



India's Hydrogen Standards: Gap Assessment and Preliminary Action Framework

September 2026

Prepared under the aegis of
National Green Hydrogen Mission

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सत्यमेव जयते

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भारत सरकार
MINISTER OF EDUCATION, CONSUMER AFFAIRS,
FOOD & PUBLIC DISTRIBUTION AND
NEW & RENEWABLE ENERGY
GOVERNMENT OF INDIA



Message

I am pleased to share the report "*India's Hydrogen Standards: Gap Assessment and Preliminary Action Framework*", developed under the National Green Hydrogen Mission. This document reflects our commitment to building a safe, efficient, and globally competitive green hydrogen ecosystem for India.

To achieve the Mission's ambition of 5 MMT per annum of green hydrogen production capacity by 2030, India must establish a strong and harmonised standards architecture. Standards, testing systems, certification pathways, and regulatory clarity are essential to ensure safety, interoperability, and market confidence. This report provides a comprehensive mapping of existing standards and identifies priority gaps across production, storage, transport, and end-use applications—offering a clear pathway for adoption, adaptation, and development of new standards.

I am encouraged by the collaborative efforts of standards bodies, regulators, industry, and research institutions in shaping this assessment. The insights presented here will support India's efforts to align with international best practices, strengthen domestic testing and certification capacity, and enable Indian technologies and products to compete effectively in global markets.

This report is an important step toward making India a global hub for green hydrogen. I look forward to its swift and effective implementation.

(Pralhad Joshi)



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भारत सरकार



सत्यमेव जयते

SHRIPAD NAIK

Minister of State for

New and Renewable Energy & Power

Government of India



FOREWORD

I am pleased to note that report “India’s Hydrogen Standards: Gap Assessment and Preliminary Action Framework”, has been prepared under the National Green Hydrogen Mission. This timely assessment will help guide our efforts to build a safe, reliable and competitive green hydrogen sector.

Hydrogen has the potential to decarbonise industries where electrification is difficult. Today, India consumes about 5 million tonnes of hydrogen annually, mostly from fossil sources. Moving this demand to renewable-based hydrogen is central to our climate goals and energy security.

Standards, testing and certification are essential for safe deployment, product quality and investor confidence. This report maps existing standards across the hydrogen value chain, identifies priority gaps, and recommends clear actions—adopt, adapt, develop, or monitor—to close those gaps.

I thank all stakeholders—standards bodies, regulators, industry, research institutions and consultants—for their contributions. I urge all concerned ministries and agencies to review the recommendations and work together to implement the priority actions without delay.


(Shripad Naik)

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Government of India
Ministry of New and Renewable Energy



Foreword

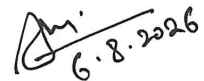
I am pleased to present the report titled *"India's Hydrogen Standards: Gap Assessment and Preliminary Action Framework"* prepared as part of National Green Hydrogen Mission. This assessment arrives at a decisive moment as India builds a safe, reliable and globally competitive green hydrogen ecosystem.

Hydrogen is emerging as a vital enabler of the energy transition and India's renewable & biomass-based hydrogen pathways offer a strategic opportunity to enhance energy security, reduce emissions, and support industrial transformation.

The National Green Hydrogen Mission sets an ambitious target of 5 MMT per annum of low-emission hydrogen production by 2030. Realising this ambition requires robust standards and quality-infrastructure ecosystem. As the report notes, a harmonised framework of standards, codes, testing systems, certification pathways and approval processes is essential to ensure safe deployment, product credibility, interoperability and international market acceptance.

This assessment maps 166 standards across the hydrogen value chain, including 31 hydrogen-specific Indian standards, and identifies gaps across production, storage, transport, end-use applications and cross-cutting safety domains. It proposes clear, actionable pathways—adopt, adapt, develop, and monitor—aligned with international references such as ISO, IEC, ASME and CEN.

I complement the dedicated efforts by experts and stakeholders who contributed to this assessment. The insights and recommendations contained herein will serve as a practical roadmap for policymakers, regulators, industry and testing agencies as we move to implement the National Green Hydrogen Mission.


(Santosh Sarangi)

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Mission Director
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Preface

The report titled “*India’s Hydrogen Standards: Gap Assessment and Preliminary Action Framework*”, aims to support the technical and institutional priorities emphasized in of the National Green Hydrogen Mission. This assessment provides a focused, evidence-based view of the standards landscape that will underpin safe deployment, industrial uptake, and export readiness for green hydrogen in India.

From a technical perspective, priority areas include: specification and qualification of electrolyzers and balance-of-plant; material and design requirements to address hydrogen embrittlement; validated test methods for high-pressure and cryogenic storage; interoperable interfaces for pipeline and tube-trailer transport; and harmonised requirements for fuel-cell systems and mobility applications. Equally important are conformity assessment mechanisms—accredited testing laboratories, certification routes, and clear approval pathways—that translate standards into implementable outcomes.

The report also highlights the need for coordinated action across BIS, PESO, PNGRB, OISD, MoRTH, testing agencies and industry. Strengthening laboratory capacity, formalising inter-agency technical working groups, and aligning Indian standards with relevant international references (ISO, IEC, ASME, CEN) where appropriate will reduce technical uncertainty and accelerate project execution.

I urge stakeholders to treat the recommendations in this report as a prioritized workplan: adopt internationally proven standards where fit-for-purpose, adapt references to Indian operating conditions, develop new standards where gaps are critical, and monitor emerging technologies and market requirements. Timely implementation of these measures will be essential to meet the Mission’s objectives and to position India as a safe and reliable supplier of green hydrogen and derivatives.

I sincerely appreciate the hard work by technical experts, standards bodies, regulators and industry partners who contributed to this assessment. The Mission will work closely with all stakeholders to operationalise the recommendations and to build the technical infrastructure required for safe, scalable and globally competitive green hydrogen deployment.

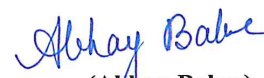

(Abhay Bakre)

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Executive Summary

The National Green Hydrogen Mission (NGHM) has created a strong platform for scaling green hydrogen and is on the path to position India as a global hub for the production, use, and export of low-emission hydrogen and its derivatives. Realising this ambition is relying on harmonized standards and codes ecosystem leading to safe implementation, production, enhancing product credibility and increasing exports

This report heralds while encapsulating the work already undertaken on standards by various institutions and presents a structured gap assessment of India's current hydrogen standards landscape. It methodically lays out, preliminary actions to address these gaps too in order to strengthen the ecosystem. The preliminary action framework is designed to support and augment the formal processes through which Indian standards are developed, validated, and notified by the Bureau of Indian Standards (BIS) and relevant statutory regulators.

The assessment is carried out by baseline mapping of standards and codes, a robust benchmarking of all existing roadmaps internationally taking into consideration India's near-term green hydrogen development pathways before presenting a preliminary action framework. The India landscape review covered the current standards inventory, progress since the launch of the NGHM, and the institutional architecture responsible for standards development, testing, certification, and approvals, including BIS, PESO, PNGRB, OISD, MoRTH and the automotive testing agencies (ARAI, ICAT), BEE, NISE, IRS, and RDSO.

India's mapped hydrogen value chain comprises **20 components and 50 sub-components**, against which **166 unique standards, codes, and reference documents** have been identified. Of these, **31 are hydrogen-specific Indian standards and codes**, with the remainder comprising international standards or reference documents used as references or under consideration for adoption or adaptation. **34 new hydrogen-related Indian standards** were issued in the fourteen months following the Mission's launch.

In order to keep consistency of treatment, clarity on scope and focus, guardrails were applied to this assessment which included renewable and biomass based pathways for production of green hydrogen, core hydrogen value chain focus, focus on assessment of published standards and implementation of the same.

The most critical part of the assessment was defining the hydrogen value chain. The value chain is organized into four segments, each disaggregated into components and sub-components that reflect the underlying technical content, operating conditions, and standards needs across the lifecycle:

The table below summarises the segments, coverage and components of the hydrogen value chain:

Segment	Coverage	Components
Production	Renewable energy input, water supply, and balance-of-plant requirements through to hydrogen generation via electrolysis and biomass-based routes	Balance of Plant; Decentralised/in-situ production; Electrolysers (ALK, PEM, AEM, SOEC); Emissions; Hydrogen Quality; Bio-based Production
Transport and Storage	Portable and bulk storage in gaseous and liquid/cryogenic form, storage safety, underground storage, and distribution	Portable Cylinders; Bulk Cylinders; Storage Safety; Underground Storage; Distribution
End-use Applications	Hydrogen use across mobility, stationary power, industrial processes, and other end uses	Fuel Cells; Hydrogen Dispensing; Road Vehicles; Domestic Applications; Industrial Applications; Shipping; Railways; Aviation
Cross-cutting Functions	General safety and enabling requirements applicable across the value chain	General Safety, covering occupational safety; fire, explosion and pressure equipment safety; hydrogen embrittlement; detection and odourisation; end-to-end system safety and layout; cybersecurity; and flow measurement

Gap Assessment: Key Findings

Each assessed sub-component is classified into one of three categories:

- No gap:** A usable Indian standard, code, or technical reference is available and considered adequate for the intended application.
- Partial gap:** A standard exists, and the degree of technical coverage is incomplete or fragmented relative to the intended application or the relevant international reference.
- Missing standard:** The component is in scope, and no usable Indian standard, code, or technical reference has been identified. This category includes areas where indigenous standards are currently under deliberation.

The table below summarises the status of standards based on the above classification for 50 assessed sub components:

Segment	Sub-components assessed	No gap	Partial gap	Missing standard
Production	14	4	5	5
Transport and Storage	16	5	4	7
End-use Applications	13	0	5	8
Cross-cutting Functions	7	3	1	3
Total	50	12	15	23

Several patterns emerge from the assessment:

- Production** shows the strongest coverage in mature technology areas. Indian standards are available for low-temperature electrolyser systems and efficiency (IS 16509, IS 19575:2026), hydrogen fuel quality (IS 16061:2026), and feedwater (IS 1070:2023). Gaps concentrate in balance-of-plant sub-components (vent systems, hydrogen supply systems, pumps and valves), high-temperature electrolysis, component-level electrolyser requirements, and well-to-gate emissions methodology.
- Transport and storage** presents a mixed position. Off-board gaseous and cryogenic portable cylinders, bulk cryogenic storage, pressure relief devices, and materials are supported by available Indian standards. Gaps concentrate in thermally activated pressure relief devices, roof safety, underground storage, and the distribution sub-segment, where indigenous standards for plant piping, transmission pipelines, rededicated gas systems, and tube trailers are either under deliberation or not yet available.
- End-use applications** show the highest proportion of missing standards, consistent with the earlier stage of deployment across stationary power generation, domestic and industrial applications, off-road vehicles, railways, shipping, and aviation. Partial coverage is available for fuel cells in vehicle applications (AIS 157, AIS 195) and gaseous hydrogen dispensing (IS 18538 series).
- Cross-cutting functions** are well supported for established safety topics such as fire, explosion and pressure equipment safety, hydrogen embrittlement, and detection and odourisation. Gaps are concentrated in end-to-end system safety and layout, cybersecurity, and flow measurement uncertainty, alongside partial coverage for hydrogen-specific occupational safety requirements.

Recommended Actions

Each identified gap is linked to one of three modes in the preliminary action framework:

- Could adopt:** Using an existing international standard, typically ISO or IEC, as an Indian standard where the international standard is directly applicable to Indian requirements. Examples include IEC 60079-14:2024 for electrical installation design in hydrogen-hazardous areas, and the ISA/IEC 62443 series and IEC 62351-9:2023 for cybersecurity in hydrogen production plants.
- Could adapt:** Using an international or industry-body reference with modifications reflecting Indian operating conditions, regulatory requirements, or technical parameters. Examples include updating IS 16735:2018 to address working pressures up to 700 bar and Type 2 and Type 4 cylinder configurations, adapting ASME B31.12 and ASME B31.8 for hydrogen transmission pipelines, and updating IS 18463:2023 to reflect relevant provisions of ISO 24251-1:2025.
- Could develop new standard:** Indigenous development where a suitable international reference is not available, or where Indian-specific parameters require a dedicated approach. Examples include vent systems, hydrogen supply systems, pumps and valves, high-temperature electrolyser efficiency, sector-specific industrial applications, and end-to-end system safety and layout.

Where technology readiness is at an early stage, including high-temperature electrolysis, domestic hydrogen appliances, and aviation applications, the recommended actions provide for pre-normative work, monitoring of international developments, and coordination with testing agencies and technology developers ahead of formal standardisation.

These actions are supported by a set of enabling measures identified in the assessment:

- Capacity building and workforce development,** through the NGHM's Skilling, Upskilling and Reskilling component implemented by MNRE in consultation with MSDE, covering operating personnel across production, storage and transportation, end-use, and safety functions.
- Approval and certification support,** including structured guidance on the sequence of approvals, required documentation, and institutional touchpoints across the project lifecycle.
- Standardised templates and documentation** for project design documents, safety case files, hazard and operability studies, emergency response plans, and inspection records.
- Industry and stakeholder participation** in Sectional Committees, Working Groups, and consultations, with feedback mechanisms during draft stages, pilot deployments, and post-notification reviews.
- Digital transparency and information access,** through a consolidated digital reference point for hydrogen-related standards, rules, regulations, and approval procedures.



Way Forward

Translating the gap assessment and preliminary action framework into a detailed implementation plan would benefit from further institutional deliberation through relevant technical committees, sectoral regulators, testing agencies and industry stakeholders. Four steps structure this transition:

- Assimilation of Gap Findings:** The gap findings, recommended actions, and underlying references could provide a common basis for review by relevant ministries, regulators, standardisation bodies, and technical committees, supporting technical validation and alignment of institutional roles.
- Prioritisation:** The sequencing of actions could take into account considerations such as safety criticality, near-term deployment relevance, implementation feasibility, institutional readiness, technology maturity, market and trade relevance, and interdependencies across the hydrogen value chain.
- Implementation planning:** The findings could provide the basis for a structured action framework covering ownership, sequencing, milestones, appropriate modes of action, and associated requirements for testing, certification, conformity assessment, and institutional coordination.
- Enabling ecosystem:** Implementation could be supported by continued development of institutional and workforce capacity, clarity on approval and certification pathways, standardised templates, and improved access to relevant standards, regulations, and approval procedures.

The findings and recommended actions presented in this report provide a preliminary basis for further institutional deliberation on standards development, adoption, and notification.

01 Introduction

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1.1 Objective of the Report

The National Green Hydrogen Mission positions India as a global hub for the production, use, and export of low-emission hydrogen and its derivatives. Achieving this ambition requires a harmonised framework of standards, codes, certification systems, testing capacity, and approval pathways that can support safe deployment, product credibility, domestic scale-up, and international market acceptance.

A structured gap assessment identifies material gaps in the current standards ecosystem and lays out preliminary actions to address them. The framework strengthens regulatory clarity, institutional coordination, testing readiness, and alignment with evolving market requirements as the Mission moves from policy intent into deployment.

A nationally and internationally harmonised standards framework supports the scale-up of low-emission hydrogen and related pathways in India along five interconnected objectives [2]:

Support Implementation of the National Green Hydrogen Mission

An operational standards agenda translates Mission-level ambition into production growth, industrial uptake, domestic manufacturing, and credible market development. This includes aligning standards with the goals of building a robust domestic low emission hydrogen ecosystem, reducing dependence on emission-intensive fuels, creating technology leadership, and enabling India to participate competitively in external markets for green hydrogen and its derivatives.

Provide a Harmonised National Reference Point Across the Low-Emission Green Hydrogen Ecosystem

A harmonised national reference point clarifies where India can adopt existing global standards, adapt references to Indian operating conditions, and develop domestic standards where a distinct national pathway is required. This is particularly important as the Mission spans production incentives, demand creation, hubs, pilots, certification, and testing infrastructure.

Identify and Prioritise Material Gaps in Low-Emission Hydrogen Standards, Codes, and Related Conformity Pathways

The standards assessment identifies gaps that affect investment, permitting, certification, procurement, safe operations, transport interfaces, and end-use deployment. This creates a gap-led basis for adoption, adaptation, indigenous development, or monitoring.

Support Safe Deployment, Regulatory Clarity, and Institutional Readiness

Low-emission hydrogen deployment requires a coordinated framework for technical requirements, safety rules, verification methods, testing protocols, inspection practices, and certification arrangements. The Mission has already recognised this need through dedicated support for testing facilities, institutional strengthening, and certification. The standards framework organises these requirements in a form usable by ministries, standards bodies, regulators, laboratories, and project developers.

Strengthen India's Ability to Align with Evolving Destination-Market Rules

As international buyers increasingly use carbon-intensity thresholds, chain-of-custody systems, and end-use specific qualification rules, the standards agenda also has relevance for international market compatibility. A clear objective is to improve compatibility between India's emerging certification and standards architecture and the requirements that are becoming material for exports.

1.2 Approach to Gap Assessment

The framework is built on a clear view of the existing low-emission hydrogen landscape of Indian and international standards. It focuses on identifying critical gaps in India's standards ecosystem and provides preliminary recommended actions to address them.

The approach draws on reviews of domestic and international frameworks, standards databases, relevant literature, and stakeholder consultations with government agencies, industry experts, project developers, testing agencies, and standardisation bodies.

Figure 1: Approach to gap assessment



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Framework development follows four linked workstreams that together provide the basis for identifying, organising, and addressing standards gaps across the hydrogen value chain.



Baseline Mapping of the Standards Landscape

Establish a consolidated reference base covering relevant Indian standards, codes, technical regulations, guidelines, and globally recognised references that influence equipment, hydrogen quality, storage and handling, derivative pathways, end-use systems, testing methods, conformity assessment, and cross-cutting safety.



International Benchmarking and Market-Reference Review

Structured benchmarking of mature standards roadmaps and policy frameworks in other jurisdictions, as well as a targeted review of destination-market qualification systems directly relevant to hydrogen and derivatives. International market access is increasingly shaped by formal qualification rules, sustainability certification, and digital traceability requirements.



Gap Assessment against India's near-term Deployment Pathways

Review whether the existing standards landscape is sufficient for use cases emerging in India today and in the near term. This includes established feedstock uses, early industrial transition applications, derivative pathways, and enabling functions such as testing, certification, and infrastructure interfaces. The assessment also considers whether gaps arise from missing standards, partial coverage, or limited technical implementation capacity.



Development of Preliminary Recommended Actions

Conversion of identified gaps into a structured set of actions covering adoption, adaptation, new development, or monitoring, with reference points across the value chain.

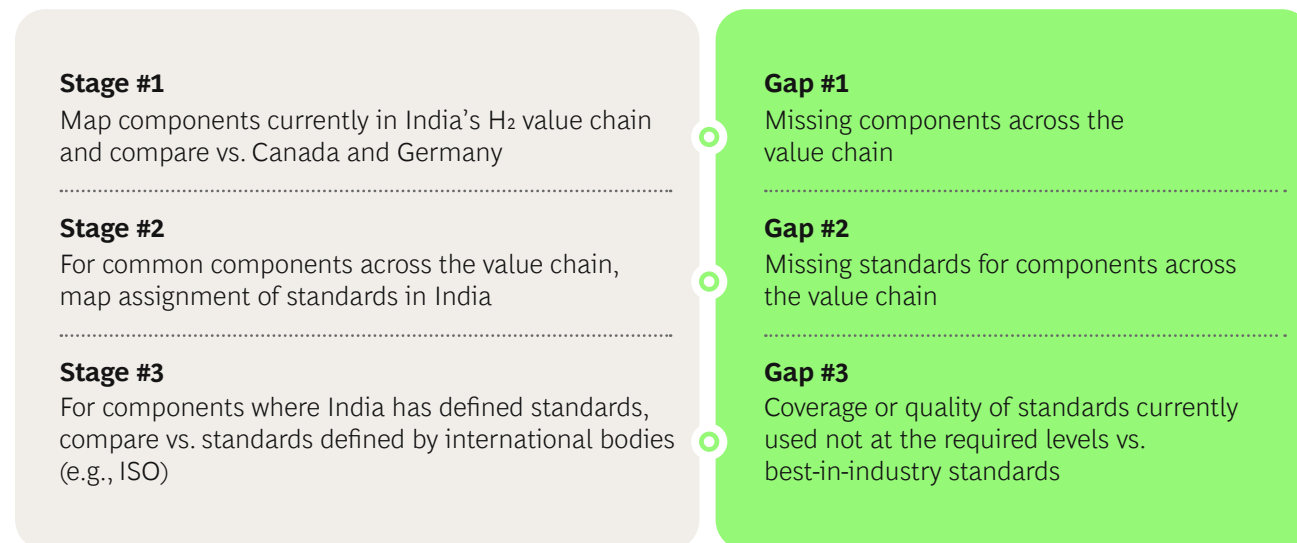
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1.3 Approach to Identifying Gaps

The Assessment was Structured in Three Stages

- The components currently represented in India's hydrogen value chain are mapped against existing Indian standards and codes.
- For components that are common across the value chain, international standards from ISO, IEC, and standards libraries of other international bodies are mapped as references.
- Where India has already defined standards, these are compared against the consolidated international references to assess alignment with best-in-class practices.

Figure 2: Green Hydrogen Market Supply Trend



This stage-wise Comparison Surfaces Three Distinct Categories of Gap:

- Missing standards: components already in scope for which no usable Indian standard, code, or technical reference is identified.
- Partial standards coverage: areas where a standard exists but the degree of technical coverage is incomplete, fragmented, or insufficient for the intended application.
- No gap: A usable Indian standard, code, or technical reference is available and considered adequate for the intended application.

1.4 Guardrails for Assessment

A defined set of guardrails maintains clarity of scope, ensures consistency of treatment, and preserves focus on the central objectives of the assessment. These guardrails establish the pathway boundary, technical coverage, treatment of standards, cross-sector approach, and evidentiary basis applied across the assessment. They also clarify the distinction between identifying standards priorities and the formal processes through which standards are developed, validated, and notified.

Renewable and Biomass-based Pathway Focus

The domestic pathway focus is anchored in renewable electricity-based and biomass-based hydrogen pathways, consistent with the National Green Hydrogen Mission and the Green Hydrogen Standard for India. Fossil-based, nuclear-based, and CCS-based hydrogen pathways are outside the direct technical scope of the assessment. External low-emission market frameworks are considered only where they influence product acceptance, certification, or competitiveness in relevant markets. This alignment is consistent with the intended policy and deployment focus, while recognising external qualification systems that may affect standards priorities.



Core Hydrogen Value Chain Focus

Coverage is limited to the core hydrogen value chain and the enabling functions required for its deployment. Cross-cutting areas such as safety, quality, and sustainability are included where they materially affect implementation. Technical focus is maintained on the areas where standards, codes, and associated institutional measures can most directly support safe deployment, interoperability, and compliance.

Standards Assessment, not Technical Validation

The exercise assesses the availability, relevance, and adequacy of standards, codes, and related implementation conditions. It does not undertake technical validation of standards through laboratory testing, engineering trials, or plant-level certification. Testing, certification, and approvals are treated as enabling conditions within the broader standards ecosystem rather than as separate downstream issues. A clear distinction is preserved between standards assessment and the formal technical functions of laboratories, certification bodies, and regulators, reflecting the current domestic position where testing infrastructure and approval pathways are themselves part of the implementation challenge.

Published Standards and Implementable Pathways Only

The assessment is based on published standards, issued codes, formal regulations, official guidance, and other credible frameworks available during the study period. Unannounced standards or unresolved policy proposals are not considered, except where near-term implementation implications are already visible. No new standards are developed as part of this exercise; the focus remains on adoption, adaptation, prioritisation, and implementation pathways. Standards are considered useful only to the extent that they can be progressed through identifiable institutions, testing capability, conformity mechanisms, and approval routes.

The resulting boundary conditions keep the assessment evidence-based, practical, and oriented toward actions that can be carried forward by the relevant institutions and stakeholders.





02

Context for Green Hydrogen Standards in India

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2.1 Green Hydrogen and the Global Decarbonisation Agenda

Low-emission Hydrogen is increasingly positioned as a complementary energy carrier to direct electrification, particularly in applications where electrification is challenging or where hydrogen-derived molecules can help reduce emissions associated with existing fuel and feedstock pathways. Globally, hydrogen demand continues to be anchored in established industrial uses, while policy frameworks are increasingly focused on scaling low-emission Hydrogen use in heavy industry, long-distance transport, and energy storage where hydrogen is expected to support the transition toward lower-emissions energy systems

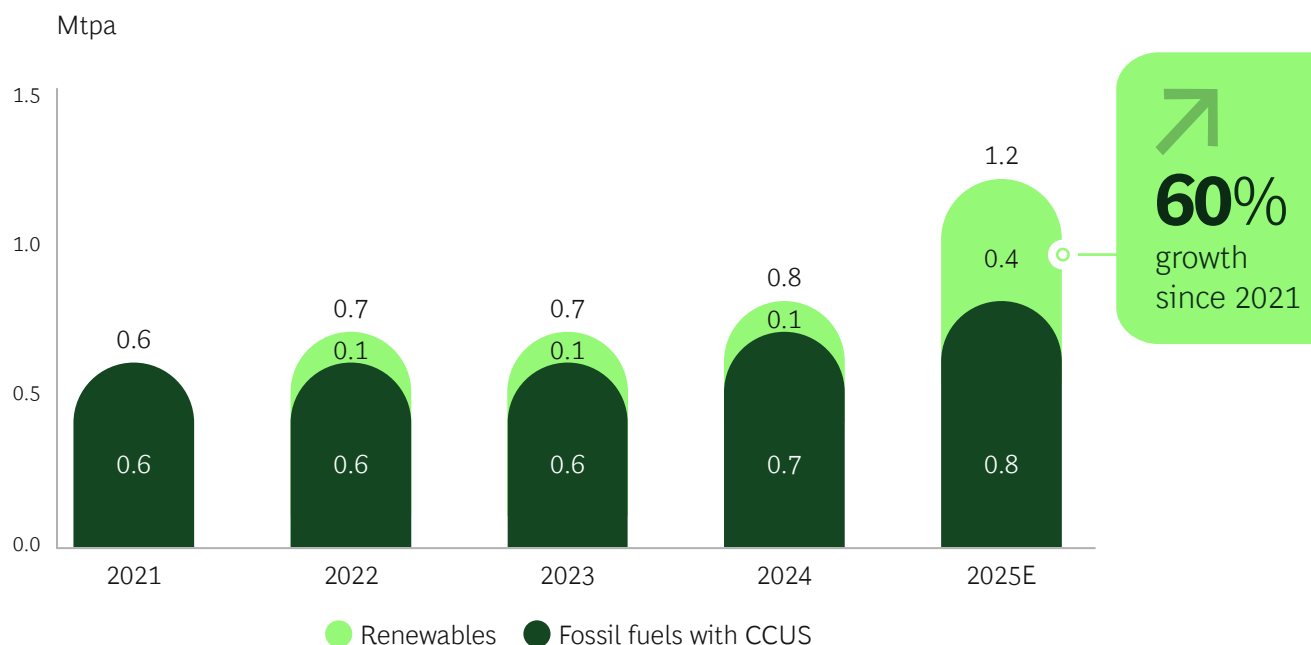
In India, Renewable-based and biomass-based Hydrogen offers an opportunity to support low-emission and domestically anchored energy pathways., including as an industrial feedstock, fuel for mobility, and across other applications. The National Green Hydrogen Mission explicitly highlights the potential of low-emission Hydrogen in areas such as petroleum refining, fertiliser production, steel manufacturing, and mobility, while also recognising the growing potential of low-emission Hydrogen-derived synthetic fuels and derivatives such as low-emission Ammonia and low-emission Methanol across the world.

As emissions-reduction commitments evolve, demand for low-emission Hydrogen and its derivatives is expected to rise, and international value chains and trade in hydrogen-derived commodities are likely to expand over time.

2.2 Global Hydrogen Demand, Supply, and the Pace of Scale-up

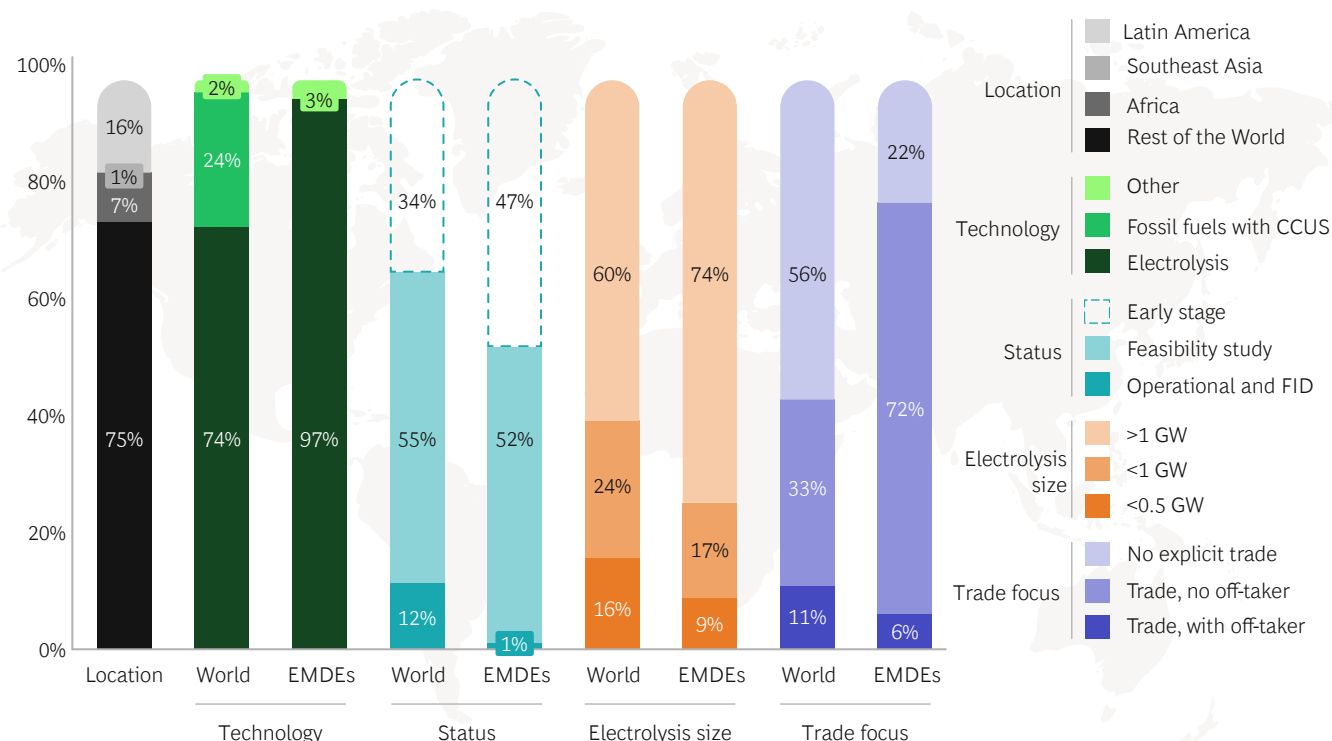
Global hydrogen demand approached approximately 100 Mt in 2024 and was expected to cross 100 Mt in 2025, with demand still concentrated in refining and industrial applications where hydrogen has been used for decades. Adoption in low-emission applications accounts for less than 1% of global demand, notwithstanding rapid year-on-year growth from a small base in some emerging sectors.

Figure 3: Low-Emission Hydrogen Market Supply Trend



On the supply side, hydrogen production remains overwhelmingly fossil-fuel-based. The International Energy Agency (IEA) reports total hydrogen production of 100 Mt in 2024, with less than 1% produced as low-emissions hydrogen. The gap between overall demand and low-emissions supply reinforces the central implementation challenge: scaling credible low-emissions hydrogen supply chains while building confidence in safety, performance, and verifiable compliance.

Figure 4: Announced projects for green hydrogen (2030, IEA)



The project pipeline is expanding, but the material share remains at early stages. Announced electrolyser capacity could grow substantially by 2030, but only a small portion of announced projects have reached a final investment decision (FID) or are under construction. Several projects have been cancelled due to uncertainty regarding demand, regulation, licensing and permitting, and financing constraints—conditions that typically intensify the importance of predictable technical requirements and approval pathways.

Similarly, infrastructure development is at an early stage. Hydrogen trade today remains limited and is mainly reflected through hydrogen-based products (notably ammonia and methanol), while long-term transition scenarios anticipate a much larger role for interregional trade in hydrogen and hydrogen-based fuels. The near-term emphasis is therefore on building domestic-scale value chains and interoperable infrastructure that can mature into cross-border markets as demand and regulatory clarity strengthen.

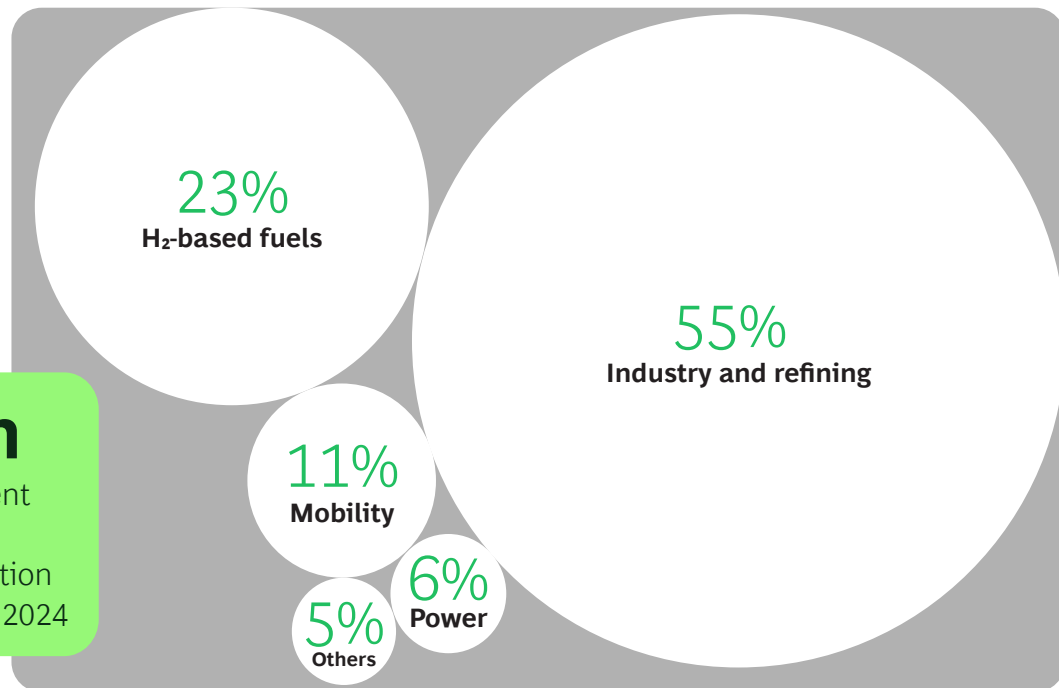
2.3 International Policy, Certification, and Market Architecture

The IEA's Global Hydrogen Review 2024 reports that almost USD 100 billion of public funds for hydrogen were announced, entered into force, or allocated to projects in the year assessed, spanning industry and refining, hydrogen-as-a-fuel, mobility, and power applications. Nearly two-thirds of this amount remains at the announcement stage and has not yet been operationalised, and 95% of commitments come from advanced economies—underscoring that while policy intent is scaling rapidly, translation into funded and executing projects remains the central implementation challenge.

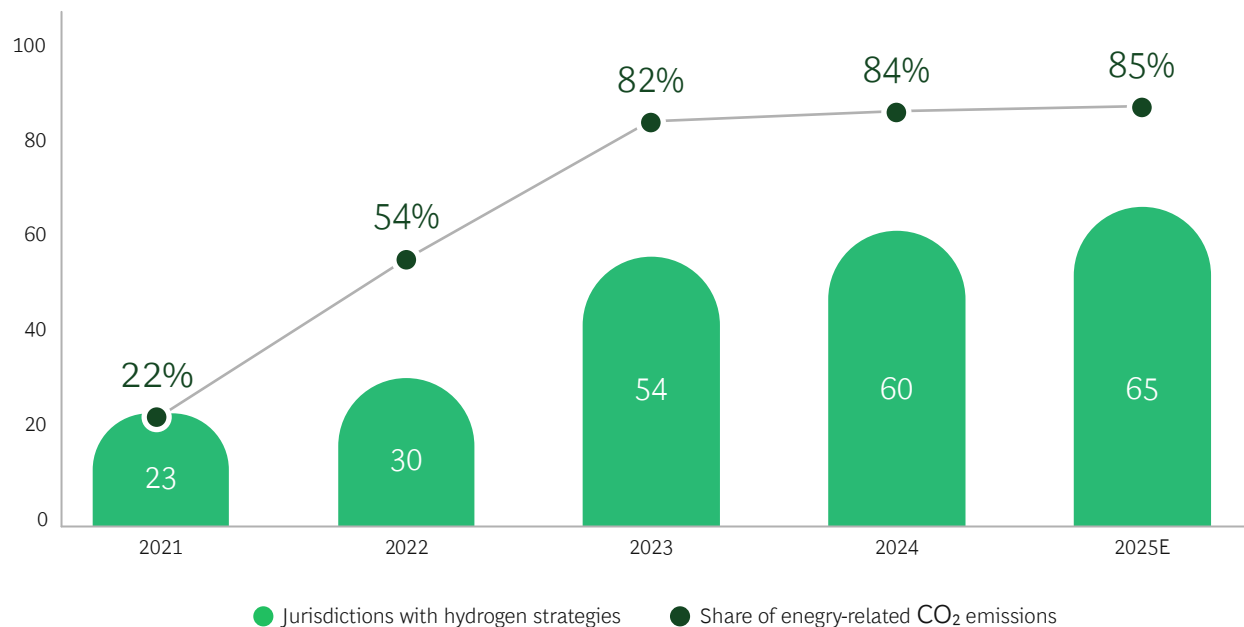

Figure 5: Investment in Low-Emission Hydrogen Production by Intended Use

\$7.9 Bn

Annual investment
in low-emissions
hydrogen production
by intended use, 2024



A total of 60 national hydrogen strategies have been published globally, covering countries that account for over 84% of global energy-related CO₂ emissions. [3]

Figure 6: Regulatory Landscape–Number of Hydrogen Strategies


02. Context for Green Hydrogen Standards in India

A defining feature of this implementation phase is the move toward operational certification frameworks for hydrogen and its derivatives, with growing reference to lifecycle-based criteria in destination markets. India along with other countries at COP28 launched a declaration of intent to work toward mutual recognition of certification schemes for low-emission Hydrogen and hydrogen derivatives, with participating governments seeking to advance solutions through international platforms. This builds momentum toward avoiding fragmented certification approaches and supports longer-term development of cross-border value chains.

In key demand centres, regulatory frameworks are increasingly explicit. The European Union's Renewable Energy Directive establishes targets for renewable fuels of non-biological origin (RFNBOs) in industry and transport, and delegated regulations provide detailed rules for how renewable hydrogen and RFNBOs are qualified under EU law.

2.4 India's Policy and Market Context under the National Green Hydrogen Mission

The National Green Hydrogen Mission (NGHM) provides a whole-of-government programme framework for scaling low-emission Hydrogen production and utilisation across sectors. The Union Cabinet press release sets out an initial Mission outlay of ₹19,744 crore, including ₹17,490 crore for the SIGHT programme, ₹1,466 crore for pilot projects, and dedicated allocations for R&D and other enabling Mission components.

The Mission establishes an ambition of at least 5 MMT per annum of low-emission Hydrogen production capacity by 2030, along with associated renewable energy capacity addition. It also highlights expected economy-wide outcomes linked to investment, jobs, reduced import dependence, and emissions-related outcomes by 2030.

The Mission document further provides a clear domestic demand baseline and sectoral focus:

Approximately 5 MMT of hydrogen is currently consumed annually in India across industrial uses including petroleum refining and ammonia production, with most hydrogen sourced from fossil fuels ("grey hydrogen").

Priority substitution and transition applications are enumerated, including replacement of emission-intensive hydrogen in ammonia and petroleum refining, blending in city gas distribution systems, steel production using low-emission Hydrogen, and use of low-emission Hydrogen-derived synthetic fuels (including low-emission Ammonia and low-emission Methanol) in mobility, shipping, and aviation.





The Mission recognises constraints that have historically slowed substitution of fossil fuels and feedstocks, including cost economics, infrastructure needs, and the absence of harmonised standards and regulations. This acknowledgement is material for standards planning, since early-scale deployments face the highest approval and bankability sensitivity to regulatory clarity, standardisation readiness, and quality infrastructure availability.

Several Mission instruments directly shape the near-term standards and codes landscape:

- **Green Hydrogen Standard for India** (August 2023) defines Green Hydrogen as hydrogen produced using renewable energy, including via electrolysis and conversion of biomass, and sets an emissions threshold of ≤ 2 kg CO₂e per kg H₂ (12-month average) for non-biogenic emissions in both electrolysis-based and biomass-based pathways.
- The same Office Memorandum indicates that a detailed methodology for measurement, reporting, monitoring, onsite verification, and certification of low-emission Hydrogen and its derivatives is to be specified by MNRE and designates the Bureau of Energy Efficiency (BEE) as the nodal authority for accreditation of agencies for monitoring, verification, and certification of low-emission Hydrogen production projects.
- **SIGHT Programme – Component I** (Electrolyser Manufacturing) provides an incentive framework with an outlay of ₹4,440 crore, with objectives including expanding indigenous electrolyser manufacturing capacity, lowering the levelised cost of hydrogen, and improving global competitiveness and quality.
- **SIGHT Programme – Component II** (Green Hydrogen Production) provides an incentive framework with an outlay of ₹13,050 crore for Green Hydrogen production (all modes), including competitive selection mechanisms and explicit linkage to the National Green Hydrogen Standard.

The Mission's pilot guidelines also strengthen the near-term relevance of standards in safety-critical and early-deployment settings. For example, shipping sector guidelines target pilot deployments of low-emission Hydrogen and derivatives in propulsion and bunkering, include safety-focused objectives, and set out a budgetary outlay for pilots through FY 2025–26.

India is also adopting a cluster-based approach for scaling hubs and infrastructure. In October 2025, three major ports (Deendayal, V.O. Chidambaram and Paradip) were recognised as Green Hydrogen Hubs, reflecting a policy emphasis on enabling infrastructure convergence and early-stage project viability in identified regions. [4]



2.5 India's Green Hydrogen Certification Scheme

The Green Hydrogen Certification Scheme of India provides the implementation mechanism for verifying compliance with the Green Hydrogen Standard for India. It is designed to establish credibility, transparency, and traceability in low-emission Hydrogen production, and to support market confidence for domestic use and trade-facing applications. The scheme covers eligible low-emission Hydrogen production pathways, defines the system boundary for emissions assessment, and establishes the institutional process for verification and certification.

Key elements of the scheme include:

Governance and institutional roles

MNRE provides overall supervision and monitoring. An implementing agency is responsible for operationalising the scheme, while a Technical Committee provides strategic oversight and approval for issuance of certificates. Verification is undertaken through Accredited Carbon Verification agencies.

Certification scope and eligible pathways

The scheme applies to Green Hydrogen production through renewable electricity-based electrolysis and conversion of biomass, consistent with the Green Hydrogen Standard for India.

System boundary and emissions threshold

Certification is linked to the well-to-gate greenhouse-gas emissions intensity of Green Hydrogen production. The Green Hydrogen Standard sets a threshold of not more than 2 kg CO₂ equivalent per kg of hydrogen, measured as a 12-month average for non-biogenic emissions.

Renewable energy and input accounting

The scheme provides the basis for assessing renewable energy use and related emissions claims, which is important for ensuring that Green Hydrogen certification is linked to credible energy sourcing and emissions accounting.

Monitoring, reporting, and verification

The scheme includes requirements for data monitoring, verification procedures, periodic reporting, and assessment of compliance with the Green Hydrogen Standard.

Certification process

The certification architecture is intended to support facility-level and production-level assurance, enabling Green Hydrogen producers to demonstrate compliance through a recognised process.

For the standards framework, the scheme establishes a bridge between technical standards and market recognition. Product credibility depends not only on equipment and safety standards, but also on consistent measurement, reporting, verification, and certification procedures linked to the Indian emissions threshold.



2.6 Role of Standards in Safe Deployment, Interoperability, and Market Creation

Figure 7: Role of Standards in safe deployment, interoperability, and market creation



Safety

- Define minimum requirements for design, installation, operation, inspection, and emergency response across the value chain
- Provide the technical basis to manage leakage, flammability, pressure handling, materials compatibility, and explosion risk
- Reduce approval uncertainty and support consistent compliance across operators, regulators, and project developers



Interoperability

- Harmonize product specifications, interface requirements, testing methods, and performance thresholds across equipment and applications
- Enable compatibility across production systems, storage, transport, refuelling, and end-use equipment
- Limit fragmentation, reduce bespoke engineering, and support scalable deployment across the ecosystem



Market formation

- Establish common rules for certification, conformity assessment, measurement, and quality assurance
- Build confidence for developers, offtakers, financiers, insurers, and testing bodies
- Underpin traceability, carbon claims, and cross-border acceptance for hydrogen and derivatives.

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Hydrogen's physical properties and operating conditions create distinctive safety and engineering considerations that reinforce the need for clear codes, standards, and compliance pathways. The U.S. Department of Energy notes that hydrogen has a wide range of flammable concentrations in air and a lower ignition energy than gasoline or natural gas, suggesting the importance of ventilation, leak detection, and appropriate system design. The NREL Hydrogen Technologies Safety Guide similarly characterises hydrogen as having a wide flammability range (4%–75% by volume) and relatively low ignition energy, emphasising why dedicated safety practices and standards-based requirements matter for safe handling and operation.

02. Context for Green Hydrogen Standards in India

Beyond safety, standards and codes support interoperability and scalable deployment by establishing consistent terminology, interfaces, performance thresholds, testing methods, and conformity-assessment expectations. DIN explicitly highlights these functions as essential for scaling hydrogen technologies and supporting legally secure action and resilient investment decisions. The DIN standardisation roadmap similarly frames coherence and coordination across standardisation activities as essential to delivering policy objectives at scale.

Standards also underpin market confidence and cross-border acceptance, particularly for hydrogen and derivatives where environmental integrity is increasingly assessed through lifecycle-based criteria.

Alignment with international standards is directly relevant to avoiding unnecessary barriers and enabling wider acceptance of products and systems in international markets. The WTO Agreement on Technical Barriers to Trade provides that where technical regulations are required and relevant international standards exist (or are imminent), Members shall use them, or relevant parts of them, as a basis for technical regulations except where ineffective or inappropriate for legitimate objectives. This reinforces the value of standards harmonisation and strategic adoption of credible international standards where suitable, while ensuring that domestic requirements remain fit-for-purpose for Indian climatic conditions, infrastructure realities, and regulatory objectives.

Collectively, these considerations indicate the relevance of a coordinated standards and codes harmonisation framework that supports safe deployment, effective implementation of Mission schemes, credible certification, and interoperable market development across hydrogen and hydrogen-derivative value chains.



03

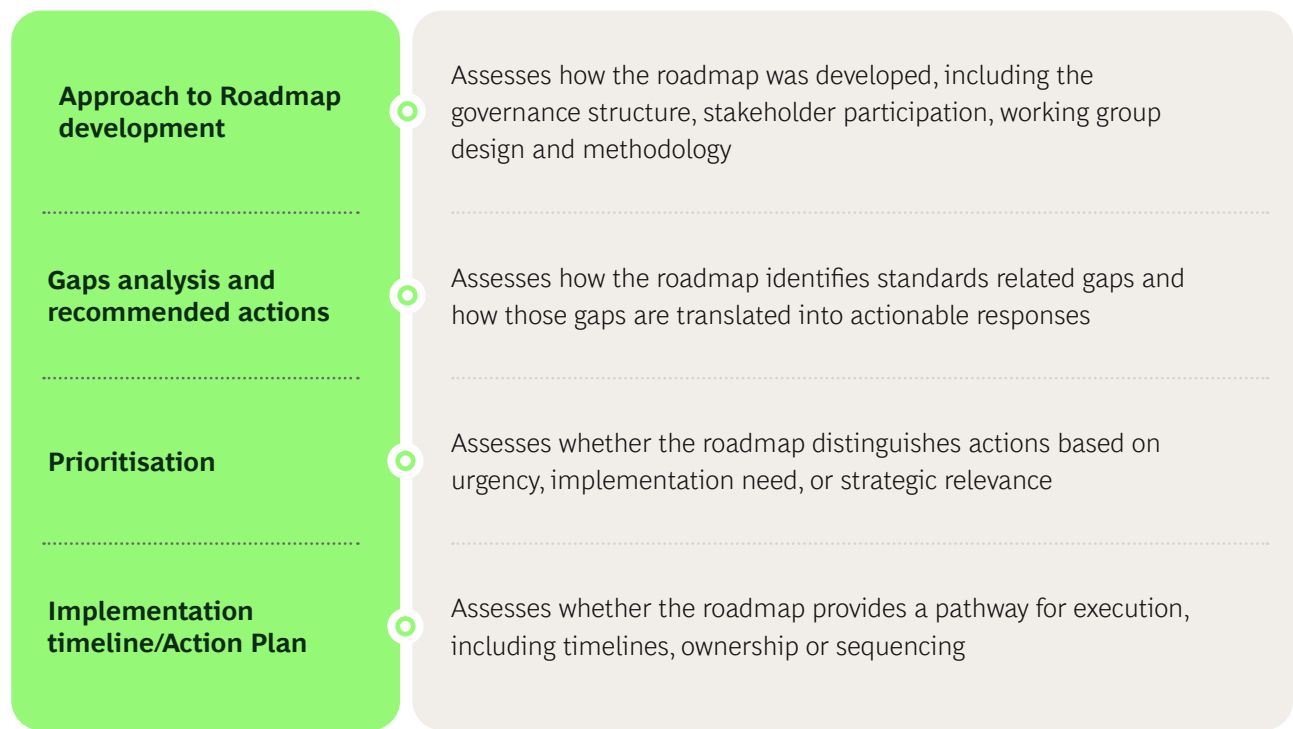
International Benchmark Assessment

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The international benchmark assessment provides a reference base for structuring India’s gap assessment and preliminary action framework. The assessment focuses on jurisdictions that have developed structured approaches to hydrogen standardisation, including Canada, Germany, and the European Union.

The benchmark draws selectively from each approach: Canada’s element-level gap mapping and prioritisation logic, Germany’s working-group-based execution structure, and the EU’s ecosystem-wide view of standardisation topics, pre-normative research, and coordination across standards bodies. [3] [4] [5]

Figure 8: Metrics defined for benchmarking



These lenses compare the scope of each roadmap, the governance model used, the method for translating gaps into actions, and the sequencing of implementation.

3.1. Canada’s Hydrogen Standards Roadmap

Canada follows a governance-led model. Natural Resources Canada launched the Hydrogen Strategy for Canada in 2020, established the Codes and Standards Working Group in 2021, and used that platform to conduct a structured gap analysis across 72 value-chain elements grouped under production, delivery and storage, and end use. The Canadian roadmap is notable for its clear institutional ownership, broad stakeholder participation, and explicit use of standards-based options to determine whether gaps could be addressed through use of existing standards, updates, adoption, or new development.

3.1.1 Overview

Figure 9: Canada's Hydrogen Roadmap (Overview)

In Canada's net-zero climate objectives, **low-carbon hydrogen** is expected to supplement electrification and other carbon mitigation approaches by supporting emissions reduction in sectors where direct electrification is less economical or technically challenging.

2020

Natural Resources Canada (NRCan) launched the Hydrogen Strategy for Canada. The strategy set out 32 recommendations, of which four were specifically tied to **codes and standards**

2021

NRCan established the **Hydrogen Codes and Standards Working Group (CSWG)** to advance this agenda. The CSWG's mandate includes:

- Carrying out a codes and standards analysis
- Identifying standards-based options to address those gaps
- Determining opportunities for development, including **prioritisation** of the most pertinent short-to medium-term standards, and communicating these priorities through a roadmap

2024

Natural Resources Canada (2024). Hydrogen Strategy for Canada: Progress Report, the role of low-carbon hydrogen in supporting **energy security, energy transition**, and broader climate objectives was reinforced.



3.1.2 Methodology

Figure 10: Canada's Hydrogen Roadmap (Methodology)

Step 1

Define the hydrogen value chain

- The roadmap adopted an NRC classification system that breaks the value chain into **72 elements**. Each element can relate to multiple existing codes or standards and/or to new standards to be developed.

Step 2

Carry out the gap analysis

- Three task forces were established as subgroups within the wider CSWG to align with the three segments of: **Production, Delivery and Storage, and End-Use**. Each task force was charged with identifying gaps and opportunities for development, harmonization, adoption, and revision of standards.
- The three task forces performed an environmental scan of Canadian, U.S., regional, and international codes and standards for each element.
- Each **value-chain element** was then categorized as having no gap, a partial gap, or a full gap.

Step 3

Identify standards-based options

- The CSWG developed a menu of actions to address each gap depending on the size of the gap, the global standards landscape, and the urgency of compliance needs.
- The roadmap explicitly preferred **harmonization and adoption** of regional/international standards over creating entirely new standards where possible.

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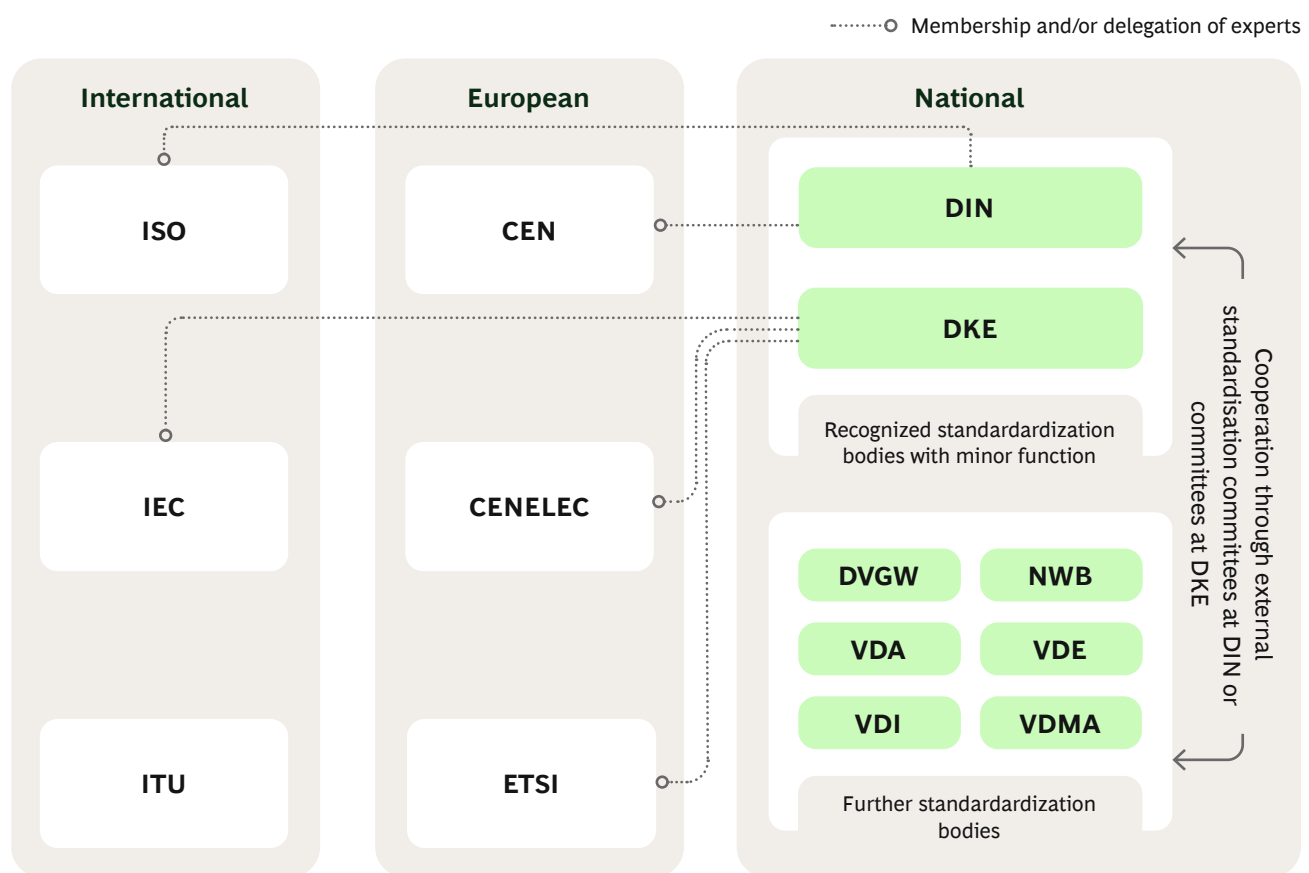
3.2 Germany's Hydrogen Standards Roadmap

Germany follows a working-group-based execution model anchored in a broader national standardisation system. Its roadmap is organised through a steering committee, five major topic areas, 12 sub-working committees, and 39 working groups spanning production, infrastructure, application, quality infrastructure, and safety-related issues. The German approach is distinguished by the creation of a standards database, the conversion of identified needs into formal recommendations for action, and the explicit link between those recommendations and funded implementation projects.

3.2.1 Overview

Germany's approach is embedded within a **multi-level standards ecosystem**, linking national bodies with European and international standardisation systems.

Figure 11: Germany's Hydrogen Roadmap (Overview)



Germany aims for climate neutrality by 2045, with strong focus on reducing emissions in the energy sector.

Hydrogen is seen as important for hard-to-electrify sectors and for energy security in a renewables-based system.

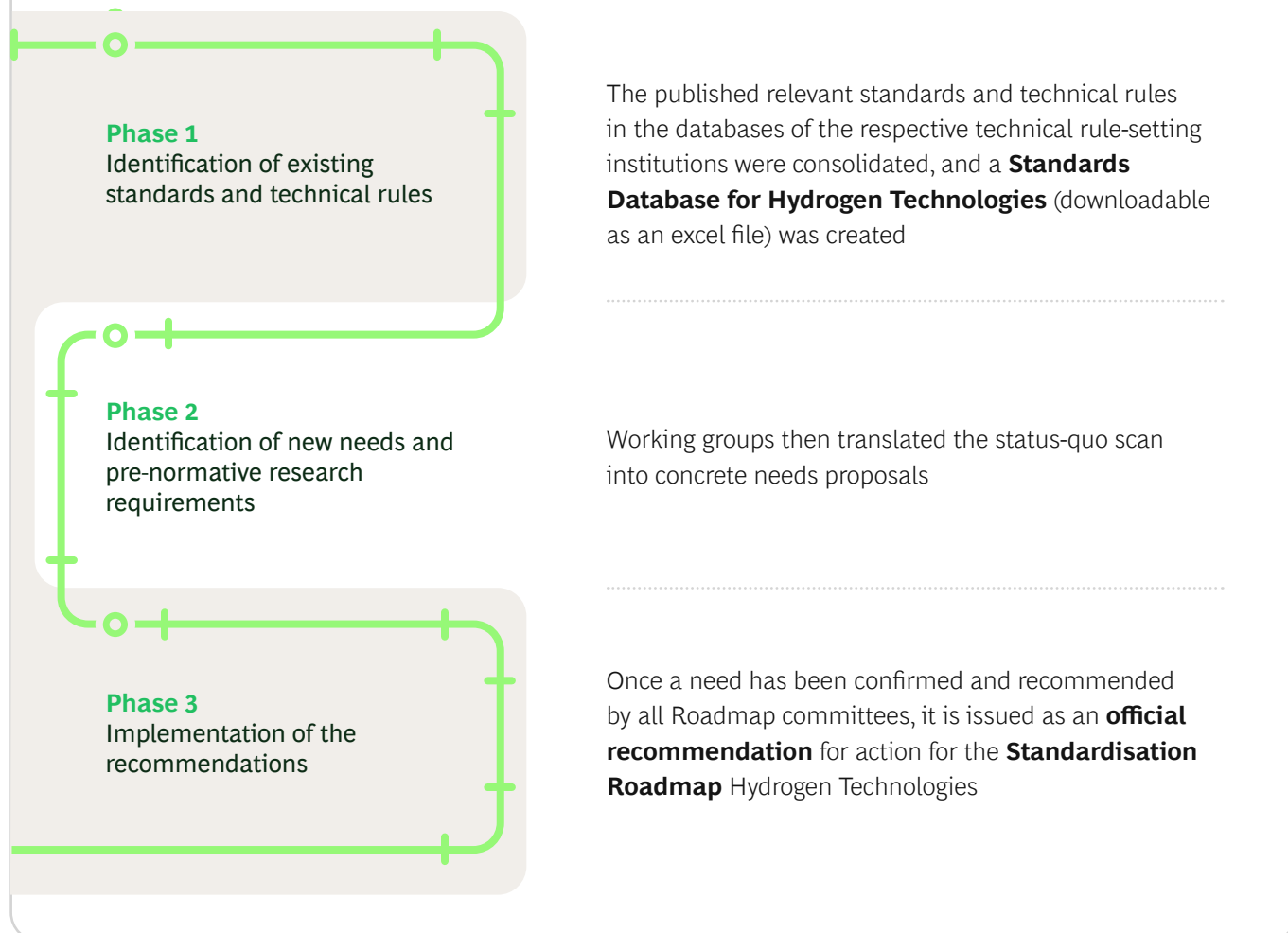
Its importance is reinforced by Germany's National Hydrogen Strategy.

A notable feature is its working-group-based approach, which supports coordinated standardisation across multiple sectors.

The roadmap covers priorities across production, infrastructure, industrial applications, mobility, buildings, and cross-cutting issues

3.2.2 Methodology

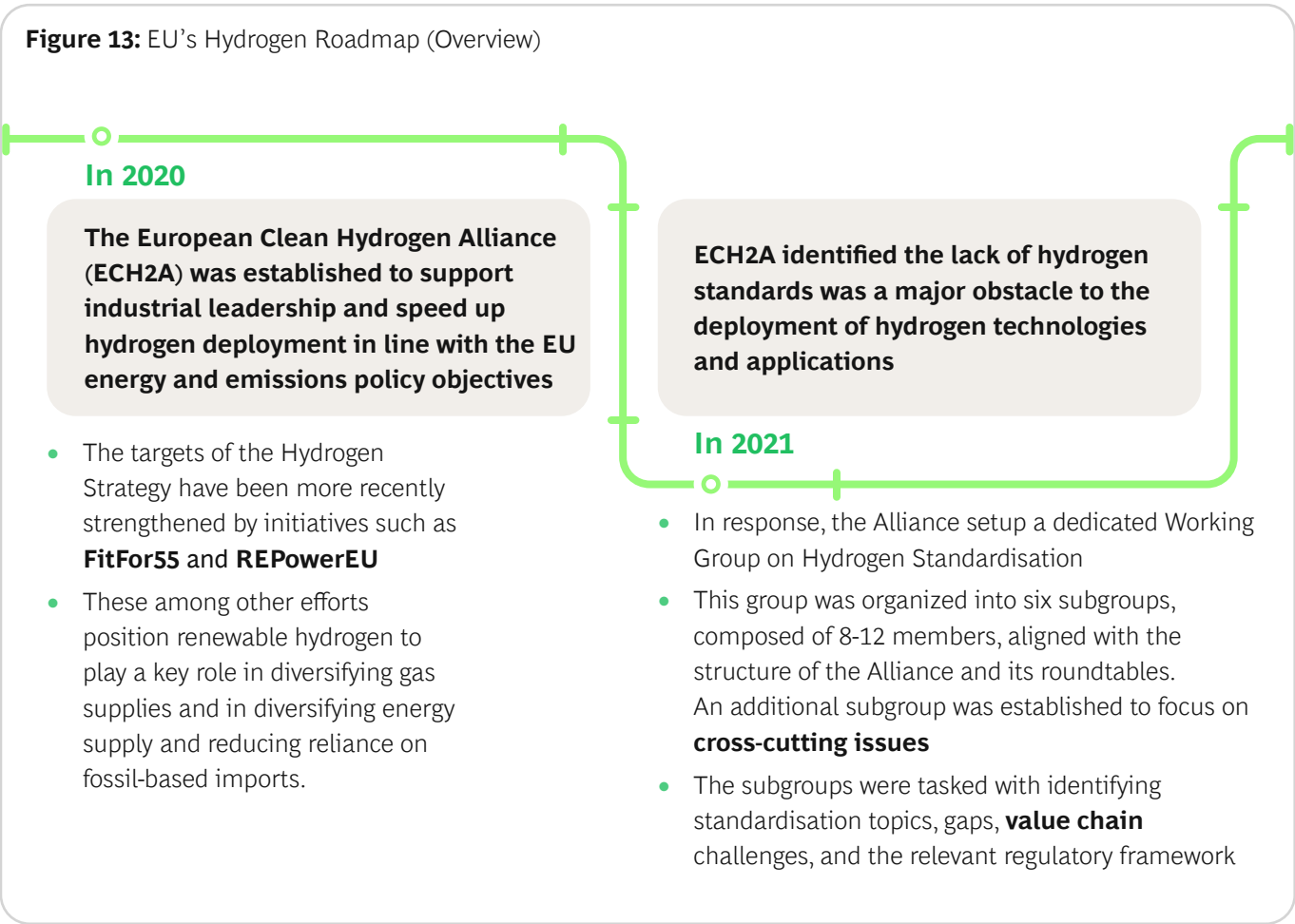
Figure 12: Germany's Hydrogen Roadmap (Methodology)



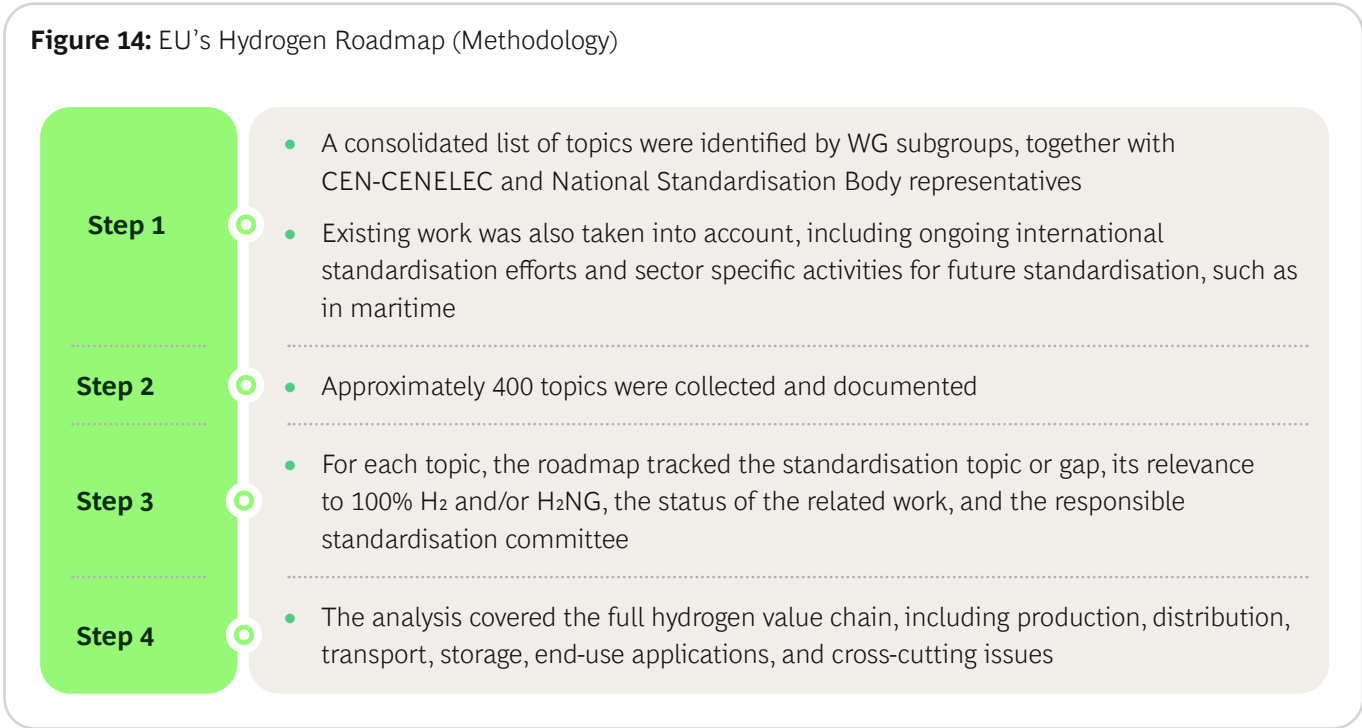
3.3 EU's Hydrogen Standards Roadmap

The EU roadmap is more coordination-led and ecosystem-wide in character. The European Clean Hydrogen Alliance set up a dedicated Working Group on Standardisation, structured into six thematic subgroups and an additional cross-cutting subgroup. Rather than using a tightly bounded national implementation architecture, the EU roadmap builds a comprehensive list of approximately 400 standardisation topics, maps them across the hydrogen value chain, and positions them within the European and international committee landscape. Its emphasis is on coordination across standardisation bodies, standardisation requests, and pre-normative research. [5]

3.3.1 Overview



3.3.2 Methodology



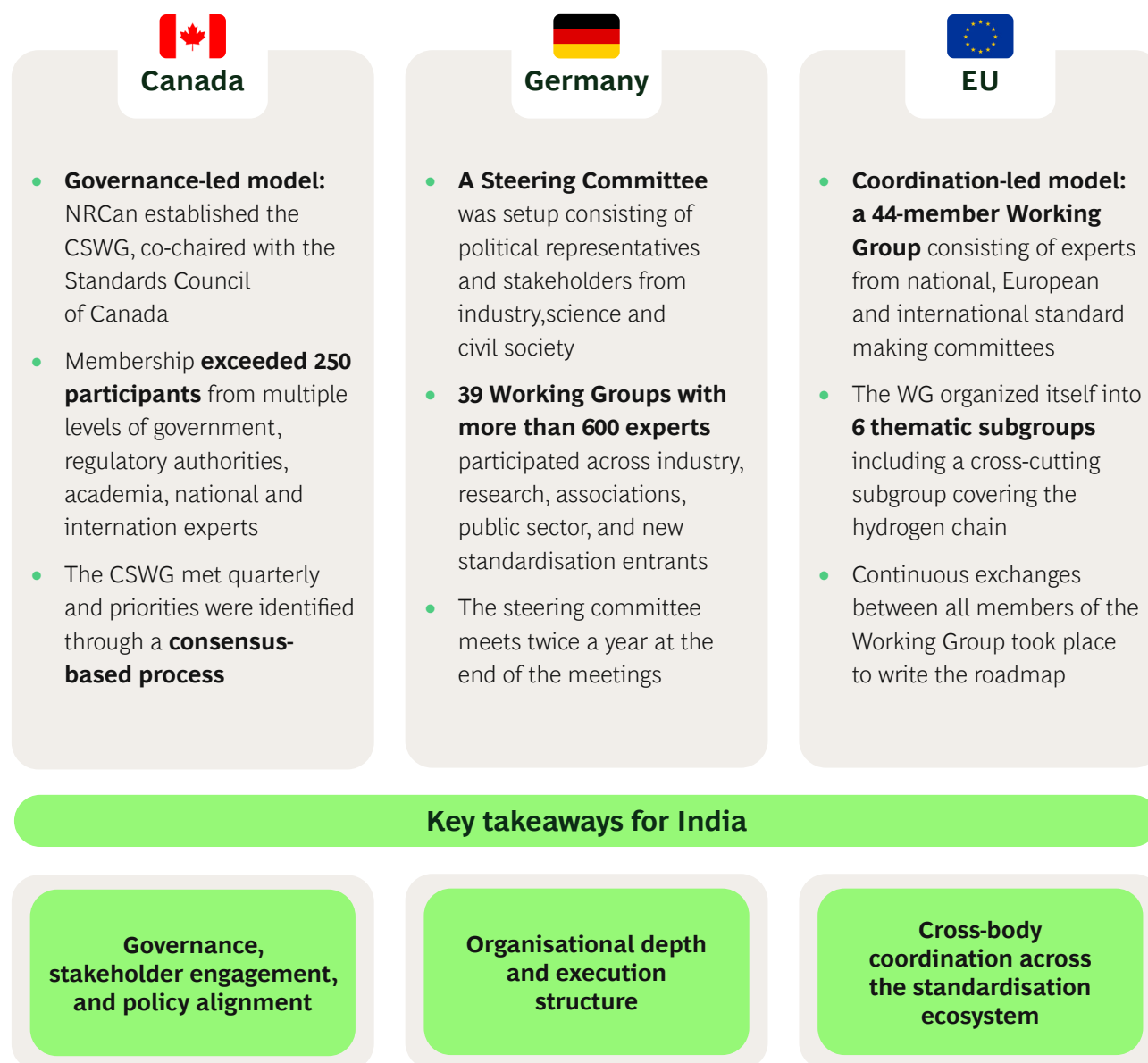
3.4 Comparing International Roadmaps against Relevant Metrics

The comparison is structured around four metrics that are most relevant for an implementable standards roadmap: roadmap development approach, gap assessment and recommended actions, prioritisation logic, and implementation timeline.

These metrics focus on how each jurisdiction organises the standards agenda, assigns responsibility, translates technical gaps into action, and sequences execution over time. The comparison also highlights design choices relevant for India: granular value-chain classification, clear institutional ownership, consistent gap categorisation, and a transparent basis for phasing recommended actions. [3] [4] [5]

3.4.1 Metric 1: Approach to Roadmap Development

Figure 15: Benchmark Comparison–Approach to Roadmap Development

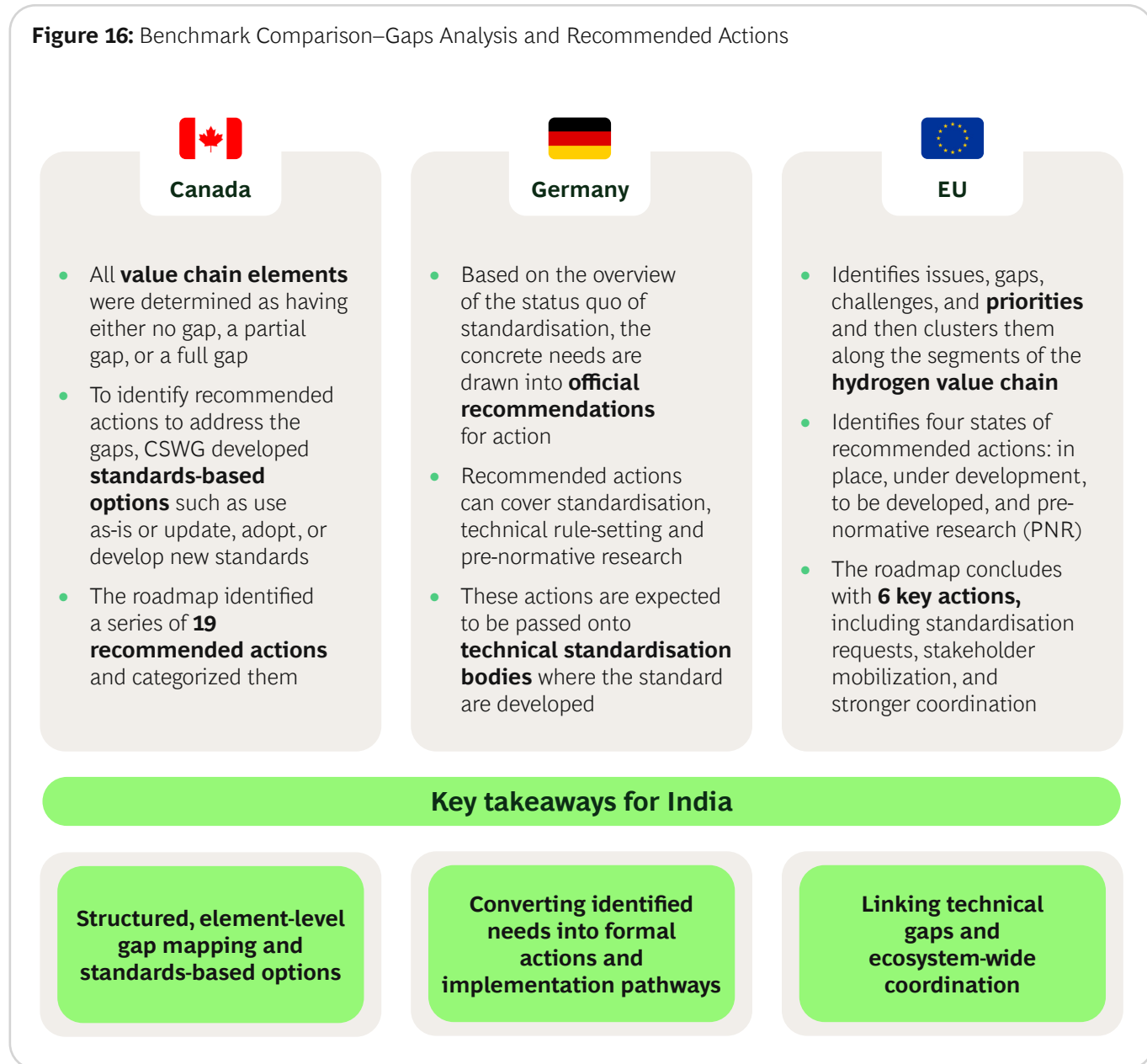




Germany's structured working-group model offers a strong reference on ownership, execution jurisdiction, and committee-led implementation. Canada's governance-led approach demonstrates how a small set of institutional anchors can coordinate broad stakeholder participation. The EU's ecosystem-wide approach focuses on alignment across standardisation bodies and pre-normative research.

3.4.2 Metric 2: Gaps Analysis and Recommended Actions

Figure 16: Benchmark Comparison–Gaps Analysis and Recommended Actions



The approaches differ in how technical assessment is converted into action. Canada applies a highly structured, element-level gap mapping process in which each value-chain element is classified as having no gap, a partial gap, or a full gap, and is then assigned a standards-based option. Germany begins with the status quo of standardisation and translates identified needs into formal recommendations that can cover standardisation, technical rule-setting, and pre-normative research. The EU links identified technical gaps to ecosystem-wide coordination needs and distinguishes whether a topic is already in place, under development, to be developed, or dependent on pre-normative research.

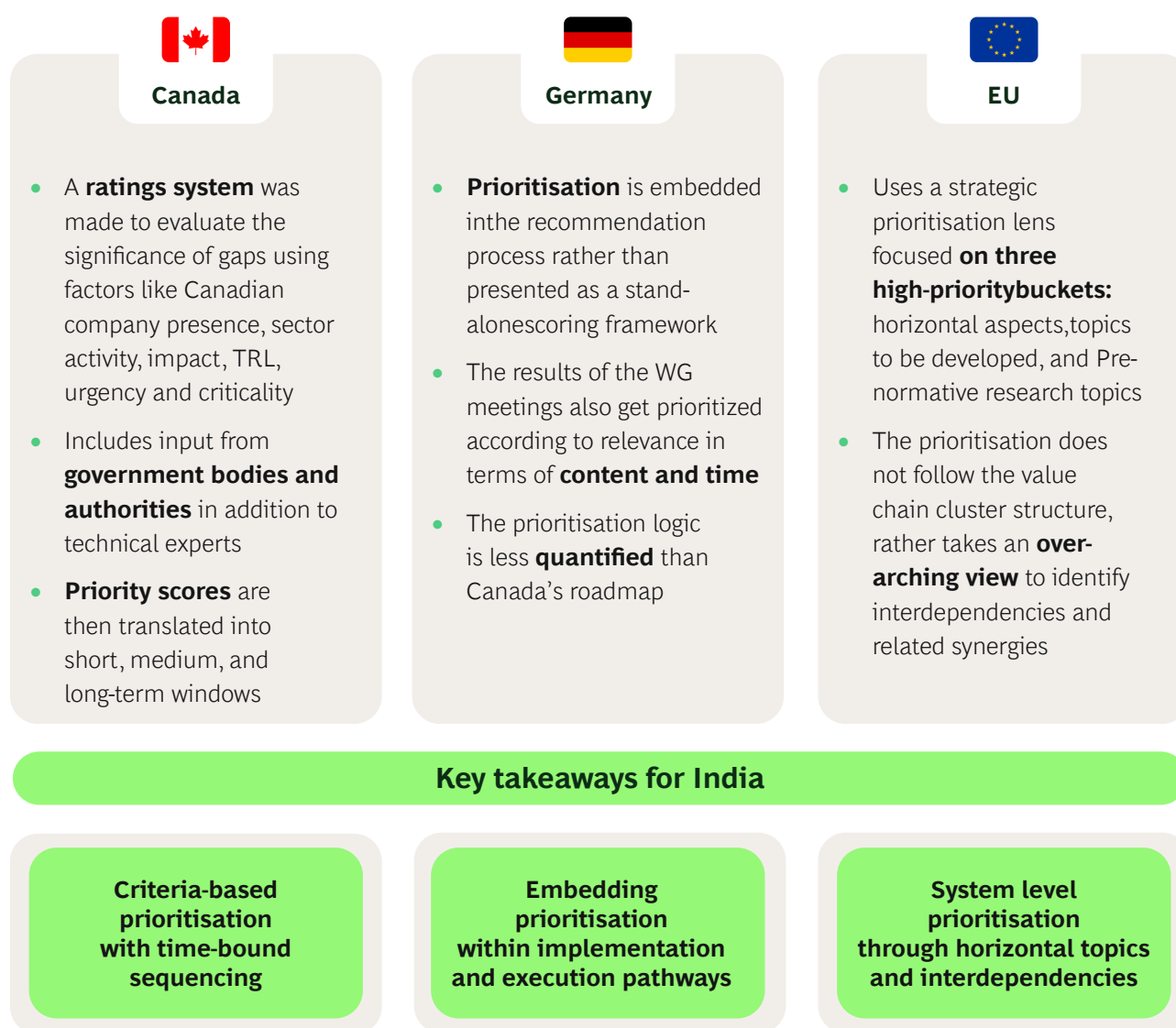
Canada's element-level gap mapping approach provides a useful basis for linking each value-chain component with a specific gap type and action pathway and is the closest analogue to the structured assessment adopted here.

3.4.3 Metric 3: Prioritisation

Canada provides the most explicit criteria-based prioritisation approach, combining variables such as sector activity, impact, technology readiness, urgency, and criticality, and then translating scores into short, medium, and long-term windows. Germany embeds prioritisation within the implementation pathway itself, with recommendations filtered through working groups and roadmap committees before being taken forward. The EU takes a more system-level view, prioritising horizontal topics, topics that still need to be developed, and areas requiring pre-normative research, thereby focusing on interdependencies across the value chain.

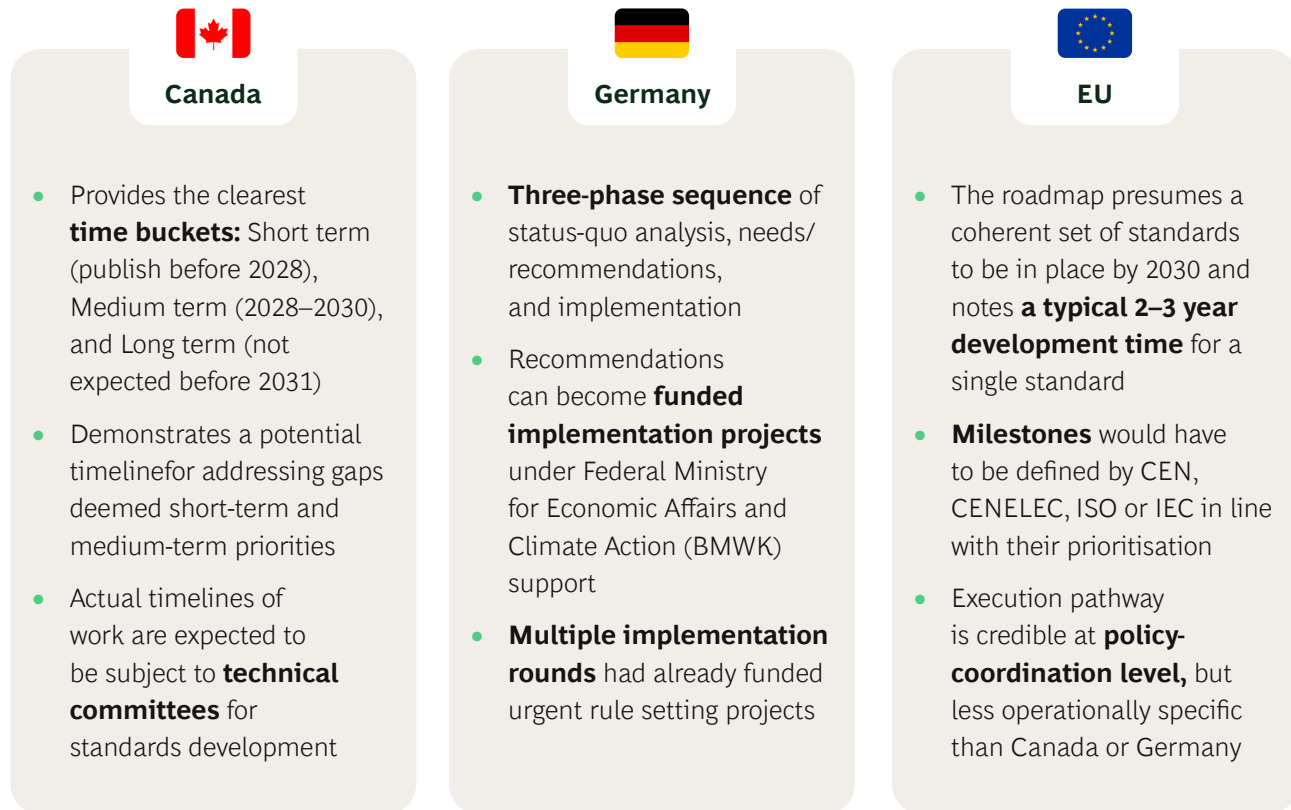
Canada's criteria-based prioritisation approach offers a useful reference for sequencing actions by urgency, safety relevance, deployment need, and implementation feasibility.

Figure 17: Benchmark comparison–Prioritisation



3.4.4 Metric 4: Implementation timeline/action plan

Figure 18: Benchmark comparison—Implementation timeline/action plan



Key takeaways for India

Clear time buckets and near-term sequencing of actions

Linking recommendations to funded implementation pathways

Coordination-led action planning through milestones and standardisation requests

Canada sets out the clearest time buckets, identifying short-term actions to be completed before 2028, medium-term actions for 2028–2030, and long-term actions beyond 2031. Germany organises implementation through a three-phase sequence of status-quo analysis, needs and recommendations, and implementation, with several recommendations moving into funded implementation projects. The EU is comparatively less operationally specific but sets out an implementation orientation by assuming that the required standards framework is in place by 2030 and by calling for milestones, standardisation requests, and stronger coordination between CEN, CENELEC, ISO, and IEC.

Canada's phased time-bucket approach provides a useful reference for translating recommended actions into near-, mid-, and long-term implementation windows.

3.5 Role of Standards Organisations and International Reference Systems

International standards organisations provide the technical reference base for several standards adopted or considered in India. ISO provides a core base across production, storage, transport, end-use, quality, and safety; IEC is particularly relevant for fuel cells and hydrogen-based power-to-power storage; CEN and CENELEC are important for gas infrastructure, pressure equipment, and refuelling interoperability in the European context; ASME remains relevant for hydrogen piping, pipelines, and pressure vessels; SAE is central for vehicle fuelling interfaces and mobility protocols; and CGA is relevant for bulk hydrogen supply, cryogenic storage, and vent systems. Other organisations such as ASTM and NFPA provide application-specific references for materials, fire safety, and ignition control.

Indian national standards are developed and published only by the Bureau of Indian Standards (BIS). Use of other international or industry-body standards depends on the authorities responsible for regulating the relevant part of the value chain. Where an indigenous standard is not yet available, regulators may permit reliance on non-Indian standards for certification to allow project continuity. Where the same standards are subsequently developed indigenously, non-ISO and non-IEC references typically serve as knowledge guidance rather than as references for direct adoption, given copyright and adaptation considerations.

India's participation in international technical committees enables domestic priorities to be reflected in evolving global standards and provides early visibility on upcoming standards. BIS, as India's national standards body, anchors this engagement through participation in ISO technical committees and corresponding national mirror committees. BIS is a participating member of ISO/TC 197 on hydrogen technologies, the central international committee for systems and devices for the production, storage, transport, measurement, and use of hydrogen. Section 6 of this document describes the broader regulatory architecture in which BIS operates, including the role of statutory authorities and sectoral regulators across the hydrogen value chain.



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04

India's Current-State Assessment

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4.3. Testing, Certification, and Approvals for Standards in India	49

India's current-state assessment establishes the baseline for identifying where the standards ecosystem is already developing and where further strengthening is required. The assessment considers the current standards inventory, progress since the launch of the National Green Hydrogen Mission, the institutional architecture for standards development, and the enabling infrastructure required for testing, certification, and approvals. This sets the reference point for the gap assessment and recommended actions that follow.

4.1 Current landscape of Standards in India

India's current standards base for low-emission hydrogen is organised across four broad categories: production, storage and transportation, end-use applications, and cross-cutting functions covering general safety, cybersecurity, and quality and measurement requirements.

Within this structure, the value-chain mapping identifies 20 components and 50 sub-components, with storage and transportation and end-use applications accounting for the largest share of the mapped landscape. The current consolidation identifies a total of 166 unique standards, codes, and reference documents across the hydrogen value chain. Of these, 31 are hydrogen-specific Indian standards and codes, and the remainder are international standards or reference documents used either as references or under consideration for adoption or adaptation. The numbers are subject to refinement as the consolidation continues through stakeholder validation.

Indian standards are typically lower in count than those in mature jurisdictions because Indian standards are often broader component-level standards that cover an entire technical area, while jurisdictions with deeper hydrogen deployment have developed more granular sub-component coverage. Low-deployment components for India's current landscape do not yet require dedicated standards unless a clear near-term need is identified. Further consolidation of the standards base is underway as part of the ongoing exercise.

4.2 Progress since the Launch of NGHM

A key feature of India's current state is the acceleration achieved after the launch of NGHM, with 34 new hydrogen-related standards issued in the fourteen months following the Mission launch, as documented in the consolidated standards mapping undertaken for this assessment and cross-referenced against the BIS standards catalogue and MNRE Working Group progress records.

The Ministry of New and Renewable Energy (MNRE) under the National Green Hydrogen Mission constituted a Working Group comprising relevant government agencies, industry stakeholders, and experts. The Working Group has three thematic subgroups, each addressing a defined part of the standards and regulations framework:



SG-I-Hydrogen Production and Use:

Convenor-CII; proposed members include IOCL, BIS, GAIL, NTPC, FAI, and CII representatives.



SG-II-Storage and Transportation of Hydrogen:

Convenor-FICCI; proposed members include DPIIT, PESO, BIS, GAIL, IOCL, and FICCI representatives.



SG-III-Hydrogen-fuelled Mobility Applications:

Convenor-SIAM; proposed members include DPIIT, PESO, MoRTH, ARAI, BIS, NTPC, and the automotive industry.

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Each sub-group brings together the relevant ministries, statutory bodies, technical institutions, and industry associations along its segment of the value chain, providing a forum for coordination across standardisation, regulation, testing, and certification considerations.

Training and Capacity Building

MNRE, in consultation with the Ministry of Skill Development and Entrepreneurship (MSDE), is implementing the Skilling, Upskilling, and Reskilling Component to develop a trained, certified, and industry-ready workforce across the hydrogen value chain. The initiative aims to build national-level training capacity through State institutions, Centres of Excellence (CoEs), and accredited training centres. Key objectives include:



Comprehensive skill-gap analysis across key areas of the hydrogen ecosystem on a continuous basis.



Creation and updating of a registry of skills required by the hydrogen value chain.



Development of Qualification Packs (QPs), training content, training manuals, and online study resources for low-emission hydrogen and allied sectors, for use across short-term training and upskilling courses.



Greater private-sector participation, with a focus on industry-led training and on-the-job training.

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Institutional architecture and standardisation process

India's hydrogen standards ecosystem has evolved from a limited standards inventory into a multi-agency implementation architecture. MNRE provides policy direction under the National Green Hydrogen Mission, while BIS anchors standards development and adoption through its technical departments and committees. PESO, OISD, PNGRB, MoRTH, ARAI, ICAT, IRS, RDSO, BEE, and NISE contribute across safety regulation, gas infrastructure, mobility certification, maritime applications, railway systems, certification, and testing support. Each of these institutions is described in more detail in the regulatory architecture set out in Section 5.

The institutional landscape has become more specialised as hydrogen deployment has moved from policy intent to project implementation. PESO's hydrogen-linked rules govern compressed hydrogen, liquid hydrogen, storage, dispensing, and safety approvals. PNGRB has initiated work on hydrogen transmission through natural-gas pipelines and city gas distribution networks. MoRTH and the automotive testing agencies are central to hydrogen vehicles, fuel systems, and type approval. BIS remains central to standards adoption and harmonisation, while NISE has been designated as the scheme implementation agency for MNRE's testing-facilities support scheme. [6] [7] [8] [9]

Clear lead-agency ownership and supporting-agency roles improve coordination across standards development, testing, certification, approvals, and enforcement. The value-chain classification used in the gap assessment therefore links each component with the institutions most relevant to standard-setting, conformity assessment, and implementation.

A dedicated information portal is under development by MNRE to consolidate hydrogen-related standards, rules, and regulations along with documentation required for approvals and a structured submission interface to the concerned authorities. A parallel standards tracker is being developed to allow periodic updates to hydrogen standards by the concerned bodies, including ownership, priority, and timelines for implementation. These tools are expected to support inter-agency coordination as deployment scales.

4.3 Testing, Certification, and Approvals for Standards in India

India's standards inventory has expanded significantly since the launch of the National Green Hydrogen Mission, and the next implementation phase requires testing, certification, and approvals capacity to scale in parallel. Standards support deployment when developers and manufacturers have access to recognised test methods, competent laboratories, conformity-assessment routes, and clearly defined approval procedures.

BIS provides the core national conformity-assessment architecture through its laboratories and Laboratory Recognition Scheme (LRS). The LRS enables recognition of outside laboratories in India and abroad, which is relevant for hydrogen because required test capabilities are distributed across mechanical, electrical, chemical, pressure-system, fuel-quality, and safety domains. BIS laboratory policy, planning, and recognition functions therefore form an important part of the testing base required for standards implementation. [10]

NISE is relevant as the scheme implementation agency for MNRE's testing-facilities support scheme under NGHM. The scheme supports identification of testing gaps, creation of new facilities, and upgradation of existing facilities for components, technologies, and processes across the value chain for hydrogen and its derivatives. This creates a direct institutional route for aligning standards development with test infrastructure. [6]

At present, hydrogen-specific testing infrastructure across the value chain remains limited. Several components are tested using infrastructure provided by manufacturers on-site, with regulators verifying parameters at the location. ARAI and ICAT provide testing facilities for several mobility-sector components and support type approval. IOCL R&D and industrial laboratories support fuel quality, hydrogen handling, and application-specific validation. Developers and technology providers, including electrolyser manufacturers, storage-system providers, refuelling-infrastructure companies, and engineering firms, contribute operating data, component-level evidence, and field feedback that informs refinement of standards.

Indian hydrogen specifications and parameters are extremely stringent and require specialised laboratories, equipment, and capability to test. This drives up the cost of setting up domestic testing infrastructure but remains a stated priority for future development. As electrolyser, cylinder, valve, storage, fuel-cell, and refuelling equipment manufacturing expands under the Make-in-India agenda, the strengthening of domestic certification pathways is expected to reduce dependence on overseas laboratories, improve product credibility, and support international market recognition.



05

Regulatory Architecture for Hydrogen Standards

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India's hydrogen ecosystem is governed by a multi-agency regulatory architecture in which statutory powers, technical standard-setting, certification, and approval functions are distributed across specialised institutions. Standards development is anchored by the Bureau of Indian Standards as the national standards body, while statutory regulators across the value chain are responsible for issuing rules, granting approvals, and enforcing safety and quality requirements within their respective mandates.

The sub-sections below describe each principal institution active in the hydrogen value chain, the scope of its statutory or technical mandate, the parts of the hydrogen value chain it covers, the most relevant rules, regulations, and public notices issued or under amendment, its role in standards assessment and development, and its engagement on the international platform.

5.1 Bureau of Indian Standards (BIS)

Mandate and Role

The Bureau of Indian Standards (BIS), established under the Bureau of Indian Standards Act, 2016, functions under the Ministry of Consumer Affairs, Food and Public Distribution and is the national standards body of India. Indian national standards (designated by the prefix "IS") can be developed and published only by BIS, either independently or by adoption or adaptation of international standards from ISO, IEC, and other globally recognised bodies. In the absence of an Indian standard, sectoral regulators may temporarily allow reliance on international or industry-body references such as ASME, API, CGA, or NFPA to allow project continuity. Once an indigenous standard is developed, such non-ISO and non-IEC references typically serve as knowledge guidance rather than direct references for adoption.

Coverage across the hydrogen value chain

BIS plays a central role across all four segments of the hydrogen value chain: production, storage and transportation, end-use applications, and cross-cutting safety. BIS standards are organised across multiple technical divisions, including the Chemical Department (CHD), Mechanical Engineering Department (MED), and Petroleum, Coal and Related Products Department (PCD), with relevant Sectional Committees responsible for the formulation of hydrogen-related standards in their respective domains.

Key hydrogen-related standards and codes

Examples of indigenously developed hydrogen-specific Indian standards include IS 19575:2026 on electrolyser efficiency and IS 16061:2026 on hydrogen fuel quality for mobility. BIS has also adopted several ISO and IEC hydrogen standards directly as Indian standards, including IS/ISO 13985:2006 on liquid-hydrogen vehicle fuel tanks and IS/ISO 15916 on basic considerations for the safety of hydrogen systems. Hydrogen-specific Indian standards have been issued for cylinders, electrolysers, fuelling stations, hydrogen detection, hydrogen quality, and cryogenic storage, among others. Indigenous standards for piping and pipelines specifically for hydrogen are under development, drawing on ASME B31.12 and ASME B31.3 as technical references.

International engagement

BIS represents India in the International Organisation for Standardisation (ISO) and the International Electrotechnical Commission (IEC) through national mirror committees. India is a participating member of ISO/TC 197 on hydrogen technologies and engages across its sub-committees and working groups, providing visibility on global standards development and an opportunity to reflect domestic priorities in evolving international standards. BIS has also signed Memoranda of Understanding with the European Committee for Standardisation (CEN) and the American National Standards Institute (ANSI) for cooperation on standards.

5.2 Petroleum and Explosives Safety Organisation (PESO)

Mandate and Role

The Petroleum and Explosives Safety Organisation (PESO), under the Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Commerce and Industry, is the statutory authority for the safe handling, storage, transport, and use of explosives, compressed gases, and petroleum products in India. The Chief Controller of Explosives (CCoE) and Controllers of Explosives administer licensing, design approvals, periodic inspections, and incident investigation under the Explosives Act, 1884; the Petroleum Act, 1934; and rules framed under these Acts including the Gas Cylinders Rules, 2016, the Static and Mobile Pressure Vessels (Unfired) Rules, 2016, Petroleum Rules, 2002, Calcium Carbide Rules, 1987, Inflammable Substance Act 1952 and MSIHC Rules, 1989.

Coverage across the hydrogen value chain

PESO's jurisdiction is most directly relevant to hydrogen storage, filling gas in cylinders, transportation by road and hydrogen cross country pipelines, refuelling, and on-site handling. This includes compressed hydrogen cylinders and cascades, bulk gaseous and cryogenic hydrogen storage vessels, tube trailers, transportation of hydrogen by pipelines, blending of hydrogen in natural gas pipelines, dispensing systems, and hydrogen generation and storage premises requiring licensing.

PESO design approvals are required for pressure vessels, Safety Relief valves, Evaporators, cylinders, valves, pressure-relief devices, and storage systems, Ex-Electrical equipment installed in Dispensers, compressors, sensors, detectors etc. used in hydrogen service.

Key hydrogen-related rules, regulations, and amendments

- Gas Cylinders (Amendment) Rules, 2025 (Hydrogen):** introduce compressed hydrogen gas cylinders within the ambit of the Gas Cylinders Rules, 2016, define a "bulk hydrogen compressed gas system" for storage exceeding 5,000 standard cubic feet (141.6 normal cubic metres), introduce the concept of low-emission hydrogen produced from renewable energy, set service life parameters for compressed hydrogen and low-emission hydrogen cylinders and cascades, and prescribe periodic hydrostatic testing requirements. The rules also expand eligibility for testing of composite cylinders within India, supporting the Make in India agenda. Electrical installations associated with bulk and non-bulk compressed gas systems, hydrogen generation systems, compressors, and dispensers need to conform to standards accepted by the Chief Controller or recommended under the National Green Hydrogen Mission.

The introduction of a new license, "FORM H," for entities involved in the generation, storage, and dispensing of hydrogen as an automotive fuel. Hydrogen cylinders manufacturing units, Testing facilities for Type-3 and Type-4 cylinders also included. The allowance for the use of lightweight materials for type-4 composite cylinders and the increase in the diameter up to 80cm of gas cylinders to align with global best practices. The promotion of domestic manufacturing and testing capabilities for composite cylinders through the "Make in India" initiative. The implementation of advanced tracking and tracing technologies for gas cylinders to enhance safety and accountability.

- Static and Mobile Pressure Vessels (Unfired) Amendment Rules, 2025:** govern the design, manufacture, storage, transport, and operation of pressure vessels used for compressed gases. The introduction of a new license, "FORM LS-1D," for entities involved in the generation, storage, and dispensing of Liquid Hydrogen LH₂ as an automotive fuel.



- **Manufacture, Storage and Import of Hazardous Chemical Rules (1989):** Reviewing and approving site plans for industrial activities and cross-country pipelines transporting hazardous chemicals including Hydrogen.
- **Petroleum (Amendment) Rules, 2024:** cover broader updates relevant to petroleum facilities, including elements that interface with hydrogen at refineries.

International engagement

PESO engages with international counterparts through participation in technical exchanges and review of international codes referenced in Indian regulatory schedules. Through the inclusion of IS, ISO, and EN codes in the Gas Cylinder Rules schedules, PESO maintains an indirect linkage with international standard-setting processes.

5.3 Petroleum and Natural Gas Regulatory Board (PNGRB)

Mandate and Role

The Petroleum and Natural Gas Regulatory Board (PNGRB), established under the PNGRB Act, 2006, regulates the refining, processing, storage, transportation, distribution, marketing, and sale of petroleum, petroleum products, and natural gas, excluding the production of crude oil and natural gas. PNGRB grants authorisations for natural-gas pipelines, city gas distribution networks, and common-carrier or contract-carrier infrastructure. With the emergence of hydrogen blending and pure hydrogen transmission, PNGRB has been progressing work on of transporting hydrogen through existing natural-gas transmission infrastructure and, in time, through dedicated hydrogen pipelines.

Coverage across the hydrogen value chain

PNGRB's direct relevance is in the transportation and distribution segments of the value chain: hydrogen blending into natural-gas transmission pipelines, blending into city gas distribution networks, dedicated hydrogen pipelines, and associated metering, tariff, and authorisation arrangements. PNGRB's authorised natural-gas pipeline network of approximately 33,000 km (of which approximately 24,000 km is operational) provides the principal candidate infrastructure for early-stage hydrogen blending corridors.

As the statutory downstream regulator for petroleum and natural gas, PNGRB has regulatory jurisdiction over natural-gas transmission pipelines and CGD networks, placing it in a unique position to steer India's transition toward hydrogen-compatible gas infrastructure. This role is aligned with Clause 6.4 of the National Green Hydrogen Mission, which states that the Ministry of Petroleum and Natural Gas (MoPNG) will enable development and facilitation of regulations through the Petroleum and Natural Gas Regulatory Board (PNGRB).

PNGRB has undertaken several strategic initiatives to support safe and technically sound hydrogen transportation through existing gas networks and future dedicated hydrogen pipeline systems.

Key hydrogen-related studies, regulations, and developments

- **Pathways for Transmission of Hydrogen in Natural Gas Pipelines and City Gas Distribution Networks (2024):** a comprehensive study conducted by PNGRB in association with the World Bank and ICF, mapping hydrogen demand and supply, technical assessment of existing pipeline networks for hydrogen-blending compatibility, commercial assessment, policy and regulatory bottlenecks, and a roadmap for hydrogen blending and pure-hydrogen pipeline development.

Roadmap on Hydrogen Transportation through Pipelines and Blending with Natural Gas:

PNGRB has developed a roadmap outlining the phased strategy for hydrogen blending and future pure hydrogen transmission.

- A central recommendation is the **National Hydrogen Testbed** with full-scale test loops for both transmission and CGD systems to generate India-specific evidence on material compatibility, safety behaviour, and operational parameters. This facility would be essential for developing national standards and enabling OEM certifications.

- **Scientific Advisory Committee:** Established to drive the development of India-specific technical and safety standards, R&D pathways, and regulatory guidance for hydrogen transportation and blending in NGPL and CGD networks, including testbed development, pilot project oversight, and risk mitigation measures.

- **Hydrogen blending pilots in CGD networks:** PNGRB has initiated India's first hydrogen blending pilots by approving five projects across Madhya Pradesh, Gujarat, Assam and Uttar Pradesh with blending levels ranging from 2% to 5%.
 - These pilots are assessing MDPE and steel pipeline behaviour, stratification, leakage characteristics, metering impacts, and consumer-end performance.
 - Initial operational findings are expected to provide key technical inputs for future hydrogen blending regulations.

- **Domestic stakeholder interactions:** PNGRB has undertaken several technical engagements, including collaboration with UK's SGN and IGEM, IITs, GERMI-Gujarat, visit to National Gas-UK, SGN-FIFE and DNV Spadeadam facilities.
 - Regular consultations with key national scientific and policy institutions, Dr. V. K. Saraswat (Member, NITI Aayog), Prof. Ajay Kumar Sood (Principal Scientific Adviser), and Shri Abhay Bakre (Mission Director, NGHM) have consistently reinforced PNGRB's central role in hydrogen transportation.
 - PNGRB's active participation in MNRE's standards committees for drafting hydrogen technical codes, along with a PNGRB representative serving on the National Hydrogen Safety Panel (NHSP) constituted under the NGHM with the approval of MNRE, contributes directly to national-level safety governance, standards, harmonisation, and coordinated regulatory preparedness.
 - PNGRB also facilitated the recent hydrogen-focused workshop at IOCL Panipat, contributing to national-level readiness discussions on pipeline and refinery integration.
 - It has also conducted stakeholder interactions on hydrogen transmission, including the 7 March 2024 mega-stakeholder interaction.

- **Typical Guidelines for Hydrogen Blending with Natural Gas:** Drafted by a PNGRB technical committee with industry representation. These guidelines establish a common technical and safety reference for hydrogen blending pilots.

- **Hydrogen Cell:** PNGRB has established a Hydrogen Cell, functioning under the purview of the Coordination Division, to lead regulatory development, technical assessments, standards alignment, and coordination with Ministries, PSUs, industry bodies, and international organisations.



- **PNGRB (Technical Standards and Specifications including Safety Standards for Petroleum Refineries and Gas Processing Plants) Regulations, 2023:** Provide the principal safety-standards framework applicable to refineries and gas processing plants.
-
- **Developments in regulations:** Out of the 20 hydrogen-relevant standards recommended by MNRE, eight have been adopted into PNGRB's regulatory framework. Six were already in force through existing T4S provisions covering natural gas pipelines and CGD networks.
 - The other two, AGA Report No. 8 (compressibility factors for hydrogen–natural gas mixtures) and IS 15677 (metering protocols for blended streams) were added through the T4S (CGD) amendments notified in the Gazette of 25 April 2024.
 - One further standard, ASME B31.12, the principal international standard for hydrogen pipelines remains under review, with adoption contingent on the inclusion of hydrogen in the PNGRB Act, 2006.
 - PNGRB has proposed amendments to the PNGRB Act, 2006 to explicitly include hydrogen transportation and blending within its regulatory mandate. This amendment is essential for enabling authorisation, safety regulation, compliance oversight, and tariff determination for hydrogen pipelines.
-

International engagement

- On 12.01.2026 a Memorandum of Understanding (MoU) between PNGRB and DVGW was exchanged by Shri Ajit Vinayak Gupte, Ambassador of India to Germany and Dr. Philipp Ackermann, German Ambassador to India, in the presence of the Hon'ble Prime Minister of India, Shri Narendra Modi, and the Hon'ble German Chancellor, Mr. Friedrich Merz, at Mahatma Mandir, Gandhinagar, Gujarat, to establish a framework for cooperation on hydrogen integration in natural gas infrastructure.
- PNGRB also has a Memorandum of Understanding with the American Society of Mechanical Engineers (ASME). It also collaborates with multilateral institutions including the World Bank and engages with international reference frameworks for hydrogen transmission and blending through its technical studies.

5.4 Oil Industry Safety Directorate (OISD)

Mandate and Role

The Oil Industry Safety Directorate (OISD), set up in 1986 by the Ministry of Petroleum and Natural Gas, is a technical directorate that formulates and coordinates the implementation of self-regulatory safety measures for the oil and gas industry in India. OISD develops standards (designated OISD-STD), recommended practices (OISD-RP), and guidelines (OISD-GDN) for design, layout, operation, inspection, and maintenance of facilities and activities in the hydrocarbon processing industry, and conducts safety audits, incident investigations, and post-incident reviews. OISD is also the notified competent authority under the Petroleum and Natural Gas (Safety in Offshore Operations) Rules, 2008.

Coverage across the green hydrogen value chain

OISD is most directly relevant to hydrogen handling within petroleum refineries and gas-processing plants, where hydrogen is used as an industrial feedstock in hydrotreating, hydrocracking, and hydrogen-unit operations, and to the broader oil and gas safety framework that interfaces with hydrogen infrastructure. As refineries adopt hydrogen for feedstock substitution, OISD's safety standards and audit framework remain directly applicable to plant design, layout, fire protection, and process safety.

Key hydrogen-related standards and codes

- **OISD has issued multiple standards** relevant to refineries and oil and gas processing, including OISD-STD-116 on fire protection facilities for petroleum refineries and gas processing plants, OISD-STD-118 on layout, OISD-STD-150 on safety in installations, and others, several of which are referenced in PESO and PNGRB regulations.
- **OISD is consolidating existing standards and standards under development relating to hydrogen** under its purview under a single consolidated framework.
- **OISD has provided extensive inputs to the Working Group on Safety** in the Indian Petroleum Sector, including identifying gaps in regulations related to the hydrogen ecosystem and the compressed biogas ecosystem.

International engagement

OISD has signed a Memorandum of Understanding with the American Petroleum Institute (API) for cooperation on standards and is a member of the International Regulators Forum (IRF), a group of leading offshore safety regulators that drives improvement in offshore safety through collaboration, joint programmes, and information sharing in the global offshore oil and gas industry.



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5.5 Ministry of Road Transport and Highways (MoRTH) and Automotive Testing Agencies

Mandate and Role

The Ministry of Road Transport and Highways (MoRTH) is the principal authority for vehicle regulation in India under the Motor Vehicles Act, 1988, and the Central Motor Vehicles Rules (CMVR), 1989. Automotive Industry Standards (AIS) are formulated by the Automotive Industry Standards Committee (AISC), approved by the CMVR Technical Standing Committee, and published by the Automotive Research Association of India (ARAI), which serves as the secretariat. Type approval, conformity of production, and certification of vehicles and vehicular components are administered through MoRTH-recognised testing agencies, principally ARAI and the International Centre for Automotive Technology (ICAT).

Coverage across the hydrogen value chain

MoRTH and the automotive testing agencies are responsible for hydrogen vehicle type approval, fuel-system component certification, onboard storage approvals, refuelling-interface safety, and crash and impact testing. This covers passenger vehicles, commercial vehicles, buses, and two- and three-wheelers using compressed gaseous hydrogen, liquid hydrogen, or hydrogen blends, in both fuel-cell and internal-combustion configurations.

Key hydrogen-related standards and codes

- **AIS-157:** Safety and procedural requirements for type approval of compressed gaseous hydrogen fuel-cell vehicles. Published initially in 2020 with hydrogen fuel-cell vehicles included within AIS until BIS specifications are framed, the standard covers safety requirements, hydrogen storage systems, fuel-cell power systems, and procedural requirements for vehicle certification.
- **AIS-195 (October 2023):** Safety and procedural requirements for type approval of hydrogen-powered vehicles using liquid or compressed gaseous hydrogen, expanding the scope to include internal-combustion configurations and liquid hydrogen storage.
- **AIS-156:** Safety requirements for electric power-train vehicles in the L-category (two-wheelers, three-wheelers, and quadricycles), drawing on UN ECE R 136, which addresses electrical safety for these vehicle categories under the WP.29 framework. AIS-156 is relevant in the context of L-category hydrogen-electric hybrid configurations, where the electric drive component requires independent certification; hydrogen fuel-system requirements for such configurations are addressed separately under AIS-157 and AIS-195.
- **Gazette notifications** G.S.R. 579, G.S.R. 585, and G.S.R. 889 cover related amendments to CMVR provisions enabling hydrogen-fuelled vehicles.

International engagement

India participates in the UN ECE World Forum for Harmonisation of Vehicle Regulations (WP.29), through which UN Global Technical Regulations (UN GTRs) and UN Regulations on hydrogen-fuelled vehicles are developed and harmonised. AIS-157 and AIS-195 draw on UN GTR No. 13 for hydrogen-fuelled vehicles. India also engages in the Asian Region Joint Public-Private Forum on vehicle regulation, and ARAI participates in the related international technical fora.

5.6 Bureau of Energy Efficiency and Supporting institutions

Bureau of Energy Efficiency (BEE)

Established under the Energy Conservation Act, 2001, the Bureau of Energy Efficiency (BEE) is a statutory body under the Ministry of Power. BEE has been designated, under the Green Hydrogen Standard for India, as the nodal authority for accreditation of agencies engaged in monitoring, verification, and certification of hydrogen production projects. BEE's role is central to the operationalisation of the Green Hydrogen Certification Scheme.

National Institute of Solar Energy (NISE)

NISE, an autonomous institution under MNRE, is the designated scheme implementation agency for MNRE's testing-facilities support scheme under the National Green Hydrogen Mission. The scheme supports identification of testing gaps, creation of new facilities, and upgradation of existing facilities for components, technologies, and processes across the value chain of hydrogen and its derivatives.

Indian Register of Shipping (IRS) and Directorate General of Shipping

IRS, a not-for-profit classification society recognised under the Merchant Shipping Act, 1958, provides classification and certification services for ships and offshore assets, and is relevant for hydrogen-fuelled vessels, hydrogen and ammonia bunkering, and marine transport of liquid hydrogen and derivatives. The Directorate General of Shipping under the Ministry of Ports, Shipping and Waterways is the statutory authority for maritime regulation.

Research Designs and Standards Organisation (RDSO)

RDSO, under the Ministry of Railways, is the principal technical adviser to the Ministry on standards for railways. It is relevant for hydrogen-fueled rail traction, hydrogen storage on rolling stock, and depot and station infrastructure. Where AIS-type provisions for road vehicles do not apply, hydrogen rail applications require dedicated standards developed in coordination with RDSO.

5.7 Inter-agency Co-ordination

Given the distribution of statutory and technical mandates across these institutions, the operating effectiveness of the standards ecosystem depends on coordination across rule-making, standardisation, testing, and approvals. The MNRE Working Group structure under the National Green Hydrogen Mission, with its three thematic subgroups, provides the principal coordination forum across the segments of the value chain. The Green Hydrogen Certification Scheme links MNRE, BEE, and the verification agencies. A single reference point is key for all hydrogen-related standards, regulations, and approval pathways across the relevant agencies – it improves the access to accurate information and supports project continuity and transparency for developers.



06

Defining the Hydrogen Value Chain

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The hydrogen value chain provides the common basis on which standards are mapped, gaps identified, recommended actions developed, and implementation responsibilities distributed across the ecosystem. A structured value-chain classification supports consistent treatment of standards across institutions and enables clear traceability between technical requirements and the components or activities to which they apply.

The value chain is organised into four core segments: production; transport and storage; end-use applications; and cross-cutting functions including general safety. Each segment is further disaggregated into components and sub-components that reflect the underlying technical content, operating conditions, and standards needs across the lifecycle.

Note

Several standards are applicable to more than one sub-component within the value chain. To avoid repetition, each standard is mapped to its most directly relevant component rather than reproduced under every sub-component to which it may also apply. This treatment is consistent with the structure of many Indian standards, which are framed at the component level and cover an entire technical area within their scope.

6.1 Production

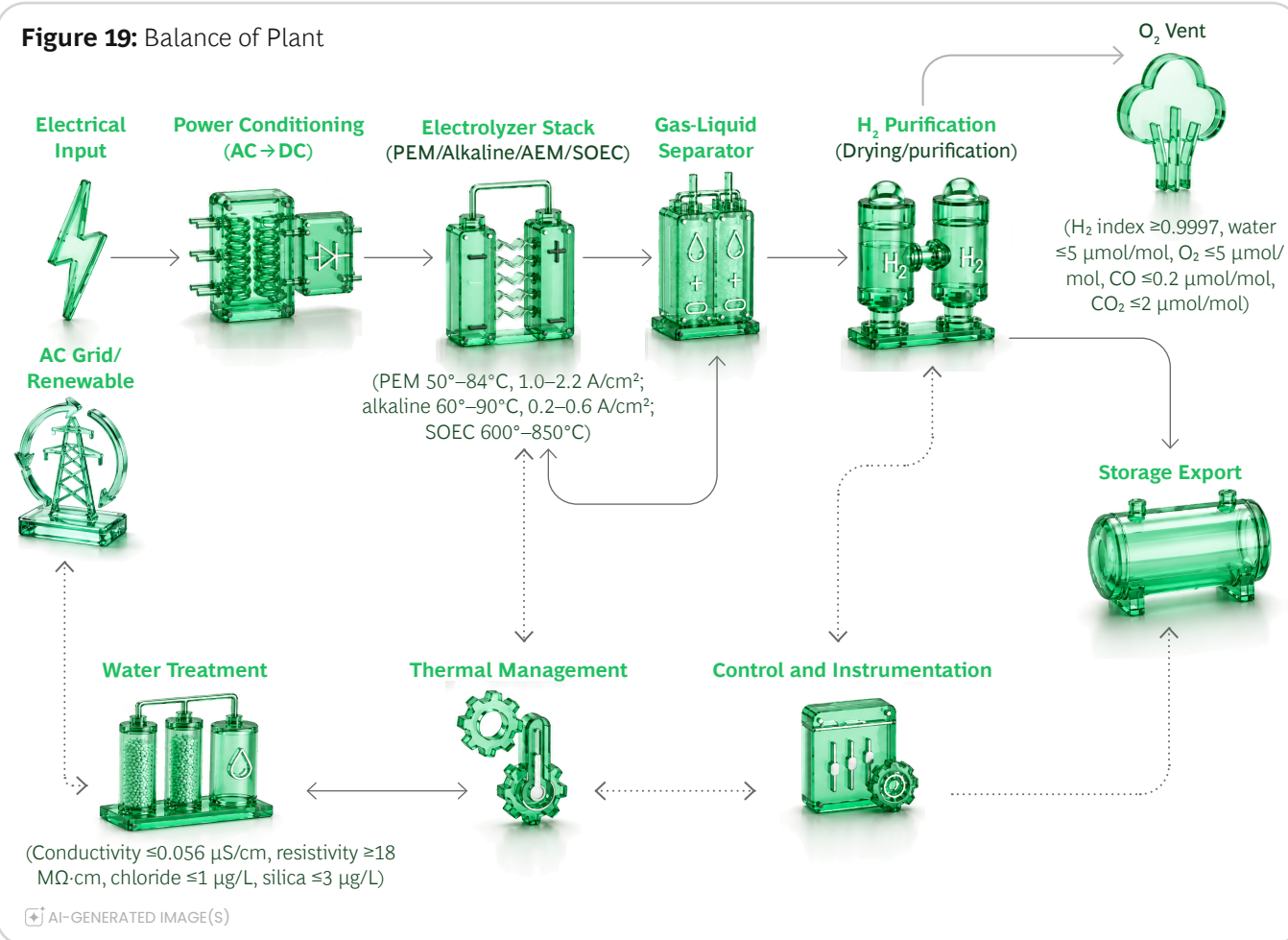
The production segment covers the hydrogen production system in its entirety—from the renewable energy input, water supply, and other balance-of-plant requirements, through to the generation of hydrogen itself. Consistent with the Green Hydrogen Certification Scheme of India [12], electrolysis-based and biomass-based production are recognised as the eligible production pathways and are treated as distinct routes within the value-chain classification.

Coverage extends to both the core production equipment and the supporting systems required for safe, reliable, and efficient hydrogen generation. The Indian threshold for green hydrogen—not more than 2 kg CO₂ equivalent per kg of hydrogen, measured as a 12-month average for non-biogenic emissions—is the reference point for certification under the Green Hydrogen Standard for India.



6.1.1 Balance of Plant

Figure 19: Balance of Plant



A significant share of operational hazards in an electrolyser plant arises within auxiliary equipment rather than within the electrolyser stack itself. Feedwater quality, the technical parameters of the electrical systems, vent systems, and other supporting components therefore require clearly defined specifications, structured inspection regimes, and periodic verification. The principal balance-of-plant sub-components and their associated requirements are summarised below:

Water purity: feedwater systems need to deliver hydrogen-grade purified water to the electrolyser, as contaminants can accelerate stack degradation and reduce efficiency over the lifecycle of the equipment.

Electrical systems: electrical systems need manage variable renewable power input, voltage stability, protection coordination, and electrical isolation, while maintaining compliance with hazardous-area requirements where applicable.

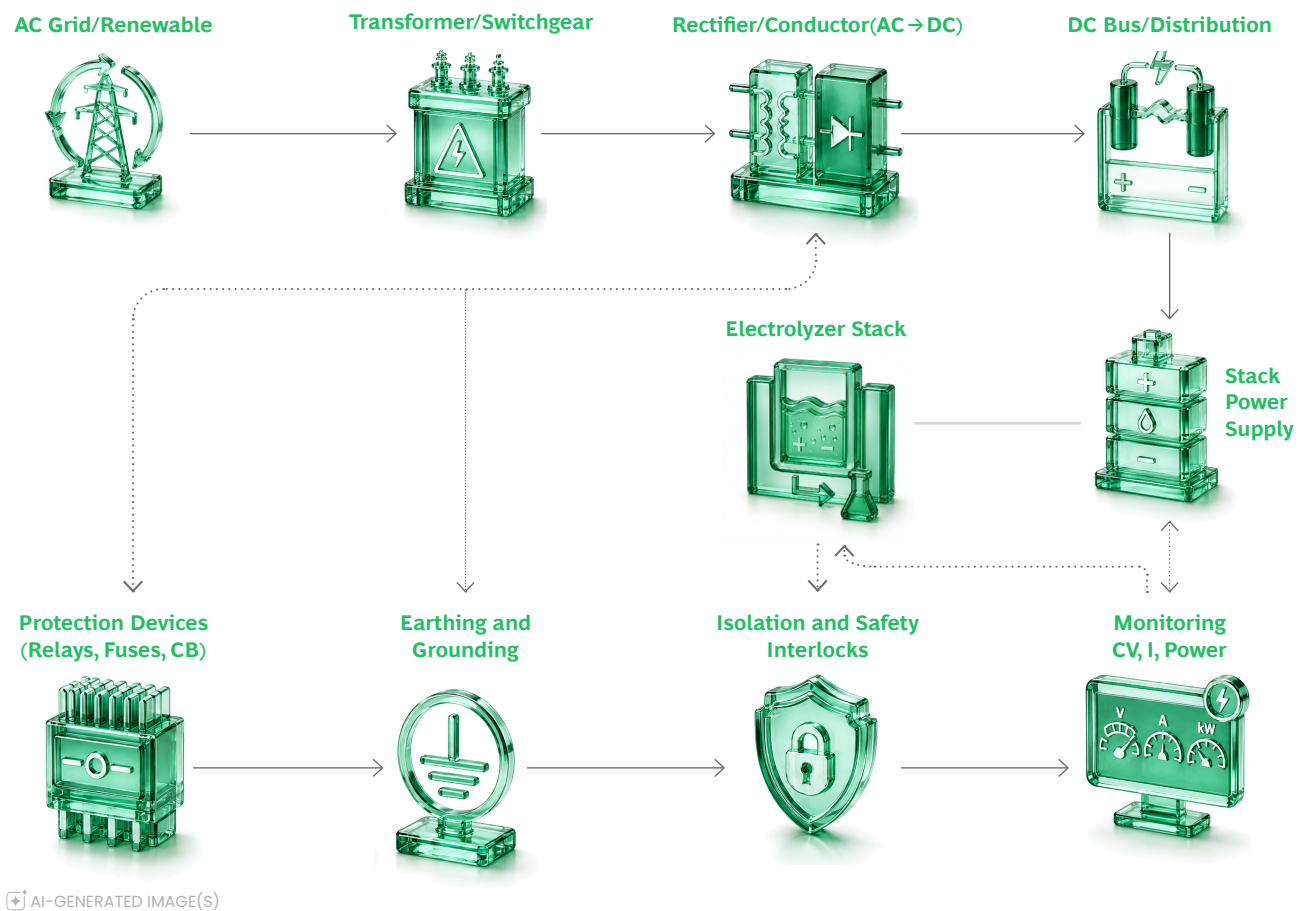
Thermal management: cooling systems are required to prevent heat-induced degradation of the electrolyser stack and its sub-components, including membranes, seals, and instrumentation.

Vent systems: vent systems are required to prevent hydrogen accumulation in the vicinity of ignition sources and in enclosed or poorly ventilated spaces.

Hydrogen supply systems: requirements extend to site selection for the production plant, equipment installation and transportation arrangements, and the safe decommissioning and removal of systems at end of life.

Pumps and valves: these components support gas handling, water supply, and pressure control across the system while preventing leakage, backflow, and unintended depressurisation.

Figure 20: Electrical systems



Standards/documents:

IS 1070:2023, IS 5572:2009, IS 16724:2018, IEC 60079-10-1:2020, IEC 60079-14:2024, NFPA 70, CGA G-5.5, CGA H-5

6.1.2 Decentralised/in-situ production systems

Under the National Green Hydrogen Mission (NGHM) [2], decentralised production is essential for end-use cases like long-haul mobility, where transportation is costly and infrastructure intensive. Currently, there are two categories of production that fall under the purview of the NGHM:

Biomass-based hydrogen production systems

Modular electrolyzers connected to rooftop solar or other decentralised RE plants like small hydro, etc.

Hydrogen refueling stations in the cities and along highways could be connected to decentralised renewable energy plants to enable in-situ production of hydrogen, which could help reduce the dependence on transported hydrogen for end-uses. For domestic and small-scale applications, modular electrolyzers can be integrated with rooftop solar or other decentralised renewable energy sources such as small hydro power plants.

Standards are required to tackle key issues such as variable renewable power input, the use of industrial or municipal wastewater compatibility, limited space for separation distances and leak detection.

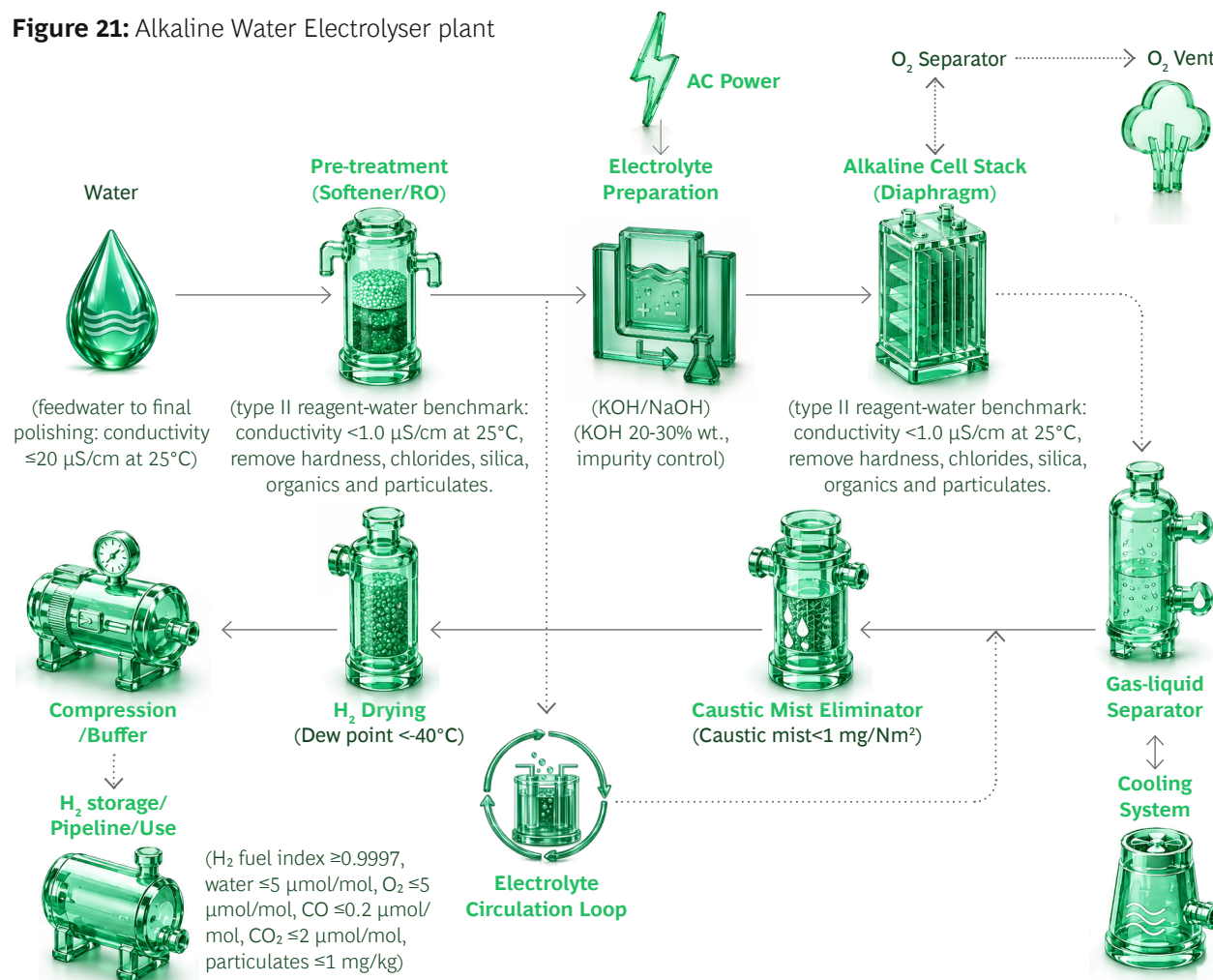
6.1.3 Electrolyzers

Electrolyzers are electrochemical devices that generate hydrogen and oxygen by splitting water using electrical energy. It remains the dominant low-emission hydrogen production route in India's policy framework and in most announced project pipelines.

Low Temperature Electrolysis

Alkaline Water (ALK) electrolyzers are a mature, commercially established technology. The electrodes are immersed in an alkaline solution, usually potassium hydroxide (KOH) and have high long-term stability and comparatively low investment costs.

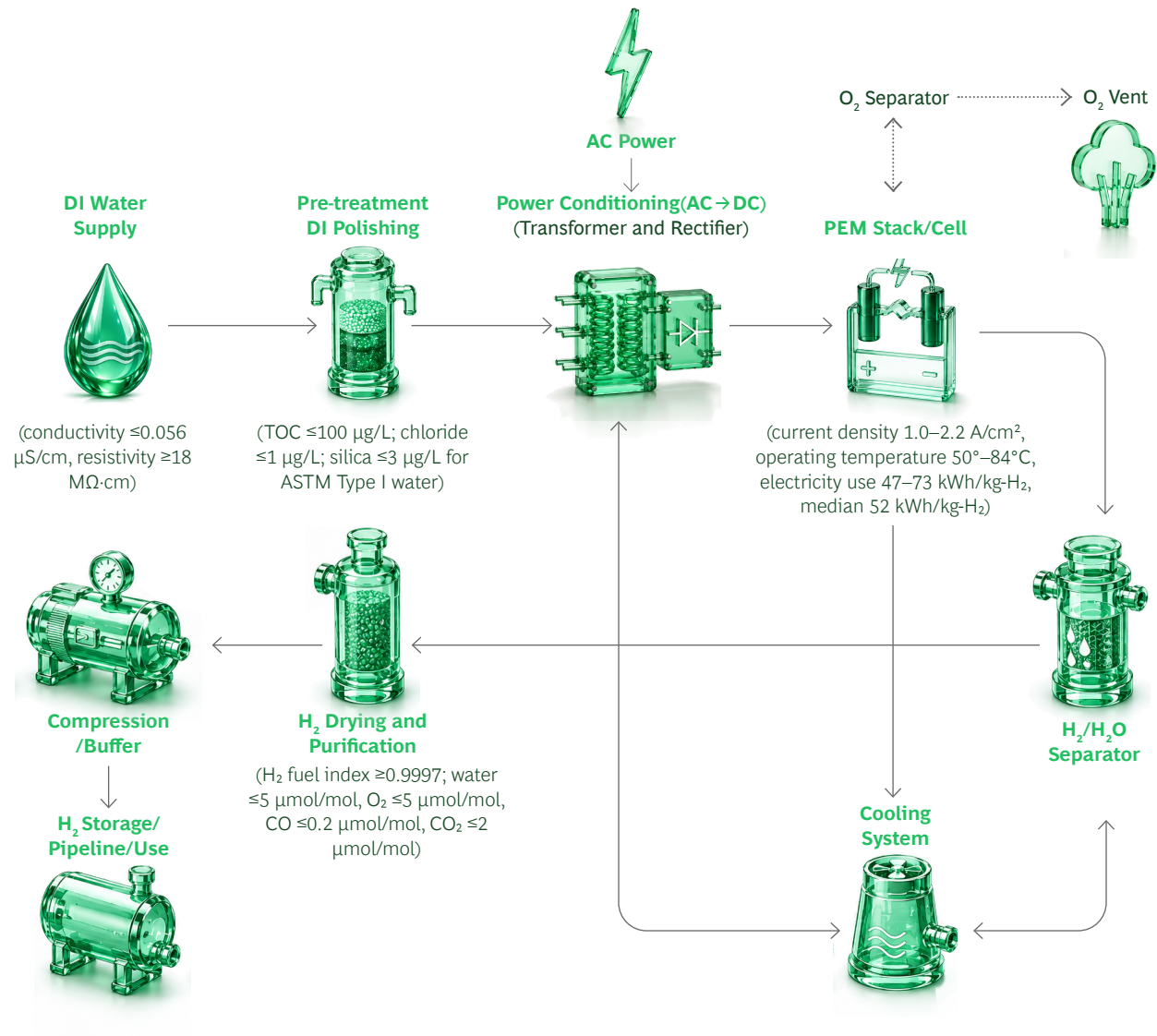
Figure 21: Alkaline Water Electrolyser plant



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Proton Exchange Membrane (PEM) electrolyzers use a solid polymer membrane and need high purity water. These respond well to variable renewable power input. This technology is primarily deployed in industrial use-cases.

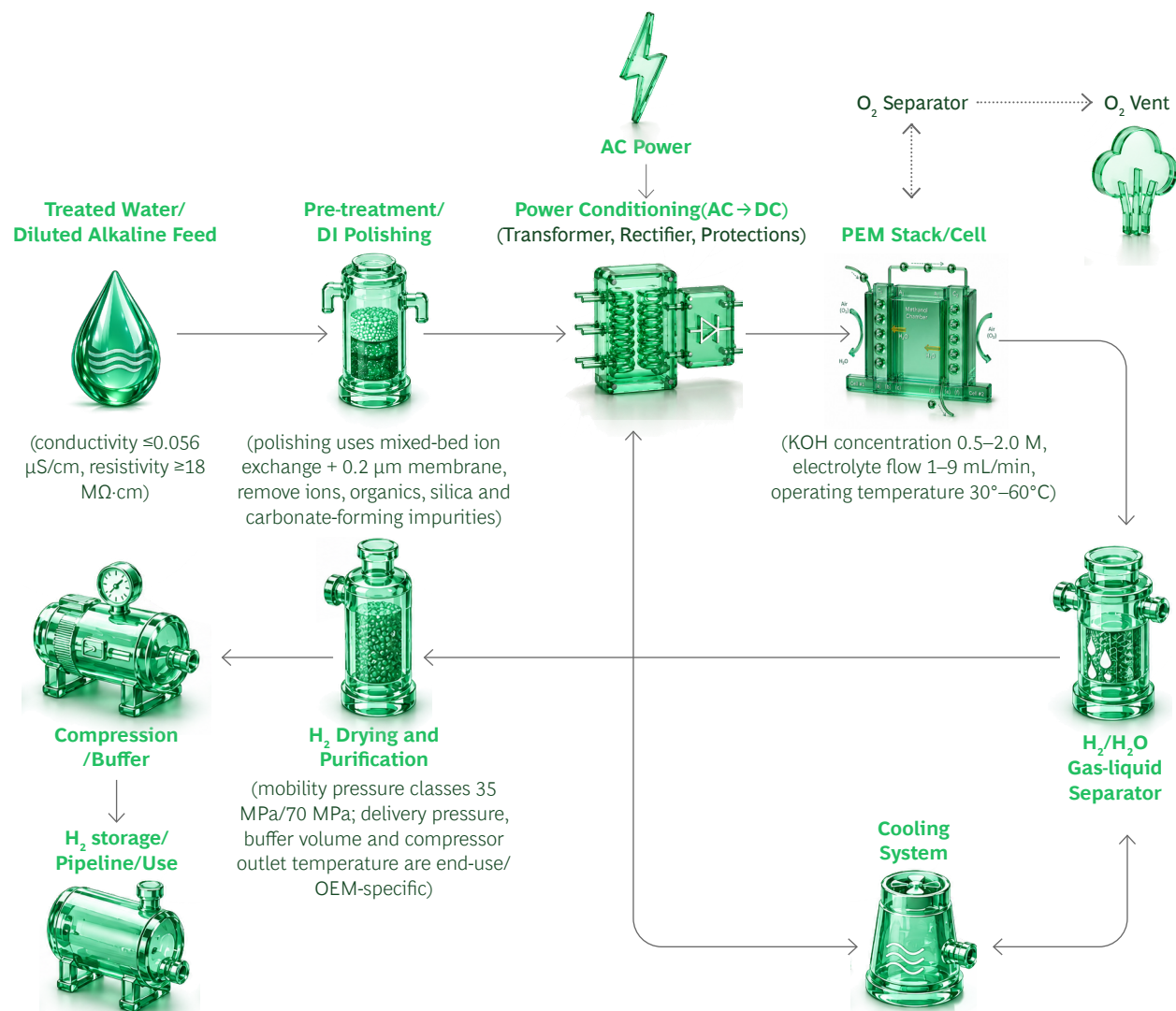
Figure 22: Proton Exchange Membrane electrolyser plant



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Anion Exchange Membrane (AEM) electrolyzers do not require noble catalysts or titanium (like PEM electrolyzers) and can be used in smaller-scale projects. It is an emerging technology and is currently regarded as in R&D stage.

Figure 23: Anion Exchange Membrane plant

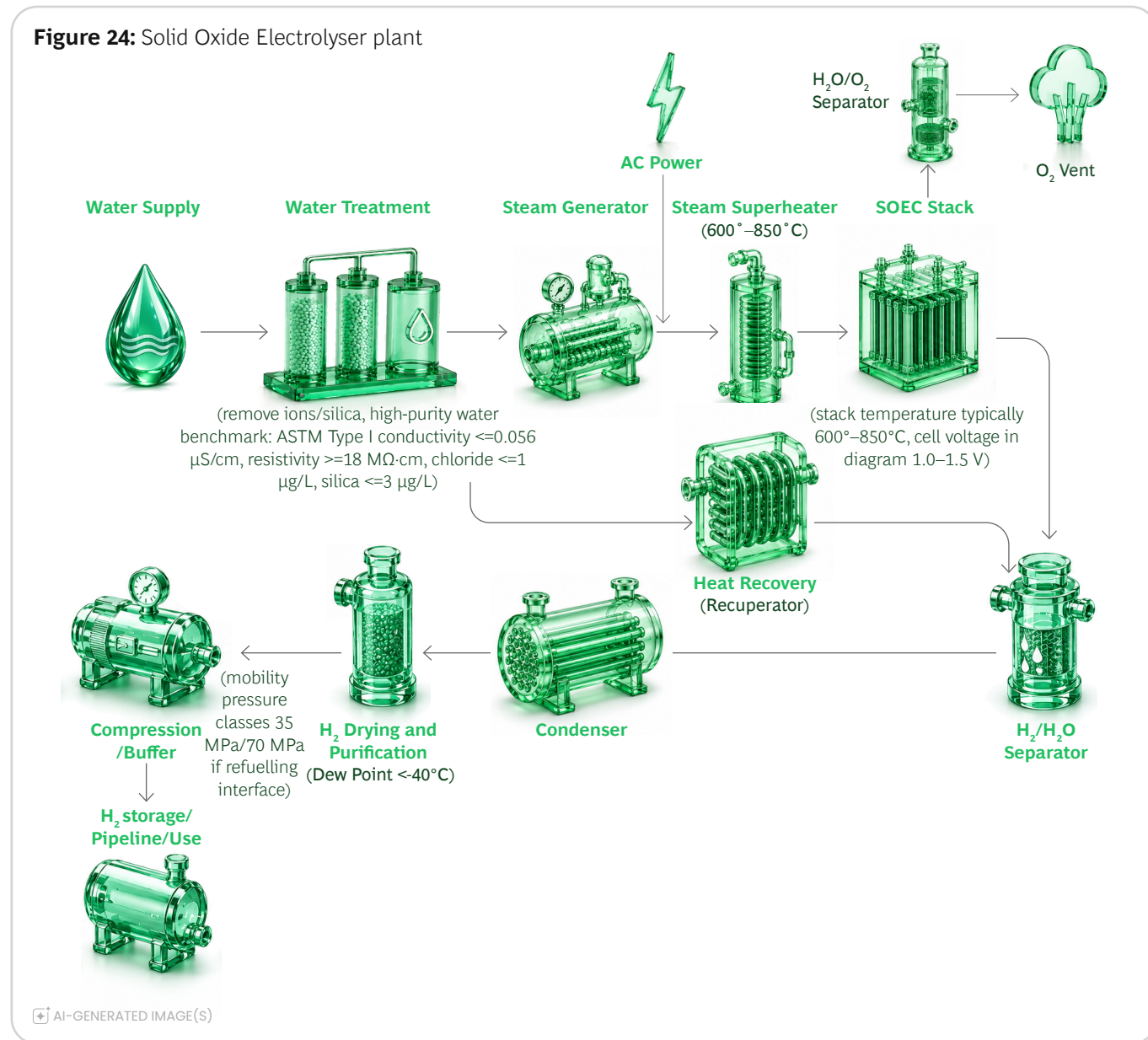


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High Temperature Electrolysis

Solid Oxide Electrolyser Cell (SOEC) operates at extremely high temperatures (700°–850°C). The high temperatures increase electrical efficiency and enable the use of non-precious metals as catalysts. Most current SOEC electrolyzers are small, kilowatt-scale and are at demonstration stage.

Figure 24: Solid Oxide Electrolyser plant



Efficiency assessments are required for both types of electrolyzers. The degradation of components can lead to gas cross-over; this is a major concern because hydrogen can enter the oxygen stream or oxygen can enter the hydrogen stream causing explosions and life-safety risks.

Principal hazard in electrolyser plants is the potential accumulation of hydrogen and oxygen gases. Such conditions create fire and explosion risks. Risk assessments have also identified gas-water separators, water-supply pumps feeding the electrolyser stack, and the electrolyser stack itself as key contributors to high-risk failure scenarios.

Standards/Documents:

IS 16509:2020, IS 16512 (Part 1):2016, ISO 22734-1:2025, ISO 22734:2019, IEC 62282-8-101:2020

6.1.4 Hydrogen Quality

Poor hydrogen quality can cause unreliable operation downstream. Impurities such as oxygen, water, carbon monoxide, hydrocarbons can damage fuel cells, affect combustion efficiency, and reduce equipment life.

Fuel-quality grades such as Grade A/B/C/D need to be distinctly explained, as different applications need different hydrogen purity. E.g., fuel-cell electric vehicles usually need very high-purity hydrogen, while hydrogen internal combustion engines may tolerate lower-purity hydrogen.

Practical system needed to collect samples, test them, verify compliance, and certify fuel quality consistently across the supply chain needs to be present.

A clear fuel-quality standard therefore is required for end-use applications and overall market confidence. [11]

Standards/documents:

IS 16061:2026, ISO 14687:2025, ISO 19880-9

6.1.5 Bio-based Production

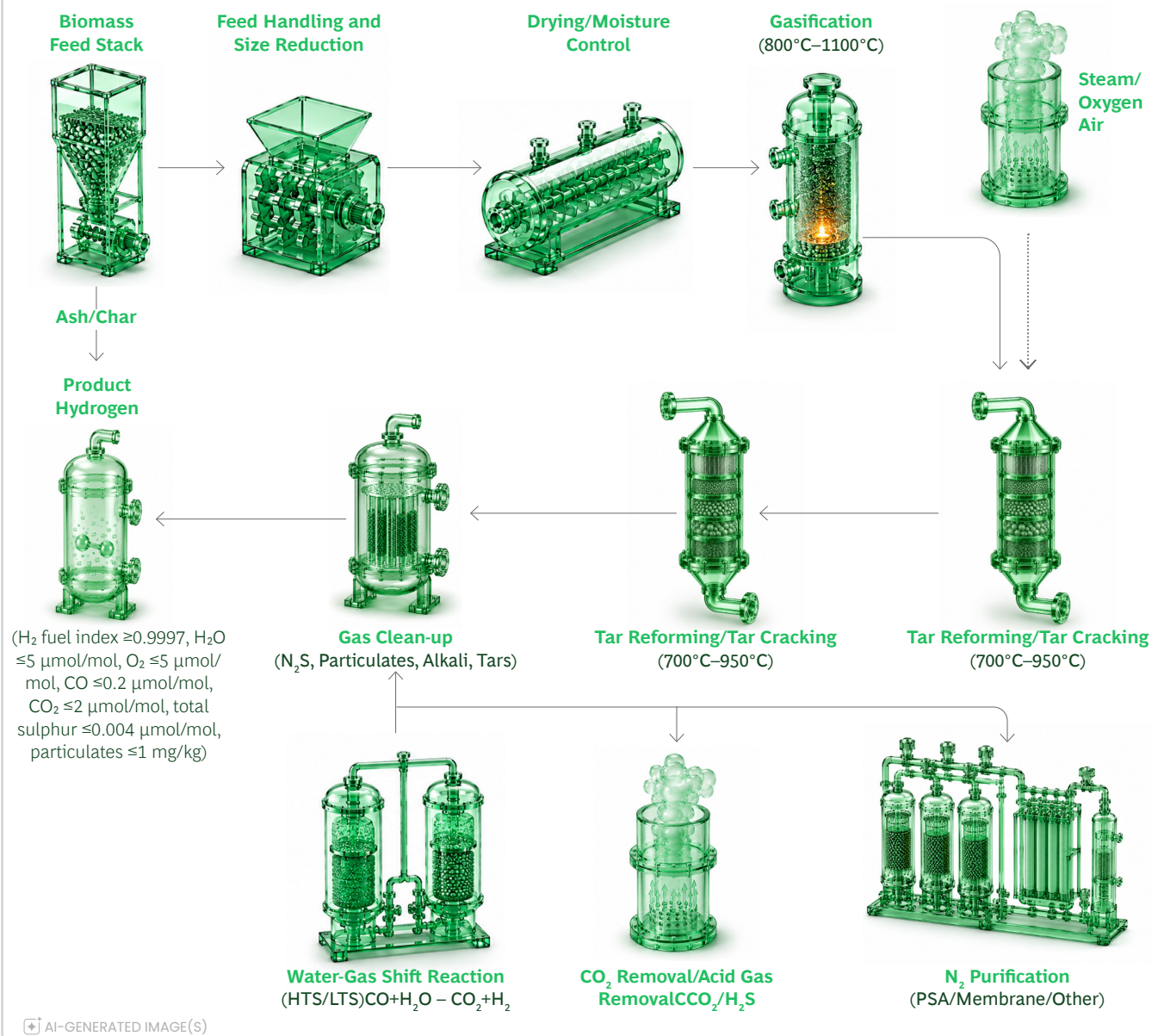
Hydrogen can be produced from renewable biological feedstock including biomass which is renewable organic material derived from plants, animals, and micro-organisms, and biogas which is also called renewable natural gas (RNG) or biomethane, is an energy-rich gas produced from biomass.

These production routes meet the requirements for low-emission hydrogen and hence are included in the value chain. The lack of a defined standard for these routes creates a risk of unreliable compliance assessment.

Biomass Gasification

Biomass gasification is the process in which biomass is converted at high temperature ($>700^{\circ}\text{C}$), into synthesis gas containing hydrogen, carbon oxides, methane, and impurities such as tar, particulates, Sulphur compounds, and ammonia. The syngas must then be cleaned and filtered to produce hydrogen of the required quality and reliable downstream processing.

Safety hazards include carbon monoxide toxicity, tar and particulate fouling, toxic exposure, fire and off-spec hydrogen entering storage and end-use systems. [12]

Figure 25: Biomass Gasification**Standards/documents:**

ISO 16110-1, ISO/CD 16110-2

Bio-methane reforming

Biomethane (also known as renewable natural gas) is a near-pure source of methane produced either by “upgrading” biogas (a process that removes any CO₂ and other contaminants present in the biogas) or through the gasification of solid biomass followed by methanation.

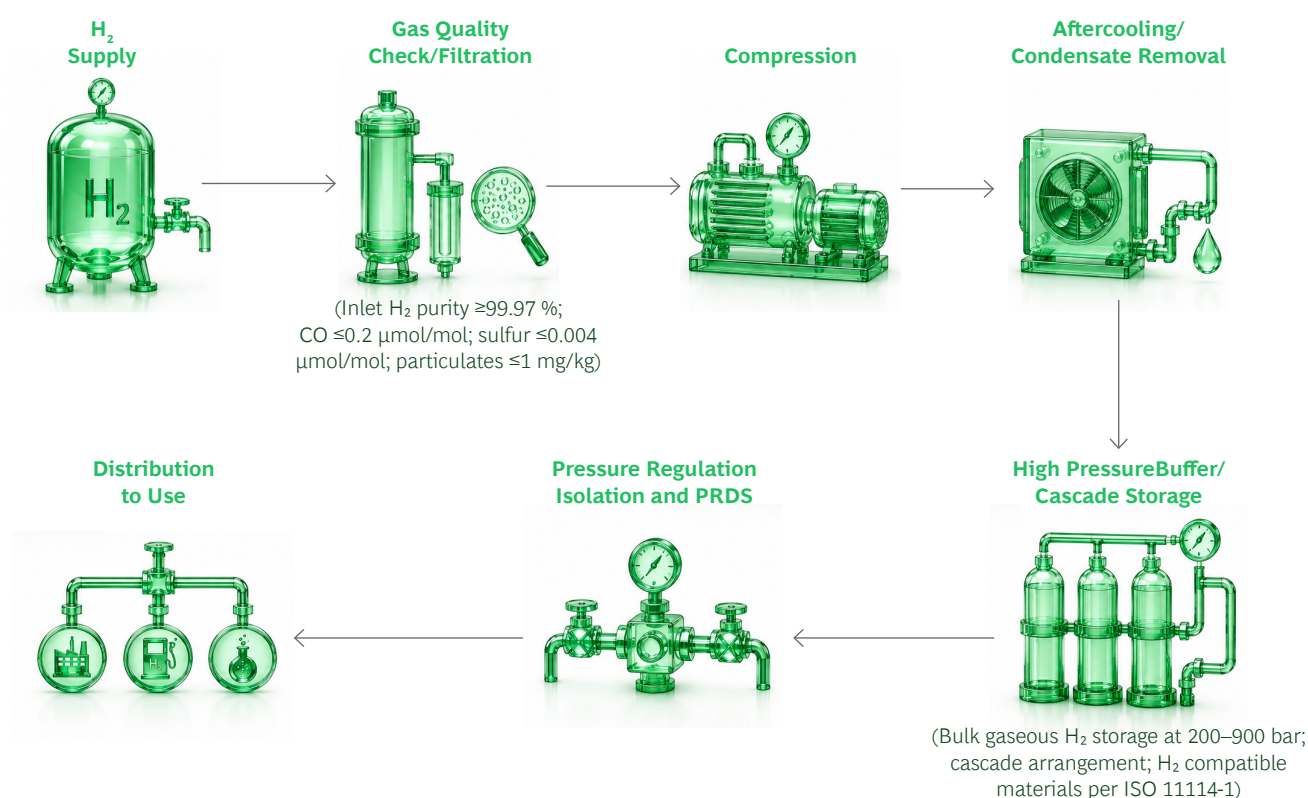
Bio-methane reforming involves high-temperature reformers, combustible gases, Sulphur compounds, and pressure systems. Standards are needed for feedstock quality, Sulphur removal, reformer safety, and hydrogen purification.

Standards/documents:

ISO 16110-1, ISO/CD 16110-2 (Under Development)

6.2 Transport and Storage

Figure 26: Gaseous H₂ Storage



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In gaseous form Hydrogen has an exceptionally low volumetric energy density, which means large storage volumes or high-pressure compression are required for practical transport and dispensing.

Liquid hydrogen offers a much higher energy density per unit volume, making it more suitable for bulk transport over longer distances, but it needs to be maintained at about -253°C in cryogenic, highly insulated tanks, and the process of liquefaction itself is highly energy intensive, requiring about 10 kWh/kg-HYDROGEN, or roughly 30% of hydrogen's heating value.

Hydrogen derivatives such as ammonia, methanol, and LOHCs are used as carrier media to improve storage and transport logistics by binding hydrogen into more manageable chemical forms. But they require additional downstream conversion steps such as cracking or dehydrogenation to recover usable hydrogen. As a result, derivatives increase process complexity, energy demand, and equipment requirements across the value chain.

6.2.1 Portable Cylinders-Gaseous H₂/H₂ Blends (On-board)

Portable hydrogen storage systems that are used in vehicles and mobile equipment are classified as On-board cylinders. Onboard cylinders are exposed to high pressure, vibration, crash loads, thermal exposure, and repeated filling cycles. If pressure rating, material compatibility or relief-device design is inadequate, failure can lead to hydrogen leakage, jet fire, rupture, explosion or risks to occupants and responders.

Standards/documents:

IS 16735, ISO 19881

6.2.2 Portable Cylinders-Liquid/Cryogenic H₂ (On-board)

Liquid or cryogenic onboard storage covers refillable liquid hydrogen fuel tanks intended for land-vehicle use. Standards address tank construction, insulation, pressure relief, boil-off management, thermal protection, filling interfaces, inspection and protection from fire and explosion. [13]

Standards/documents:

IS/ISO 13985:2006; CGA P-12; ISO/DIS 13985; IS/ISO 11120:2015; CSA/ANSI HGV 2-2023, GCR 2016, ISO/DIS 13985.

6.2.3 Portable Cylinders-Gaseous H₂/H₂ Blends (Off-board)

Off-board gaseous hydrogen or hydrogen-blend storage covers portable cylinders, cylinder banks and mobile storage not permanently installed on vehicles. Standards could define design approval, storage pressure, materials, cylinder bundles, valves, PRDs, inspection, transport interface, filling, and emptying procedures.

Standards/documents:

DIN EN 17339:2025, IS 16735:2018; ISO 19881:2025; CEN-EN 12245; BS EN 17339; IS/ISO 11515:2022; ISO 7866; ISO 9809-1/2/3; IS/ISO 11119-1/2/3; ISO 16111:2018; IS/ISO 11120:2015; IS 7285 Part 1 and Part 2, GCR 2016, ECE/UN R134, IS 17613:2025, IS/ISO 9809 (Part 2):2019, IS 7285 (Part 1), IS 7285 (Part 2)

6.2.4 Portable Cylinders-Liquid/Cryogenic H₂ (Off-board)

Off-board portable cryogenic hydrogen storage covers transportable vacuum-insulated vessels and portable cryogenic containers that are containers not permanently installed on vehicles. These systems are used for the storage, transfer, and supply of liquid hydrogen at production sites, refuelling stations, industrial facilities, laboratories, and other off-board locations.

Standards should address vessel design, fabrication, insulation, inspection and testing, pressure relief and protection from fire and explosion hazards.

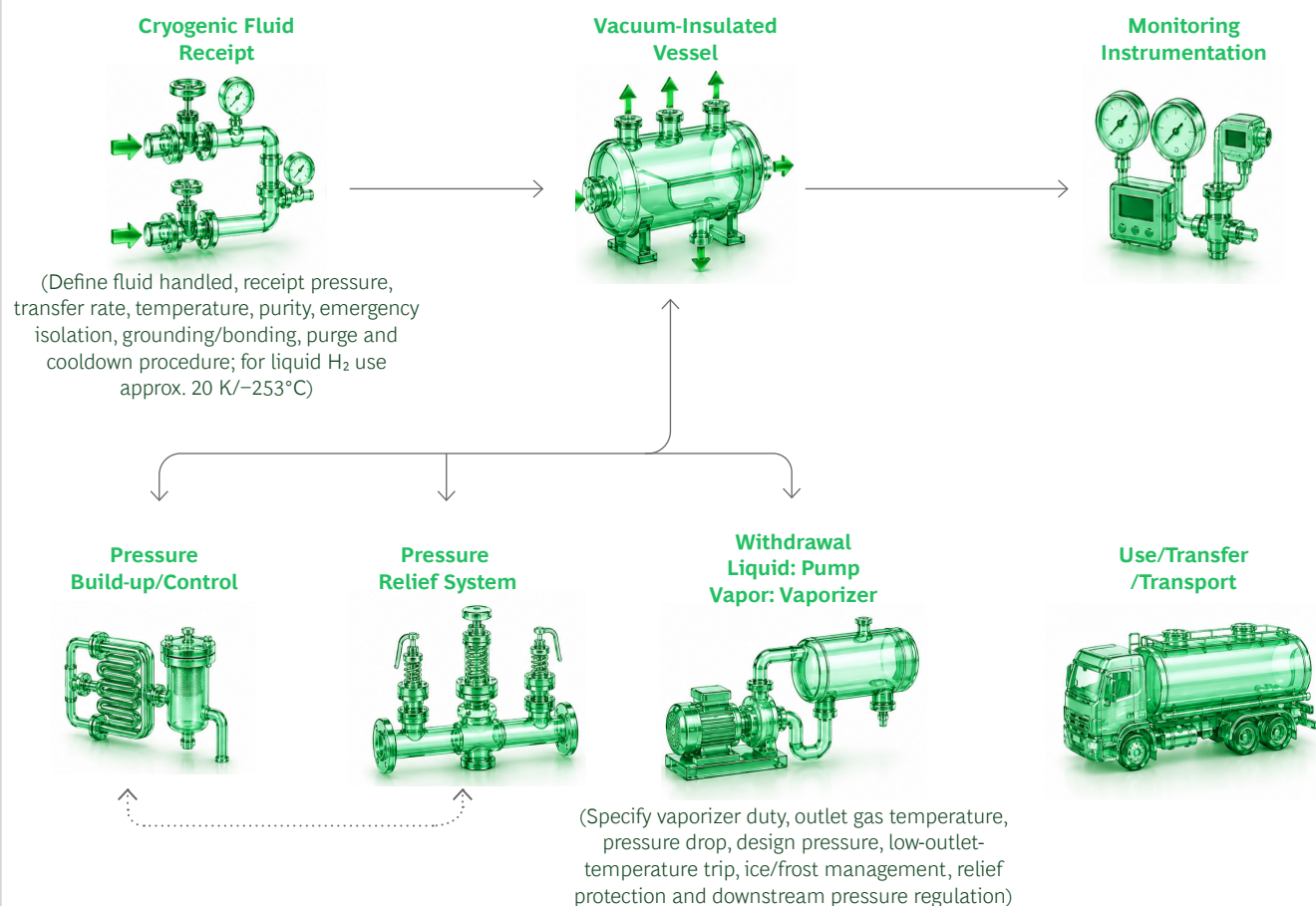
Standards/documents:

IS 18719 (Part 1):2024, IS 18719 (Part 2):2024, ISO 21029-1:2018, ISO 21029-2:2015 (Under development), IS 16017:2024, IS 8198:2004



6.2.5 Bulk Cylinders-Stationary High-Pressure Gaseous H₂ Storage

Figure 27: Cryogenic Storage



AI-GENERATED IMAGE(S)

Bulk gaseous hydrogen storage covers large stationary hydrogen high pressure vessels and bulk cylinder systems used at production sites, refueling stations, industrial sites, and storage facilities.

Standards can provide the basis for cylinder design, cyclic testing, bonfire testing, pressure-relief devices, periodic inspection, and transport approval; regulation is needed because vessel failures can injure workers, first responders, and the public.

The 2019 Kjørbo hydrogen refueling-station incident illustrates how a leak in storage can create an ignitable hydrogen-air mixture. Additionally, NTSB's Diamond Bar report shows how compressed-hydrogen trailer releases can lead to sustained fire and escalation.

Standards/documents:

NFPA 2; NFPA 55; CGA H-5; IS/ISO 11114-1/2/3/4; AD 2000; ANSI HGV 2; CGA P-12; CGA PS-46; GB/T 34583; BPVC Section VIII Division 3; ISO/TS 15916:2026.

6.2.6 Bulk Cylinders-Cryogenic/Liquid Hydrogen

Bulk cryogenic or liquid hydrogen storage covers large stationary or transportable cryogenic vessels. Cryogenic temperatures can cause material embrittlement and cold burns, boil-off can create overpressure, and vented hydrogen can accumulate or ignite if not safely dispersed.

Standards/documents:

IS 18608:2024; IS 19060 Part 1:2024; ISO 21029-1:2018; CGA P-41-2023; EIGA 06/19; CGA P-12; NFPA 55; ISO/TS 15916:2026; CGA P-28; EN 1797:2001, EN 13530 Series, EN 13458 Series, ISO 20421-1:2019

6.2.7 Storage Safety

Pressure Relief Device

Pressure relief devices protect hydrogen cylinders and storage systems against hydrogen container bursts in the event of a nearby fire. Weakening of the storage system at elevated temperatures can result in such a burst. The role of Pressure Relief Device (PRD) is to release some or all of the system fluid in the event of abnormally high pressure. If PRDs are absent or incorrectly installed and not maintained, the outcome can lead to explosion.

Standards/references:

CGA S-1.1; CGA S-1.2; CGA S-1.3

Thermally Activated Pressure Relief Device

Thermally activated pressure relief devices are designed to protect tanks and pressure vessels from rupture during exposure to abnormally elevated temperatures (overheating), such as a fire. The device gets triggered when its specified temperature (typically 110° C) is reached and releases the hydrogen from the tank out through a safety vent in a very short time. It is an important safeguard for hydrogen vessels and needs to be typically designed and installed in accordance with proper standard requirement. [14]

Standards/documents:

ISO 19882:2025

Roof Safety

Hydrogen is much lighter than air and rises after release. This is normally helpful for dispersion, but a roof or poorly ventilated structure can trap hydrogen at high points. This trapped hydrogen poses a risk of ignition and can cause explosions. [15]

Standards/documents:

CGA PS-46

Materials

Hydrogen can degrade susceptible materials and reduce toughness or fatigue life. Material degradation may not be visible during routine operation, but it can lead to delayed cracking, leakage, rupture, fire, or explosion. Material standards are therefore essential for safe cylinder, vessel, valve, and fitting design.

Standards/documents:

JIS H 7201:2007, ISO 17081:2014, DIN EN ISO 683-2:2018-09, ASTM G148, DIN EN 10083-3, ASTM A533/A533M, ASTM A372/A372M, ASTM A29/A29M, CSA/ANSI CHMC 1:2026, IS/ISO 11114 (Parts 1-4), IS 12145:1987, IS 19559:2026, IS 5517:1993, IS 2062 (Part 2):2026

6.2.8 Underground Storage

Underground hydrogen storage facilities, such as salt caverns, require dedicated standards for design, construction, and operation. These standards address the site selection, pressure, and temperature limits.

Standards/documents:

CGA PS-17, API RP 1114, API RP 1115

6.2.9 Distribution

Plant piping [16]

Plant piping refers to industrial piping systems used within hydrogen production plants, storage facilities, and refueling stations. If piping materials, joints or sub-components are not properly installed for hydrogen transport, the consequences can include leakage, brittle fracture, jet fire, explosion, equipment damage, and unsafe maintenance exposure.

Standards/documents:

ASME B31.3, API/ANSI 5L and DIN EN 13480 series

Transmission Pipelines

Transmission pipelines refer to long-distance pipelines used to transport hydrogen or H₂ blends at higher pressures. These systems are outside plant boundaries and serve broader network supply.

Hydrogen transmission pipelines create public-safety risks because failures can release large quantities of hydrogen over long distances with undetected leakage and more embrittlement-related failures.

Standards/documents:

ASME B31.12; ASME B31.8; DIN EN 1594:2024, API Spec 15S

Rededicated Gas Systems

Rededicated gas systems are existing natural-gas systems that are converted for hydrogen or H₂ blend transportation. Existing gas systems may contain ageing joints, incompatible materials, and have components which are not qualified for hydrogen handling, hence dedicated standards need to be in place that cover commissioning, control, and assessment of material and other components.

Standards could also explicitly cover hydrogen blending in existing natural gas pipelines. Standardising the use of current gas pipelines to carry natural gas-hydrogen blends can enable early use of existing infrastructure and reduce future retrofit costs.

Standards/documents:

CEN/TS 17977:2023

Valves, Hoses and Pipe Threads

Hydrogen can leak through imperfect seals, poorly specified valves or pipe threads can lead to gas leakage, pressure loss, and pose ignition risk. Hoses are exposed to bending, abrasion and repeated connection which can lead to degradation of the component. These are critical connection points in the distribution systems and there are standards on material compatibility and leakage limits.

Standards/documents:

DVGW G 406:2025-12, CGA V-1, ISO 228-1:2000, ISO 7-1:1994, ISO 16964:2019, IS 18608:2024, IS 3224:2021

Tube Trailer

Trucks that haul gaseous hydrogen are called tube trailers. Gaseous hydrogen is compressed into long cylinders or tubes that are mounted and stacked on a trailer.

Storage vessels can increase hydrogen carrying capacity, but they require clear standards for design approval, pressure rating, materials, safety devices, and inspection for transport safety.

Standards/documents:

CGA P-74-2019, GCR, IS/ISO 11120, BS EN ISO 10961:2019, EN 13807:2026, ISO 10961:2019, BS EN 17339:2024

6.3 End-use Applications

6.3.1 Fuel Cells

Hydrogen fuel cells generate electricity through a chemical reaction between hydrogen and oxygen, in which H_2 reacts with oxygen across an electrochemical cell similar to a battery to produce electricity, water, and small amounts of heat.

Unlike batteries, which add weight and require longer recharge times, fuel cells can power heavy loads over longer distances and be refueled quickly. This efficiency is a major advantage for long haul trucking, where minimising downtime is crucial. [17] [18]

Fuel cells are mainly considered under 2 application categories:

Vehicle (Mobile) applications

Fuel cell energy systems are increasingly being used or tested across road vehicles, buses, trains, industrial trucks, construction equipment, and demonstrations shown in mining machinery, drones, and ships.

Key safety requirements include hydrogen fuel quality, fuel-system damage prevention, crash, and impact protection, and refueling interface safety.

Standards/documents:

AIS 157, AIS 195, GTR-13, ISO 23273:2013

Power generation (Stationary) applications

Fuel cells can provide primary power, combined heat and power (CHP) or backup power to a facility. These can be installed as part of the electric grid ensuring reliable power without disruption due to grid failure or blackouts.

Standards are needed for electrical safety, overheating, accumulation of flammable gas and interaction with nearby storage facilities in cases where fuel cells are deployed in occupied buildings and public facilities. [19]

Standards/documents:

IEC 62282-3-100:2019

6.3.2. Hydrogen Dispensing

Gaseous hydrogen refueling

Hydrogen refueling stations combine high-pressure storage, compression, controls, and human interface points. The major hazards are high-pressure leak, storage failure, overfill, ignition during fueling, and unsafe vent or purge management.

Standards can define fueling protocols, nozzle/receptacle interfaces, separation distances, emergency stop systems and leak detection.

Liquid hydrogen refueling

Additional risks from handling liquid hydrogen include hazards like cryogenic burns, and leaks during hose connection or disconnection.

Regulatory interventions are relevant because these stations are public-facing assets located in urban or roadside settings.

Standards/documents:

ISO 19880-1:2020, ISO 19880-3:2018, ISO 19880-5:2025, ISO 19880-8:2024, IS 18538 Part 1:2023; IS 18538 Part 3:2023; IS 18538 Part 5:2023; IS 18538 Part 8:2023, ISO 13984:2026, GB/T 34584-2017 (restricted), ISO 13984:2026, ISO 17268-1:2025, ISO/DIS 17268-2 (Under development), SAE J2600 (Under update), SAE J2799_202603, SAE J2601_202005

6.3.3 Road Vehicles (H₂ ICE)

Hydrogen Internal Combustion Engine (ICE) technology is regarded as a robust hydrogen powertrain option because it builds on well-proven internal combustion engine technology and existing component supply chains. Hydrogen ICEs also do not require platinum-group metals and can offer lower tailpipe CO₂ emissions than diesel engines, subject to fuel pathway and operating conditions.

Fuel-cell systems when compared to H₂ ICE require more complex power electronics and thermal management and their supply chains are still developing at scale. As a result, several OEMs (JCB, Volvo) are exploring or deploying H₂ ICEs as a near-term hydrogen powertrain solution for heavy-duty and off-road vehicles. [22] [23]

On-road Vehicles

On-road vehicles use cases are passenger buses, cars that use compressed gaseous hydrogen or H₂ blends as engine fuel. The main hazards include H₂ leakage, pressure system failures, ignition near hot engine surfaces. Because these vehicles operate in public areas, standards are needed for safe operation.

Standards/documents:

ISO 21266-1:2018

Off-Road Vehicles

Hydrogen can be used in powering construction equipment, powered trucks, mining vehicles, and agricultural equipment. These applications face harsh conditions like dust, impact, and vibrations, while also working in remote environments without access to high power electrical infrastructure.

Hydrogen ICE powered off-road vehicles/machines are already in early commercial deployment in international markets, including the UK and Europe.

Standards/documents:

None

6.3.4 Domestic Applications

Domestic hydrogen use introduces the most sensitive public-safety interface because the hazard shifts from industrial trained operators to average household members and installers. Standards are needed to address concerns like indoor accumulation from small leaks, ignition from everyday sources, material compatibility, and the need for effective ventilation or detection.

Standards/documents:

None

6.3.5 Industrial Applications

Hydrogen has a long history of being utilised in a wide variety of industries, and the majority of hydrogen today is used in fields like oil refining, ammonia production, and methanol production.

Hydrogen is upcoming in hard to abate sectors like the Steel industry where it trials are beginning to use hydrogen as a replacement to coal to reduce emissions in the steel manufacturing process.

Standards are needed because these applications operate in worker populated facilities with routine maintenance and shutdowns. If controls are weak, the consequences can include flash fire, explosion, equipment damage, and worker injury.

Standards/documents:

Application-specific hydrogen standards are not available.

6.3.6 Railways

Hydrogen rail applications combine vehicle-storage hazards with confined-space risks in depots, tunnels, and platforms. The main concerns are hydrogen accumulation in enclosed rail spaces. These transport assets face vibrations and fixed infrastructure interfaces. Rail therefore requires railway specific standards, not just generic pressure-vessel compliance.

Standards/documents:

IEC 63341-1:2025

6.3.7 Shipping

Shipping introduces bunkering risk, confined machinery spaces, cryogenic or carrier handling at ports, boil-off or vent management, and interactions with marine fire protection and hazardous-area rules. Standards are needed for marine fuel storage, bunkering interfaces, transfer hoses, emergency shutdown, ventilation, and cargo/fuel segregation.

Standards are critical because marine assets move between ports and jurisdictions and because bunkering failures can affect crews, terminals, and nearby public areas.

For the carriage of (Liquid Hydrogen) LH₂ in bulk, gas carriers may comply with the International Convention for the Safety of Life at Sea (SOLAS), which defines minimum requirements for the construction, equipment, and operation of ships. [20]

Hydrogen derivatives as marine fuels

Low-emission Methanol, being a hydrogen derivative, would require the same level of attention as low-emission Ammonia and low-emission Hydrogen under SIGHT Mode-2A and 2B. [25] These derivatives are considered as marine fuels because they can carry hydrogen in a denser and more easily transportable form than gaseous hydrogen.

However, their use introduces distinct shipping risks, including fuel toxicity, and low-flashpoint handling.

Standards/documents:

ISO 11326:2024, ISO 24132:2024, ISO 6583:2024, IMO MSC.1/Circ.1687

6.3.8 Aviation

Aviation applications are at an early development stage.

Standards/documents:

Not available

6.4 General Safety

General safety is the necessary cross-cutting layer that applies across the entire hydrogen value chain. Gas leakage detection, hydrogen embrittlement, plant separation distances, and explosives safety are typically taken into consideration.

6.4.1 Occupational Safety

Worker safety requirements, operating procedures, maintenance, inspection, and incident response at hydrogen facilities.

Standards/documents:

OSH Code 2020, 29CFR1910.103, 29CFR1910.119

6.4.2 Fire and Explosion Safety

Fire prevention, explosion protection, hazardous-area classification, ignition-source control, grounding, bonding, and electrical protection.

Standards/documents:

GCR 2024, IS 5572:2009, NFPA 2, NFPA 3, NFPA 55, NFPA 56, NFPA 68, EN 14994:2007, IEC 60079-10-1:2020

6.4.3 Hydrogen Embrittlement

Hydrogen embrittlement describes the process by which hydrogen enters and diffuses into certain metals, causing them to become brittle and fractured. The main safety concern is that such degradation may not be visible during operation but can lead to leakage, rupture, and explosion. [22]

Standards/documents:

IS 18463:2023, IS 18435 (Part 11):2023, ISO 7539-11:2013, ISO 24251-1:2025, GB/T-34542.3 (restricted), ISO 10587:2000, ISO 16573-1:2020, ISO 15330:1999

6.4.4 Detection, Monitoring and Odourisation

Detection and monitoring cover hydrogen sensors, leak detection, ventilation activation, inspection frequency.

Standards/documents:

IS 16253:2016; ISO 26142:2010; NREL 62062

6.4.5 End-to-End System Safety and Layout

End-to-end system safety and layout cover separation distances, facility layout, vent locations, and system interfaces across the entire hydrogen value chain from production to end use.

Standards/documents:

GB/T 29729; GB/T 34542.1; AIAA G-095; CGA PS-48-2024; EIGA 075/21; NREL/TP-5400-60948; ISO/TS 15916:2026

6.4.6 Cybersecurity

Cybersecurity covers protection of hydrogen production plants, refueling stations, metering systems, and emergency shutdown controls. Hydrogen facilities may rely on automated controls and remote operations and cybersecurity requirements could address access control, data integrity, system recovery, and safe-state operation.

Standards/documents:

IEC 62351-9:2023; ISA/IEC 62443 Series

6.4.7 Flow Measurement and Uncertainty

Flow measurement and uncertainty cover metering accuracy, pressure and temperature correction, and uncertainty evaluation. These requirements are relevant for hydrogen production, storage and transport, and applications where accurate measurement is needed for safety and commercial transactions.

Standards/documents:

ISO 5167-1:2022; ISO 5168:2005



07

Gap Assessment and Key Findings

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The gap assessment consolidates the standards mapping undertaken across the hydrogen value chain and identifies areas where further action may be required. The assessment distinguishes between gaps arising from absence of standards, partial technical coverage, limited applicability to emerging use cases, and areas where standards exist but require alignment with more current or more specific international references.

The findings below are presented by value-chain segment. For each segment, the table identifies the relevant component, available Indian standard, reference standards considered, and the observed gap. The recommended actions that follow are designed to address the gaps.

7.1 Structure of the Gap Assessment

7.1.1 Basis of assessment

The assessment is built on four inputs that together provide the basis for identifying and organising gaps:

Value-chain definition

A common hydrogen value-chain structure provides a reference frame against which standards coverage is assessed.

Standards mapping

Existing Indian standards, standards under development, and relevant international references provide the starting point for assessing the extent of coverage.

Current-state assessment

Institutional architecture, testing capacity, certification arrangements, and approvals pathways provide the implementation context for the standards base.

International and market-facing references

External qualification systems and internationally used references provide context on the level of treatment required for domestic deployment and international alignment.

7.1.2 Types of gaps assessed

The gap assessment is structured around a limited number of gap types so that findings remain comparable across segments:

Missing standards

Components already in scope for which no usable standard, code, or technical reference has been identified.

Partial standards coverage

Areas where a standard exists, but the degree of technical coverage is incomplete, fragmented, or insufficient for the intended application.

No gap

A usable Indian standard, code, or technical reference is available and considered adequate for the intended application.





7.2 Key Findings and Recommended Actions

7.2.1 Production

S. No.	Component	Sub-component	Available Indian standards/codes	International standards/documents include, but not limited to (for reference)	Gaps observed
1	Balance of Plant	Water Purity	IS 1070:2023, IS 19575:2026	ASTM WK93670 (under development)	<ul style="list-style-type: none"> No Gap Water quality depends on the type of electrolyser – needs to be reviewed
2	Balance of Plant	Electrical Systems	IS 5572:2009, IS 16724:2018, IS 16509 (Under revision)	IEC 60079-10-1:2020, IEC 60079-14:2024, NFPA 70	<ul style="list-style-type: none"> Partial Gap Electrical equipment and installations in explosive gas atmospheres – needs to be reviewed
3	Balance of Plant	Vent Systems	Not available	CGA G-5.5	<ul style="list-style-type: none"> Indigenous standards not available
4	Balance of Plant	Hydrogen Supply Systems	Not available	CGA H-5	<ul style="list-style-type: none"> Indigenous standards not available
5	Balance of Plant	Pumps and Valves	Not available	Not available	<ul style="list-style-type: none"> Indigenous standards not available
6	Electrolysers (Low Temperature)	System Level (PEM, ALK, AEM)	IS 16509:2020	ISO 22734-1:2025, ISO 22734:2019, IEC 62282-8-101:2020	<ul style="list-style-type: none"> No Gap IS 16509 under revision basis ISO 22734-1:2025
7	Electrolyser (Low Temperature)	Efficiency (PEM, ALK, AEM)	IS 19575:2026	Not available	<ul style="list-style-type: none"> No Gap
8	Electrolysers (High Temperature)	System Level (SOEC)	Not available	IEC 62282-8-101:2020 (under revision)	<ul style="list-style-type: none"> Indigenous standards not available
9	Electrolysers (High Temperature)	Efficiency	Not available	Not available	<ul style="list-style-type: none"> Indigenous standards not available
10	Electrolysers	Component Level	Not available	Not available	<ul style="list-style-type: none"> Indigenous standards not available
11	Emissions	Well-to-Gate Emissions	Not available	ISO 19870-1:2026, ISO/DIS 19870-2,3,4 (under development)	<ul style="list-style-type: none"> Indigenous standards not available Emission calculation methodology available under the Green Hydrogen Certification Scheme of India (GHCI)
12	Hydrogen quality	Fuel Quality	IS 16061:2026, IS 19873:2026, IS 1090:2002	ISO 14687:2025, ISO 19880-9, ISO 21087:2019	<ul style="list-style-type: none"> No Gap
13	Bio-based production	Biomass Gasification	IS 16512 (Part 1): 2016	ISO 16110-1, ISO 16110-2:2010	<ul style="list-style-type: none"> Partial Gap No indigenous standard for biomass to hydrogen covering feedstock specification
14	Bio-based production	Bio-methane Reforming	IS 16512 (Part 1): 2016	ISO 16110-1, ISO 16110-2:2010	<ul style="list-style-type: none"> Partial Gap No indigenous standard for bio-methane to hydrogen processes

XX Partial Gap XX Full Gap XX No Gap

Recommended Actions

Water purity: Could adapt

IS 1070:2023 and IS 19575:2026 provide a starting point for electrolyser feedwater use. Inclusions for hydrogen-production-specific parameters for conductivity, ionic impurities, silica, organics, particulates, microbial content, and technology-specific tolerance levels require further deliberation within relevant technical committees.

- The treatment may be issued as either an annexure to the existing standard or a dedicated guidance note linked to electrolyser performance and durability.

Electrical systems: Could adopt or adapt

- IEC 60079-14:2024 may be adopted as an Indian standard to cover electrical installation design in hydrogen-hazardous areas
- IS 16724:2018 could be updated to align with IEC 60079-10-1:2020; including hydrogen-specific application data for electrolyser and balance-of-plant configurations.

Vent systems: Could develop new standard

CGA G-5.5 may be used as a reference for Indian requirements on hydrogen vent routing, discharge height, dispersion, ignition-source control, inspection, and integration with plant-level safety reviews.

Hydrogen supply systems: Could develop new standard

CGA H-5 provides a strong reference for production plants, refueling sites, storage systems, and industrial facilities.

- Requirements include specifications for site layout, equipment installation, transfer points, emergency isolation, and safe removal or decommissioning of hydrogen supply systems.

Pumps and valves: Could develop new standard

Minimum technical specifications required for pumps, valves, seals, and fittings used in hydrogen production and balance-of-plant systems.

- Standards require coverage for hydrogen compatibility, leak tightness, pressure rating, backflow prevention, cyclic operation, maintenance, and inspection.

Electrolysers-system level, high-temperature/SOEC: Could adopt or adapt

IEC 62282-8-101 may be used as a reference for high-temperature/solid oxide electrolysis systems, including thermal cycling, stack safety, electrical safety, gas separation, and failure-response logic.

- High-temperature electrolysis requires integration within the broader electrolyser standards framework so low-temperature and high-temperature systems are treated coherently.

**Electrolysers-high-temperature efficiency: Could develop new standard**

- An efficiency-assessment framework could be developed for high-temperature electrolysers once sufficient test data and operating experience are available.
- Definitions for measurement boundary, heat input treatment, auxiliary load treatment, degradation assumptions, and reporting format require further detailing.
- Coordination with testing agencies and technology developers required before finalising mandatory test methods.

Electrolysers-component level: Could develop new standard

- Component-level specifications require detailing for membranes, stacks, electrodes, catalysts, valves, seals, sensors, and other safety-critical ancillaries.
- Critical to establish parameters for minimum performance, durability, material compatibility, leak-tightness, and safety requirements.
- Requires deliberation within relevant technical committees to determine whether component requirements can be issued as standalone standards or annexures to system-level electrolyser standards.

Hydrogen Quality: Could develop testing capacity

Domestic testing infrastructure required for testing hydrogen purity across Fuel Cell Electric Vehicles and Hydrogen Internal Combustion Engines.

Biomass gasification: Could adopt or adapt

- Standard requires specifications for feedstock characterisation, gasifier safety, syngas cleanup, tar and particulate control, carbon monoxide handling, pressure relief, hydrogen purification, and product-quality requirements.

Bio-methane reforming: Could adopt or adapt

Deeper assessment required to check whether existing fuel-processing standards can be adapted for biogas/biomethane-based hydrogen production.

- Requires coverage across biomethane quality, sulphur removal, methane slip, reformer safety, catalyst protection, gas cleanup, hydrogen purification, and certification-linked emissions treatment.

7.2.2 Storage and transport

S. No.	Component	Sub-component	Indian standards/ codes	International standards/ documents include, but not limited to (for reference)	Gap Recognised
1	Portable Cylinders (<3000 L)	Gaseous H ₂ /H ₂ Blends Storage (on-Board)	IS 16735:2018	ISO 19881:2025	<ul style="list-style-type: none"> Partial Gap IS 16735:2018 needs review against ISO 19881:2025 IS does not cover higher working pressure (upto 700 Bar) IS does not cover higher water capacity (up to 1000L) IS does not cover Type 2 and Type 4 cylinders.
2	Portable Cylinders (<3000 L)	Liquid/ Cryogenic H ₂ Storage (on-Board)	IS/ISO 13985: 2006 IS/ISO 11120:2015	CGA P-12, ISO/DIS 13985, (Under development) CSA/ANSI HGV 2-2023, ISO/DIS 13985 (Under development)	<ul style="list-style-type: none"> Partial Gap Without a current LH₂ on board standard, operators rely on case-by-case PESO approval which is not scalable.
3	Portable Cylinders	Gaseous H ₂ /H ₂ Blends Storage (off-Board)	IS 16735:2018, IS/ISO 11515: 2022, IS 17613:2025, IS/ISO 9809 (Part 2): 2019, IS/ISO 11119 (Parts 1, 2, 3): 2020, IS/ISO 11120: 2015, IS 7285 (Part 1): 2018, IS 7285 (Part 2): 2017, IS 19037:2023	CEN-EN 12245, DIN EN 17339:2025, ISO 7866, ISO 9809-1, ISO 9809-2, ISO 9809-3, ISO 16111:2018, ISO 11623:2023, ECE/UN R134	<ul style="list-style-type: none"> No Gap IS 16735:2018 (Under Revision)
4	Portable Cylinders	Liquid/ Cryogenic H ₂ (off-board)	IS 18719 (Part 1): 2024, IS 18719 (Part 2): 2024, IS 16017:2024, IS 8198:2004	ISO 21029-1:2018 (Under development), ISO 21029-2:2015	<ul style="list-style-type: none"> No Gap
5	Bulk Cylinders	Stationary High-Pressure Gaseous H ₂ Storage	IS/ISO 11114 (Parts 1, 2, 3, 4)	NFPA-2, NFPA 55, ISO 11114-6:2022, ISO 11114-5:2022, CGA H-5, AD2000, ANSI HGV 2, CGA P-12, CGA PS-46, GB/T 34583, (Restricted) BPVC.VIII.3, ISO/TS 15916:2026, Fuel Gas Code (IFGC), Section 706.3	<ul style="list-style-type: none"> Partial gap ISO 11114 Part 5 and Part 6 need to be reviewed

XX Partial Gap XX Full Gap XX No Gap



S. No.	Component	Sub-component	Indian standards/ codes	International standards/ documents include, but not limited to (for reference)	Gap Recognised
6	Bulk Cylinders	Cryogenic/ Liquid Hydrogen	IS 18608:2024, IS 19060: Part 1: 2024	CGA P-41-2023, EIGA 06/19, CGA P-12, NFPA 55, ISO/TS 15916:2026, CGA P-28, EN 1797:2001, ISO 20421-1:2019 (Under revision), EN 13458 Series, EN 13530 Series	• No Gap
7	Storage Safety	Pressure Relief Device	IS 5903:2025	CGA S-1.1, CGA S-1.2, CGA S-1.3	• No Gap
8	Storage Safety	Thermal Pressure Relief Device	Not available	ISO 19882:2025	• Indigenous standards not available
9	Storage Safety	Roof Safety	Not available	CGA PS-46	• Indigenous standards not available
10	Storage Safety	Materials	IS/ISO 11114 (Parts 1-4), IS 12145:1987, IS 19559:2026, IS 5517:1993, IS 2062 (Part 2): 2026	JIS H 7201:2007, ISO 17081:2014, DIN EN ISO 683-2:2018-09, ASTM G148, DIN EN 10083-3, ASTM A533/A533M, ASTM A372/A372M, ASTM A29/A29M, CSA/ANSI CHMC 1:2026, ISO 11114-5:2022	• No Gap
11	Underground Storage	Cryogenic/ Liquid H ₂	Not available	CGA PS-17, API RP 1114, API RP 1115	• Indigenous standards not available
12	Distribution	Plant Piping (Gaseous H ₂)	Not available	ASME B31.3, API/ANSI 5L, DIN EN 13480 Series	• Indigenous standards not available (Under deliberation)

XX Partial Gap XX Full Gap XX No Gap

S. No.	Component	Sub-component	Indian standards/ codes	International standards/ documents include, but not limited to (for reference)	Gap Recognised
13	Distribution	Transmission Pipelines (Gaseous H ₂)	Not available	ASME B31.12, ASME B31.8, DIN EN 1594:2024, API Spec 15S	<ul style="list-style-type: none"> Indigenous standards under deliberation
14	Distribution	Transmission Pipelines (Rededicated Gas System)	Not available	CEN/TS 17977:2023	<ul style="list-style-type: none"> Indigenous standards not available
15	Distribution	Valves, Hoses and Pipe Threads	IS 18608:2024, IS 3224:2021, IS 19035:2023	DVGW G 406:2025-12 CGA V-1 ISO 228-1:2000, ISO 21011:2008, ISO 7-1:1994, ISO 16964:2019	<ul style="list-style-type: none"> Partial Gap Indigenous standards not available for high pressure flexible hose assemblies
16	Distribution	Tube Trailer	GCR IS/ISO 11120	CGA P-74:2019, BS EN ISO 10961:2019, EN 13807:2026, ISO 10961:2019, BS EN 17339:2024	<ul style="list-style-type: none"> Indigenous standards not available

XX Partial Gap XX Full Gap XX No Gap

Recommended Actions

Portable cylinders-gaseous H₂/H₂ blends storage, on-board: Could adapt

- IS 16735:2018 could be updated to address higher working pressures up to 700 bar where relevant.
- Coverage could be expanded to include higher water capacity up to 1,000 L.
- Standards need to include Type 2 and Type 4-cylinder configurations.
- Updated ISO 19881:2025 may be adapted.
- ECE/UN R134 Part I could be adopted for Compressed Hydrogen Storage Systems (CHSS) to support vehicle type approval under the CMVR framework in accordance with the Gas Cylinders Rules.
- Adoption requires alignment of India's vehicle-level storage certification with the WP.29 framework and facilitate recognition in markets where UN Regulations are the basis for vehicle type approval.

Portable cylinders-gaseous H₂/H₂ blends storage, off-board: Could adapt

- Technical review of DIN EN 17339:2025 required to assess relevance for off-board gaseous hydrogen.

**Bulk cylinders-Stationary High-Pressure Gaseous H₂ Storage: Could adopt or adapt**

An indigenous framework for bulk gaseous hydrogen storage can be developed using mature references such as NFPA 2, NFPA 55, CGA H-5, IS/ISO 11114 series, AD 2000, ANSI HGV 2, CGA PS-46, BPVC Section VIII Division 3, and ISO/TS 15916, Fuel Gas Code (IFGC) Section 706.3.

- Technical specifications required for pressure-vessel design, material compatibility, cyclic loading, relief systems, inspection, emergency response, and approval requirements.

Thermal pressure relief device: Could adopt or adapt

ISO 19882:2025 provides a strong reference for thermally activated pressure relief devices used in hydrogen vessels and vehicle storage systems.

- Technical specifications required for activation temperature, response time, vent routing, fire exposure conditions, and periodic inspection.

Roof safety: Could adapt

CGA PS-46 covers hydrogen accumulation risks under roofs and poorly ventilated structures, and could be used as a reference to design indigenous treatment for roof design, ventilation, dispersion, detection, and ignition-source control.

Underground storage: Could adapt

CGA PS-17, API RP 1114, and API RP 1115 may be reviewed for site selection, cavern, or reservoir integrity, well materials, monitoring, operating pressure, and emergency planning.

Plant piping: Could adapt

An indigenous hydrogen plant-piping standard could be developed using ASME B31.3, API/ANSI 5L and DIN EN 13480 as reference bases.

- Requires consideration for production-to-compression, compression-to-storage, cascade-to-compressor, and storage-to-dispensing interfaces.
- Guidance and technical specifications required for material selection, welding, pressure testing, leak testing, inspection, maintenance, and hazardous-area treatment.

Transmission pipelines: Could adapt

Technical specifications for a hydrogen transmission-pipeline standard could be adapted for Indian requirements using ASME B31.12, ASME B31.8, and DIN EN 1594 as reference bases.

- Standard needs to address material compatibility, fracture control, pressure limits, leak detection, metering, gas quality, emergency response, and right-of-way safety.
- A comprehensive standard-build process requires coordination with PNGRB, BIS, PESO, OISD, and pipeline operators. [8]

Transmission pipelines-rededicated gas systems: Could adapt

CEN/TS 17977:2023 provide detailed specifications for existing natural-gas systems to hydrogen or hydrogen blends, including material compatibility, joint integrity, commissioning, control systems, and end-use compatibility checks. These specifications could be adapted to Indian conditions after review within relevant technical committees.

Valves, hoses, and pipe threads: Could adopt or adapt

Pathways to adopt or adapt could be reviewed for relevant references such as DVGW G 406, CGA V-1, ISO 228-1, ISO 7-1, and ISO 16964.

- Requirements need to be defined for hydrogen leakage limits, thread compatibility, hose integrity, valve performance, material suitability, and inspection.
- Requirements can also be applied to similar parameters across storage, refueling, transfer, distribution, and maintenance interfaces.

Tube trailer: Could adapt

CGA P-74-2019 can be adapted for tube design, pressure rating, mounting, transport safety, pressure-relief devices, periodic inspection, emergency response, and operating controls.

- Requirements would need alignment with PESO approvals and road-transport safety requirements. [7]

7.2.3 End-use applications

S. No.	Component	Sub-component	Indian standards/ codes	International standards/ documents include, but not limited to (for reference)	Gaps observed
1	Fuel cells	Vehicle Applications	AIS (157, 195), G.S.R. 579, IS 19036:2023	GTR-13, ISO 23273:2013	<ul style="list-style-type: none"> Partial Gap Indigenous stack durability validation standards are not available
2	Fuel cells	Stationary Power Generation	Not available	IEC 62282-3-100:2019, IEC 62282-3-200:2025, IEC 62282-3-202, IEC 62282-3-201:2025, IEC 62282-3-300:2012,	<ul style="list-style-type: none"> Indigenous standards not available
3	Hydrogen Dispensing	Refueling Station (Gaseous hydrogen)	IS 18538 Part 1: 2023, IS 18538 Part 3: 2023, IS 18538 Part 5: 2023, IS 18538 Part 8: 2023, IS/ISO 17268:2020	ISO 19880-2:2025, ISO 19880-3:2018, ISO 19880-5:2025, ISO 19880-7:2025, ISO 19880-8:2024, ISO 19880-9:2024, ISO 19885-1:2024, GB/T 34584-2017 (restricted), ISO 17268-1:2025, ISO/DIS 17268-2 (Under development), SAE J2600 (Under update), SAE J2799_202603, SAE J2601_202005	<ul style="list-style-type: none"> Partial Gap Indigenous standards do not cover refueling connection devices (e.g., nozzle, receptacle, O-rings) Indigenous hydrogen refueling station cooling standards are unavailable. Heavy-duty 350 bar refueling interoperability is still evolving in India. Fueling accuracy and calibration protocols are not mature. ISO 17268-1:2025 needs to be reviewed

XX Partial Gap XX Full Gap XX No Gap



S. No.	Component	Sub-component	Indian standards/ codes	International standards/ documents include, but not limited to (for reference)	Gaps observed
4	Hydrogen Dispensing	Refueling Station (Liquid Hydrogen)	Not available	ISO 13984:2026	<ul style="list-style-type: none"> Indigenous standards not available
5	Road Vehicles	Fuel System Components	IS/ISO 12619:2014 (Parts 1,2,3) IS/ISO 12619:2016 (Parts 4,5) IS/ISO 12619:2017 (Parts 6-16)	ISO 19887-1:2024	<ul style="list-style-type: none"> Partial Gap ISO 19887-1:2024 needs to be reviewed
6	Road Vehicles	On road (Hydrogen and H ₂ blends ICE, H ₂ electric Hybrids)	G.S.R. 889, G.S.R. 585, IS/ISO 23828:2013, IS 19281 (Part 1, 2):2025	ISO 23828:2022, EN 13807:2026	<ul style="list-style-type: none"> Partial Gap Indigenous hydrogen-electric hybrid integration standards not available
7	Road Vehicles	Off-road/Special Vehicles	Not available	Not available	<ul style="list-style-type: none"> Indigenous standards not available
8	Domestic Applications	H ₂ Burners, Heaters	Not available	Not available	<ul style="list-style-type: none"> Indigenous standards not available
9	Industrial Applications	Steel, Iron and Fertilizer Industry	Not available	Not available	<ul style="list-style-type: none"> Indigenous standards not available Sector specific standards are not available.
10	Shipping	Liquid Hydrogen	Not available	ISO 11326:2024, ISO 24132:2024	<ul style="list-style-type: none"> Indigenous standards not available
11	Shipping	Hydrogen derivatives (Methanol, Ammonia)	Under deliberation	ISO/DIS 23397 (Under development) ISO 6583:2024 (Under development) IMO MSC.1/Circ.1687	<ul style="list-style-type: none"> Partial Gap (Indigenous standards under deliberation)
12	Railways	Trains	Not available	ISO/CD 19887-2 (Under development)	<ul style="list-style-type: none"> Indigenous standards not available
13	Aviation	Aerial Vehicles	Not available	ISO/AWI 19888-1 (Under development)	<ul style="list-style-type: none"> Low Technological Readiness

XX Partial Gap XX Full Gap XX No Gap

Recommended Actions

Fuel cells – vehicle applications-power generation at plant: Could develop new standard

- Standard requires development of technical specifications for indigenous fuel cell stack validation as well as detailed guidance for domestic deployment.

Road vehicles-on-road H₂ ICE: Could adopt or adapt

- Pathways to adopt or adapt EN 13807:2026 could be reviewed for hydrogen internal-combustion applications.
- Deeper technical assessment required for differentiated fuel-quality, storage, combustion-safety, and vehicle-interface requirements for H₂ ICE applications.
- Consideration may be required for FC-Battery hybrid integration and thermal management.

Road vehicles-off-road/special vehicles: Could develop new standard

- Certification pathways require alignment with ECE/UN R134 Parts I and II for gas-system component design in hydrogen-powered off-road machinery.
- UN R96 references may be considered for engine compliance where applicable.
- Development of machinery-directive-level conformity requirements can be monitored as Indian standards for this category mature.

Hydrogen Dispensing (Gaseous, Liquid): Could adopt or adapt

- Requires detailing for hydrogen fueling measurement and calibration requirements.
- ISO 19880-7:2025 could be referenced to cover rubber O-rings and housing dimensions for high-pressure gaseous hydrogen devices in hydrogen fuelling stations.
- Consensus among infrastructure developers, OEMs, and regulators would help to clearly define hydrogen purity requirements across hydrogen ICE vehicles and FCEVs.
- India-specific hydrogen refueling interoperability requirements need to be established, with particular focus on compressor performance, pre-cooling reliability, and operation under high ambient temperatures during summers.

Domestic applications-H₂ burners and heaters: Could develop new standard

International pilots, appliance testing, and safety evidence need to be monitored before development of domestic standards.

- Pre-normative work may be used to assess appliance compatibility, indoor ventilation, leak detection, flame stability, installer competence, and user safety.

Industrial applications: Could develop new standard

Sector-specific standards or guidance could be developed for hydrogen use in steel, iron, fertiliser, and other industrial applications.

- Technical specifications would be required across burner systems, furnaces, kilns, feedstock interfaces, gas quality, purging, flame control, ventilation, and management of change.

Shipping: Could adopt or adapt

ISO 11326:2024 and ISO 24132:2024 may be adopted or adapted for hydrogen-derivative marine applications where applicable.

- Standard would need to define technical specifications for bunkering, onboard storage, fuel transfer, ventilation, segregation, emergency shutdown, and port-side safety.

Aviation: Could develop new standard

- International development of aviation-specific hydrogen standards need to be monitored to track implications for liquid hydrogen storage, airport refueling, transfer couplings, venting, exclusion zones, and emergency response.



7.2.4 Cross-cutting functions

S. No.	Component	Sub-component	Indian standards	International standards/ documents (for reference)	Gaps observed
1	General Safety	Occupational Safety	OSH Code 2020, IS 15201:2022	29CFR1910.103, 29CFR1910.119	<ul style="list-style-type: none"> India's OSH Code provides a general worker-safety framework but does not define hydrogen plant specific safety requirements. Detailed Indian vent stack guidance is limited.
2	General Safety	Fire, Explosion and Pressure Equipment Safety	Gas Cylinders Rules, 2024, IS 5572:2009, IS/ISO 16528-1:2007, IS/ISO 16528-2:2007, BPVC.VIII.1	NFPA 3, NFPA 2, NFPA 56, NFPA 55, NFPA 68, EN 14994:2007, IEC 60079-10-1:2020	<ul style="list-style-type: none"> No Gap
3	General Safety	H ₂ Embrittlement	IS 18463:2023, IS 18435 (Part 11): 2023, IS 18435-11, IS 19406, IS 17175 (Part 1,2) IS 6243, IS 17445, IS 19407, IS 18436:2023	ISO 7539-11:2013, ISO 24251-1:2025, GB/T-34542.3 (Restricted), ISO 10587:2000, ISO 16573-1:2020, ISO 2626:1973, ISO 15330:1999	<ul style="list-style-type: none"> No Gap
4	General Safety	Detection and Odorisation	IS 16253:2016	NREL 62062, ISO 26142:2010	<ul style="list-style-type: none"> No Gap
5	General Safety	End-to-End System Safety and Layout	IS 16749:2018	GB/T 29729, (restricted) GB/T 34542.1, (restricted) AIAA G-095, CGA PS-48-2024, EIGA 075/21, NREL/TP-5400-60948, ISO/TS 15916:2026,	<ul style="list-style-type: none"> Indigenous standards not available
6	General Safety	Cyber Security	Not available	IEC 62351-9:2023, ISA/IEC 62443 Series	<ul style="list-style-type: none"> Indigenous standards not available
7	General Safety	Uncertainty in fluid flow	Not available	ISO 5167-1:2022, ISO 5168:2005	<ul style="list-style-type: none"> Indigenous standards not available

XX Partial Gap XX Full Gap XX No Gap

Recommended Actions

Occupational safety: Could adopt or adapt

- Relevant specifications are provided in 29CFR1910.103 and 29CFR1910.119 as reference material for worker safety, operating procedures, maintenance, training, emergency response, and process safety management.
- Vent system standards would need to include vent routing and dispersion safety.

H₂ embrittlement: Could adapt

IS 18463:2023 and IS 18435 Part 11:2023 may be updated to reflect relevant provisions of ISO 24251-1:2025.

- Embrittlement treatment requires linkages with cylinders, pressure vessels, piping, pipelines, valves, fittings, and storage systems. Detection and Odorisation: Develop new standards

**Layout, siting, and end-to-end system safety: Could develop new standard**

- Provisions under GB/T 29729, GB/T 34542.1, AIAA G-095, CGA PS-48-2024, and EIGA 075/21 may be utilised where technically suitable for Indian conditions.
- Framework can link production, storage, transport, refueling, and end-use safety interfaces.
- FCPS controller standards may require alignment with ISO 26262-1:2018 for road transport safety.

Cybersecurity: Could adopt

- Plant-specific cybersecurity guidance can be adopted from the ISA/IEC 62443 series and IEC 62351-9:2023 for hydrogen production plants.

Uncertainty in fluid flow: Could adapt

ISO 5167-1:2022 and ISO 5168:2005 provide detailed specifications and guidance for flow uncertainty evaluation for liquid hydrogen and derivatives. These specifications can be adapted to Indian conditions after evaluation within relevant technical committees.

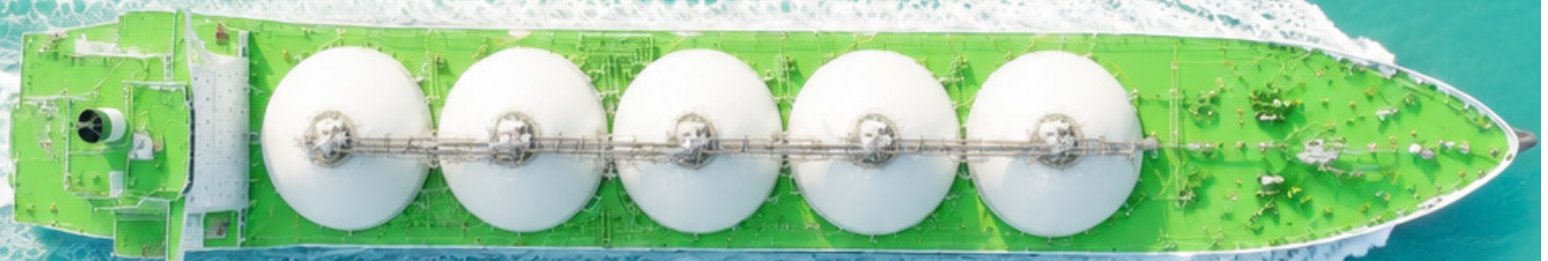


AI-GENERATED IMAGE(S)

08

Way Forward

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The gap assessment establishes a structured view of where India's hydrogen standards ecosystem stands today, the gaps that remain, and the categories of action through which those gaps can be addressed. Translating this assessment into a detailed implementation plan would benefit from further institutional deliberation through technical committees, sectoral regulators, testing agencies, and industry stakeholders. This section outlines how the assessment can be assimilated, the principles that can guide prioritisation, the structure of a comprehensive implementation plan, and the foundational enablers that underpin its successful execution.

8.1 Assimilation of Gap Findings

Assimilation is the first step in operationalising the assessment. The gap findings, recommended actions, and underlying references provide a baseline that can be reviewed by sectoral ministries, statutory regulators, standardisation bodies, and technical committees to validate institutional ownership and align with sectoral priorities.

Assimilation across institutions can be supported by the following considerations:

- Mapping each gap and recommended action to the institution best placed to take it forward, while recognising the statutory mandates of regulators and the standards-development role of the Bureau of Indian Standards.
- Validating the technical content of recommended actions through relevant Sectional Committees and Working Groups, with structured stakeholder consultations across producers, equipment suppliers, testing agencies, and end users.
- Recognising near-term deployment realities such as feedstock substitution in refining and fertilisers, blending pilots, and early mobility applications, so that institutional attention is directed where standards needs are most immediate.
- Establishing a shared reference base across ministries and regulators so that the same gap statements, references, and indicative actions inform parallel rule-making, approval, and standardisation processes.

8.2 Approach to Prioritisation

Prioritisation determines the sequence in which identified gaps are taken up for action. A consistent set of criteria allows the relevant institutions to evaluate gaps in a transparent and comparable manner, while retaining the flexibility to reflect sectoral and regional realities. The criteria set out below can serve as an indicative framework for institutions undertaking prioritisation through their technical committees.

Indicative criteria for prioritisation include:

Criticality to safety and integrity

Gaps directly affecting the safe handling, storage, transport, and use of hydrogen warrant earlier attention, particularly where they relate to high-pressure operations, hydrogen embrittlement, leak detection, and emergency response.

Near-term deployment relevance

Gaps that affect projects already underway or expected in the near term—such as feedstock substitution in refining and fertilisers, early-stage blending, hydrogen hubs, and pilot mobility applications—carry higher implementation urgency than gaps tied to longer-horizon use cases.

Implementation feasibility

Gaps where statutory ownership is clear and where the corresponding Sectional Committee, regulator, or testing agency is already engaged can move faster than those requiring inter-agency coordination or capacity development.

Institutional readiness and ownership

Gaps where statutory ownership is clear and where the corresponding Sectional Committee, regulator, or testing agency is already engaged can move faster than those requiring inter-agency coordination or capacity development.

Technology maturity and TRL

Components and pathways at higher technology readiness levels typically support earlier standardisation, while low-TRL areas warrant monitoring and pre-normative work before formal standardisation is initiated.

Market and trade relevance

Gaps with material implications for destination-market acceptance, certification recognition, and international trade in low-emission hydrogen and its derivatives merit attention proportionate to their effect on competitiveness.

Inter-dependencies across the value chain

Where one gap is a precondition for another (for example, interface standards required before integrated system standards can be finalised), the dependency sequence informs the order of action.

Applying these criteria together-rather than any single criterion in isolation-allows prioritisation to balance safety, deployment urgency, feasibility, and longer-term ecosystem development. The relevant technical committees can calibrate the exact weighting to reflect sectoral priorities.

8.3 Building a Comprehensive Implementation Plan

A comprehensive implementation plan converts prioritised gaps into a structured programme of action with defined ownership, timelines, and verification milestones. Such a plan can be developed by the responsible institutions through their technical committees and is most effective when it is structured around the hydrogen value chain and the cross-cutting enabling functions identified in the assessment.

Indicative structural elements of a comprehensive implementation plan:

Action register by value-chain segment

A consolidated register of recommended actions organised by production, storage and transportation, end-use applications, and cross-cutting functions, with sub-component-level traceability to the gap statements.

Defined ownership and accountability

Each action linked to a lead institution (BIS Sectional Committee, statutory regulator, testing agency, or ministry) and supporting institutions, including the Sectional Committee panel or Working Group where standards-development work is anchored.



Time horizons and indicative milestones

Differentiated time horizons (for example, near-term, medium-term, and long-term) consistent with administrative timelines for technical committee work and rule-making, with indicative milestones for drafting, public review, and notification.

Mode of action

Each action tagged by mode-Adopt (use of an international standard as-is), Adapt (adoption with modifications for Indian conditions), Develop new standard (indigenous development), or Monitor (track international developments before action)-to support consistency of treatment across the plan.

Testing and conformity-assessment linkages:

Each action linked to the corresponding testing capability, accreditation route, and certification pathway required to support implementation, with explicit identification of where capacity-building or infrastructure is needed.

Inter-agency coordination touchpoints:

Identification of touchpoints where coordination between BIS, sectoral regulators (PESO, PNGRB, OISD, MoRTH/ARAI/ICAT, and others), and the Ministry of New and Renewable Energy may be required, with a defined mechanism for resolving overlaps in approval and certification pathways.

Review and refresh cycle

A defined cycle for revisiting the action register and incorporating updates from international standards (ISO, IEC), revisions to adopted references, evolving sectoral priorities, and learning from pilots and early-stage deployments.

Linkage with destination-market requirements

Recognition of evolving certification frameworks and qualification rules in key destination markets, so that implementation choices remain aligned with the needs of export-oriented projects without compromising domestic priorities.

A plan structured along these lines remains anchored to near-term implementation priorities while preserving the flexibility to integrate emerging technologies, new use cases, and updates from the international standards ecosystem as the low-emission hydrogen sector matures.

8.4 Enablers for Implementation

Developing a strategy for low-emission hydrogen standards requires consideration of a set of enabling conditions that span institutional capacity, testing infrastructure, conformity-assessment processes, industry participation, and information transparency. Strengthening these enablers in parallel with the standards-development effort supports the credibility, consistency, and operational efficiency of the framework.

Capacity building and workforce development

A trained, certified, and industry-ready workforce across the hydrogen value chain is a foundational enabler for implementation. The Ministry of New and Renewable Energy (MNRE), in consultation with the Ministry of Skill Development and Entrepreneurship (MSDE), is implementing the Skilling, Upskilling and Reskilling Component of the National Green Hydrogen Mission to develop national-level training capacity through State institutions, Centres of Excellence (CoEs), and accredited training centres. The scheme covers operating personnel across production, storage and transportation, end-use, and safety functions. Sustained capacity development supports consistent application of standards on the ground and the build-up of technical expertise within standardisation, testing, and certification institutions.

Approval and certification support

Project developers benefit from clarity on the sequence of approvals, the documents required, and the institutional touchpoints across the lifecycle of a project. Structured knowledge support-including standardised checklists, application templates, and procedural guidance for hydrogen projects-reduces approval-cycle uncertainty and supports consistent application of safety and quality requirements across sectoral regulators.

Standardised templates and documentation

Standardised templates for project design documents (PDDs), safety case files, hazard and operability studies, emergency response plans, and inspection records support consistency in submissions and reviews across regulators. A common documentation baseline aligned with the underlying standards reduces interpretation differences across approval authorities and improves the speed and quality of the review process.

Industry and stakeholder participation

Active participation of industry, project developers, equipment manufacturers, testing agencies, and research institutions in Sectional Committees, Working Groups, and stakeholder consultations supports the technical robustness of standards. Structured industry feedback mechanisms during draft stages, pilot deployments, and post-notification reviews allow on-ground experience to inform standards revision cycles.

Digital transparency and information access

A single digital-reference point can be designed to consolidate up-to-date standards, rules, regulations, and approval procedures relevant to the hydrogen value chain. Key functionalities could potentially include listing of standards along with bifurcation for different use cases and project types, automated update notifications for adopted and referenced international standards, and access-based functionality for submission and approval of project design documents across ministries and agencies.



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