERVIEW OF INDIA'S HYDROGEN RD&D CLUSTERS

Since the launch of the National Hydrogen Mission, India has seen the announcement of numerous large-scale hydrogen projects across both the public and private sectors. The country's approach to research, development, and demonstration (RD&D) is characterized by localised partnerships between industry and research institutions.

Notably, the Indian Institutes of Technology (IITs) operate 23 locations focused on hydrogen RD&D, working collaboratively with local industries and stakeholders on projects tailored to regional strengths and priorities.

India hosts over 100 research groups dedicated to fuel cell technology, with an additional focus on enhancing water-splitting efficiency and advancing materials, catalysts, and electrodes. The Delhi region is a major hub for hydrogen RD&D activities.

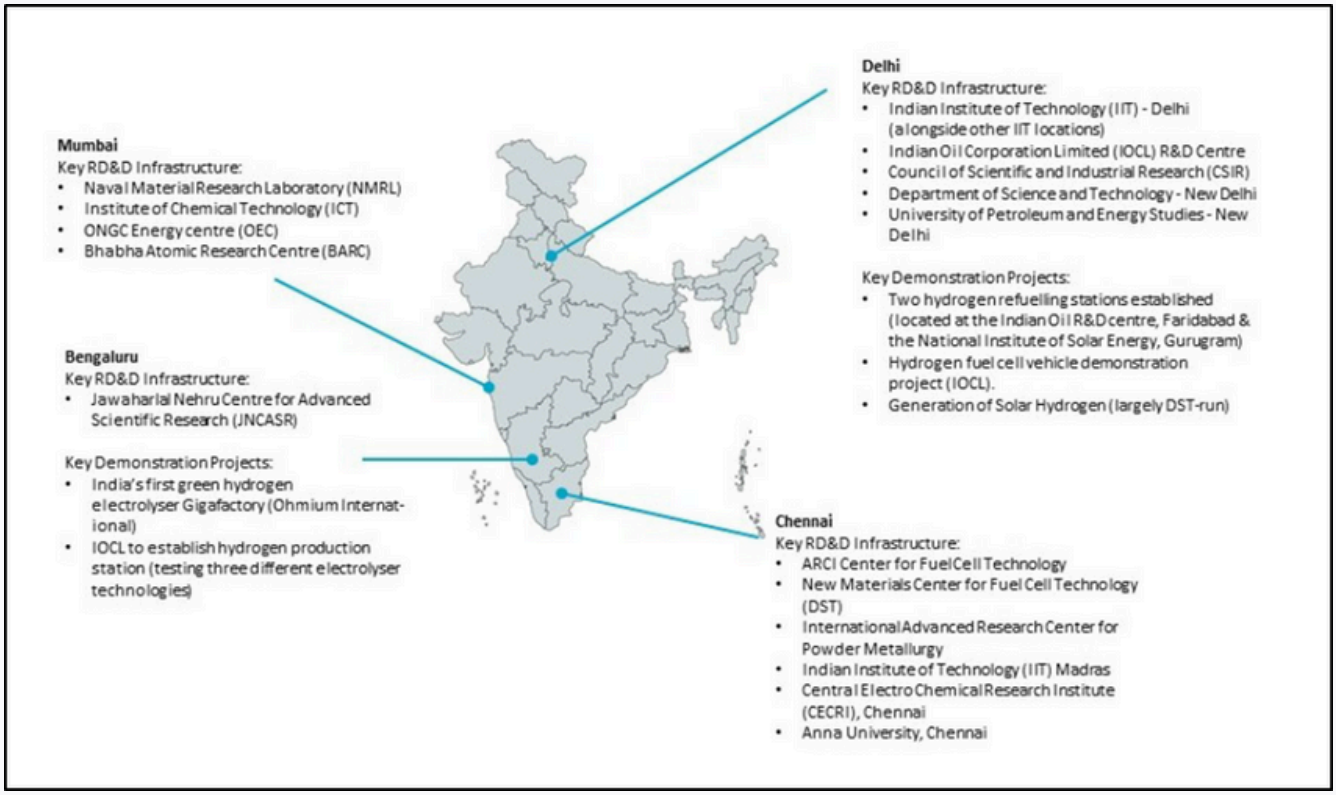
Many pilot and demonstration projects receive support from the private sector, often through government-backed Production Linked Incentive (PLI) schemes administered by agencies like the Ministry of Renewable Energy (MNRE), which aim to drive progress in specific technology areas

# HYDROGEN VALLEYS

The Government of India has approved funding of DKK 5 million each over five years to four Hydrogen Valleys in the country. The approval was granted by the Department of Science and Technology under the Union Ministry of Science and Technology based on the merits and preparedness of the recommended Hydrogen Valley Innovation Clusters (HVICs). The selected HVICs and their focus areas are:

| HVIC LOCATION | HYDROGEN PRODUCTION METHOD | APPLICATION FOCUS |
|---|---|---|
| Pune | Bioethanol and electrolyser | Fine chemicals and mobility industries |
| Jodhpur | Biomass and electrolyser, ammonia production | Internal combustion engines and city-gas blending |
| Bhubaneshwar | Electrolyser | Steel and mobility sectors |
| Kerala | Biomass and Electrolyser | Shipping and roadways |

# AREAS OF HIGH R&D ACTIVITIES IN INDIA




**Source - CSIR Hydrogen R&D collaboration opportunities: India**

# INDIA'S GREEN HYDROGEN R&D PRIORITIES

India's Ministry of New and Renewable Energy (MNRE) has developed a comprehensive R&D roadmap to address the challenges and opportunities in the hydrogen sector. The following section summarizes the key objectives and gaps as outlined in the report*. Addressing these gaps through targeted R&D and strategic partnerships will be crucial for advancing the hydrogen supply chain.

## 1 | HYDROGEN PRODUCTION

**Objectives:**

- **Cost Reduction (CAPEX, OPEX): Lower the capital and operational expenses of hydrogen production.**
- **Efficiency: Enhance the overall efficiency of hydrogen production processes.**
- **Durability & Reliability: Improve the durability and reliability of production systems.**
- **Low Carbon Emission: Minimize carbon emissions from hydrogen production.**
- **Circular Economy: Promote sustainability and recycling within the production process.**
- **Design & Development: Advance the design and development of electrolysers and their balance of plant (BOP) components.**
- **Materials & Components Stock: Ensure a steady supply of essential materials and components.**
- **Deployment Rates: Increase the deployment rate of hydrogen production technologies.**

**Gaps:**

- **PEC, PC, Biological Methods, Fuel Processing, Thermochemical Hydrogen: Need advancements in these areas.**
- **Catalyst Tolerance: Development of catalysts that can tolerate CO is required.**
- **Separation Technology: Membrane/chemical separation methods for H2 and O2 need improvement.**
- **Interfacial Chemistry: Enhancement in catalyst/electrolyte interfaces.**
- **Corrosion Resistance: Need for materials that resist corrosion and high temperatures in thermal hydrogen production.**
- **Theory & Modelling: Better understanding of the mechanisms of hydrogen production and chemical processes.**
- **Life Cycle Assessment (LCA): Implementation of comprehensive LCA for production processes.**



*the report is titled "R&D Roadmap for Green Hydrogen Ecosystem in India" published in Oct 2023.

# 2 | HYDROGEN STORAGE

**Objectives:**

- **Efficiency & Safety: Develop efficient, safe, low-cost, durable, and high-density storage solutions for quick refueling.**
- **Cost Reduction: Lower the CAPEX of hydrogen storage to less than ₹30,000/kg by 2030.**
- **Underground Storage: Study, identify, and validate underground storage options, reducing CAPEX to less than ₹3,000/kg by 2030.**
- **Development of Storage Solutions: Advance the development of Type III/IV compressed hydrogen tanks, and explore new materials like alloys, porous materials, and composites.**
- **Material Identification: Use machine learning and AI for material identification.**
- **Demonstration Units: Create demonstration units (tanks/canisters) for various applications.**
- **Safety Protocols: Establish comprehensive safety protocols.**
- **Deployment Rates: Increase deployment rates of hydrogen storage solutions.**

**Gaps:**

- **Raw Materials: Lack of raw materials like aluminium alloy liners and carbon fibre for Type III cylinders.**
- **Manufacturing: Absence of manufacturing units for high-pressure valves.**
- **Testing Facilities: Lack of testing facilities, regulations, and standards for hydrogen storage.**
- **Regulatory Support: Insufficient regulatory support and standardisation.**

# 3 | HYDROGEN TRANSPORT

**Objectives:**

- **Efficiency: Improve the efficiency and reduce the cost of hydrogen liquefaction technologies and other new technologies.**
- **Round Trip Efficiency: Enhance the round trip efficiency, LCA, and chemistry of hydrogen carriers.**
- **Hydrogen Pipelines: Develop 100% hydrogen pipelines.**
- **Cost Reduction: Reduce costs by increasing the capacity of tube trailers.**
- **Large-Scale Transport: Enable large, efficient liquid hydrogen transport on roads and ships.**

**Gaps:**

- **Testing Infrastructure: Inadequate testing infrastructure for hydrogen transport.**
- **Pipeline Issues: Challenges associated with hydrogen transport in pipelines.**
- **Manufacturing Capability: Limited manufacturing capability for transport-related equipment.**
- **Regulatory Compliance: Need for stringent regulations in transport and safety.**
- **Cryogenic Transport: Address issues related to cryogenic hydrogen transport.**
- **LOHC Conversion: Improve the conversion and reconversion of LOHC, considering scalability and environmental health impacts.**
- **Ammonia Cracking: Address NOx emissions from ammonia cracking.**
- **Leakage and Safety: Ensure safety protocols to prevent leakage during transport.**

# HYDROGEN PRODUCTION RESEARCH INITIATIVES

Various research groups in India are engaged in Research, Development, and Demonstration (RD&D) projects on hydrogen production. Below is a summary of the hydrogen production research initiatives by various research organisations in India.

| STAKEHOLDER | TYPE | FOCUS AREAS | POTENTIAL ROLES IN COLLABORATION |
|---|---|---|---|
| Bhabha Atomic Research Centre (BARC) | Government Research Institute | Electrolysis methods, thermo-chemical splitting, high-temp steam electrolysis, photocatalytic generation | Technology development, pilot projects, collaborative research |
| CSIR - CECRI, Karaikudi | Government Research Institute | PEM electrolysis, seawater hydrogen generation, photochemical oxidation, novel composite electrolytes | Technology transfer, industry collaboration, advanced research |
| ONGC Energy Centre (OEC) | Corporate R&D Center | Large-scale hydrogen generation, thermo-chemical water splitting, energy system integration | Industry collaboration, technology scaling, resource mobilization |
| Indian Oil R&D Centre, Faridabad | Corporate R&D Center | Indigenous hydrogen pathways, biomass gasification, solar-powered electrolysis, bio-CNG reforming | Demonstration projects, technology scaling, industry collaboration |

| STAKEHOLDER | TYPE | FOCUS AREAS | POTENTIAL ROLES IN COLLABORATION |
|---|---|---|---|
| KPIT Technologies | Private Technology Company | Biomass-to-hydrogen technologies, microbial dark fermentation, biomass gasification, distributed generation | Technology development, commercialisation, industry collaboration |
| The Energy and Resources Institute (TERI) | Non-profit Research Institute | Dark fermentation, lignocellulosic biomass hydrogen production, pilot-scale fermentation processes | Technology development, pilot projects, research funding, stakeholder engagement |
| CSIR - IICT | Government Research Institute | Biohydrogen from biogenic waste, process optimisation, pilot-scale production | Technology demonstration, industry collaboration, research funding |
| IIT Kharagpur | Academic Institution | Biohydrogen via dark fermentation, utilisation of organic wastes, pilot-scale production | Research collaboration, pilot projects, academic research |

In addition to these key research initiatives, many other research institutions in India are working on improving cell design for high performance and increasing cell/stack robustness. Detailed projects are covered in the annex.

# HYDROGEN STORAGE INITIATIVES

India's roadmap for hydrogen storage emphasises the need for efficient, low-cost, and durable solutions to facilitate easy and quick refueling. Objectives include reducing the CAPEX of hydrogen storage to less than INR 30.000 per kg by 2030 and developing Type III and IV compressed hydrogen tanks. The roadmap also calls for the study and validation of underground storage options and the use of machine learning (ML) and artificial intelligence (AI) for material identification.

Institutes in India has also undertaken significant research and development efforts in solid-state hydrogen storage. The research work being carried out at various institutions in this area is summarised below:

| STAKEHOLDER | TYPE | FOCUS AREAS | POTENTIAL ROLES IN COLLABORATION |
|---|---|---|---|
| Indian Institute of Technology Bombay (IIT Bombay) | Academic Institution | Hydrogen storage materials (metal hydrides, chemical hydrides, LOHC), system design and analysis | Research collaboration, technology development, performance analysis |
| Bhabha Atomic Research Centre (BARC), Mumbai | Government Research Institute | Hydrogen storage materials (main group elements, transition metals/alloys, porous carbon, nanotubes) | Development of storage technologies, research collaboration |
| Indian Oil R&D Centre, Faridabad | Corporate R&D Center | Hydrogen value chain, Type 3 composite cylinders for hydrogen storage | Industry collaboration, technology scaling, application development |

| STAKEHOLDER | TYPE | FOCUS AREAS | POTENTIAL ROLES IN COLLABORATION |
|---|---|---|---|
| DST – IIT Bombay Energy Storage Platform on Hydrogen | Collaborative Research Platform | Metal Hydrides (MH) synthesis and characterisation, fast reaction beds, MH thermal management | Large-scale synthesis, performance analysis, collaborative research |
| DST-Nonferrous Materials Technology Development Centre (NFTDC), Hyderabad | Government Research Institute | Hydrogen-based materials for energy devices | Research collaboration, material development, integration with other institutions |
| DST-IIT Hyderabad Integrated Clean Energy Material Acceleration Platform on Bioenergy and Hydrogen | Collaborative Research Platform | Biomass-to-hydrogen production, thermochemical systems, integration with bio-electrochemical and photocatalytic units | Development and scaling of production systems, research collaboration |
| Department of Science & Technology (DST) Advanced Hydrogen and Fuel Cell Program | Government Department | Hydrogen storage materials, catalysts, membranes, fuel cells, electrolysers | Support for indigenous development, implementation of hydrogen applications |

# HYDROGEN TRANSPORT DEVELOPMENTS

Progress in hydrogen transportation in India has been limited compared to global advancements. While hydrogen movement via pipelines, tube trailers, and marine transportation is well-established globally, India's efforts are still in the early stages. The focus is on pilot projects and initial developments.

## PIPELINE TRANSPORTATION:

- Gas Authority of India Ltd. (GAIL): Initiated a pilot project in Indore, Madhya Pradesh, to test the feasibility of hydrogen blending in the City Gas Distribution (CGD) network.
- Pipeline Infrastructure Limited (PIL): Partnered with DNV to integrate hydrogen into existing gas network assets.

## CYLINDER TRANSPORTATION:

- INOXCVA: Supplied the world's largest liquid hydrogen storage tank (238 $m^3$) for a hydrogen plant in South Korea.
- Chart Industries Inc.: Constructed over 800 hydrogen tanks at its facility in India.
- Linde: Provides various storage and transport solutions, including insulated tanks for liquid hydrogen and pressure-tight containers for compressed hydrogen.
- Air Liquide: Focuses on enhancing tank material strength for hydrogen storage.
- BHEL: Developing Type-IV hydrogen and CNG cylinders, with plans to establish dedicated Centers of Excellence (CoEs) and a national testing facility.

## RAIL TRANSPORTATION:

- The Indian Railways began transporting LNG in October 2022, and a comprehensive examination for hydrogen transport is underway. Compressed hydrogen gas is listed for freight, with a cost of INR 5.830 per tonne for 3.500 km.

## AMMONIA PRODUCTION:

- Avaada Group: Secured a deal with the Government of Rajasthan for a green ammonia facility with a production capacity of one million tonnes per annum.

- ACME Group: Established a pilot green hydrogen and ammonia plant in Bikaner, Rajasthan, with plans for additional facilities in Karnataka, Odisha, and Tamil Nadu.

## METHANOL PRODUCTION:

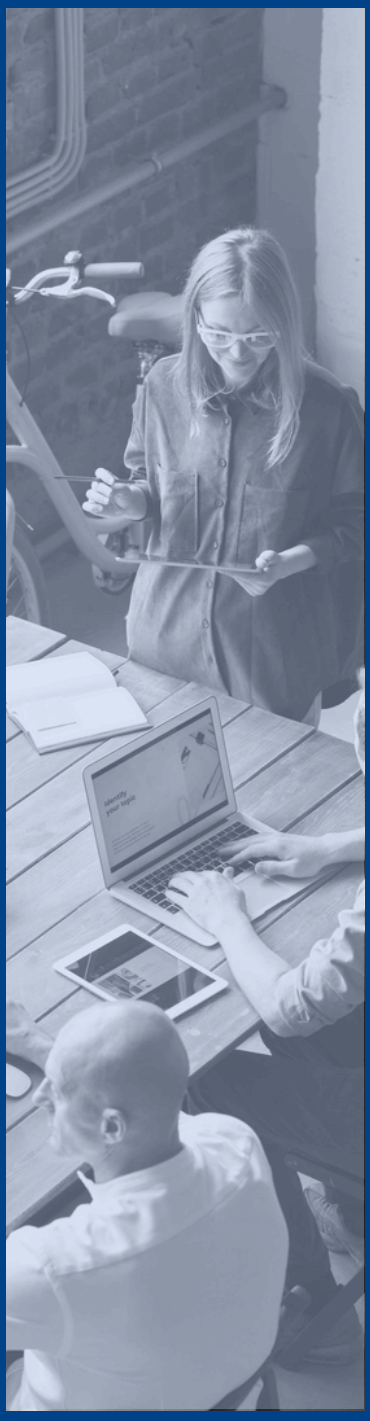
- Larsen and Toubro (L&T) and (National Thermal Power Corporation (NTPC): Collaborating on a demonstration plant for $CO_2$-to-methanol production, using captured $CO_2$ and environmentally friendly hydrogen generated via electrolysis.

# CONCLUSION

This report outlines India's current green hydrogen R&D landscape and identifies key stakeholders across the value chain. It highlights significant progress in hydrogen production, storage, and transport through various research institutions and industry collaborations. Despite these advancements, challenges such as cost reduction, efficiency improvements, and material development remain.

The 2024 bilateral call between India and Denmark called “Cutting-edge Hydrogen Technologies” offers a valuable opportunity to leverage these insights and foster international collaboration. By engaging with identified stakeholders, both countries can advance green hydrogen technologies and accelerate progress toward a sustainable, low-carbon future.

# CONTACT US



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