पी एन जी आर बी
PNGRB

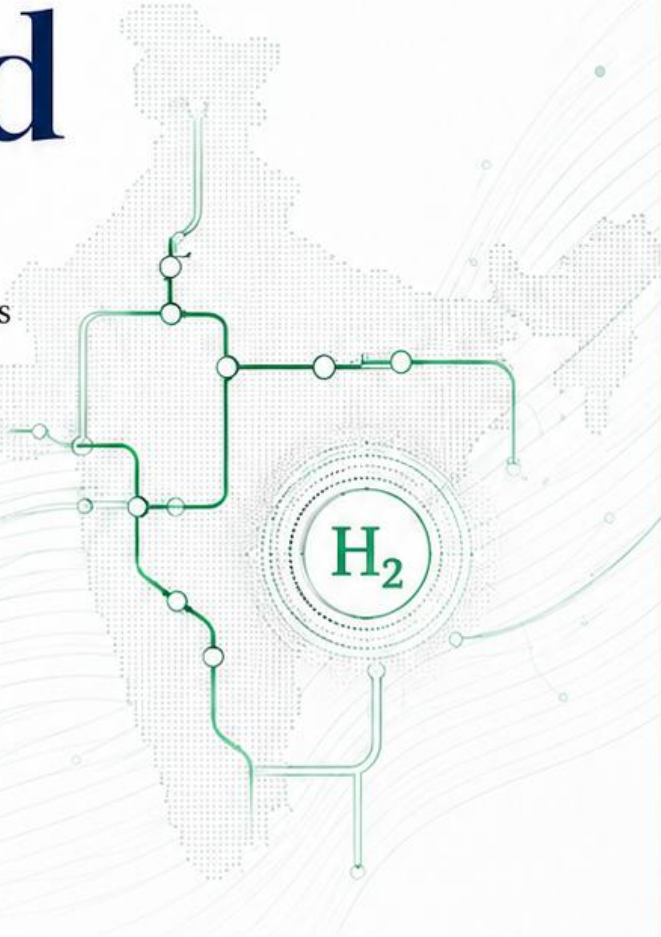
PETROLEUM AND NATURAL GAS REGULATORY BOARD

HYDROGEN CELL · COORDINATION DIVISION

Hydrogen Transportation as Natural Gas Blend

PNGRB's Work on Hydrogen Transportation through Pipelines and Blending with Natural Gas

An account of the institutional, technical and evidentiary hydrogen transportation architecture built by India's downstream petroleum and natural gas regulator



A KNOWLEDGE PAPER

July 2026 · New Delhi

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FOREWORD

India has set itself on the path of becoming a global hub for green hydrogen. While high ambitions are announced in missions and outlays, however, they are realised in infrastructure, standards, and institutions. Somewhere between the electrolyser and the burner tip lies a question that receives far less attention than it deserves: how will hydrogen actually move?

For a molecule that is produced where renewable power and water are abundant, and consumed where industry and cities are, the answer will substantially run through pipelines and India's natural gas pipeline network, built over decades and regulated by this Board, is the most credible carrier available. Blending hydrogen with natural gas offers a further advantage: it gives a nascent industry assured offtake in its most fragile years. But a pipeline network is not made hydrogen-ready by declaration. It is made ready by evidence.

A question arises as to whether regulatory oversight ought to precede this new technology. Often, there is a suspicion on the role of Regulators. PNGRB combines multiple roles – technical, legislative and developmental. Hydrogen needs all three. It is a highly inflammable and diffusive molecule for which technical and safety solutions have to be developed and mandated. Framing of Regulations to authorise pipelines, permit it's co-mingling with natural gas and assuring access rights to consumers is a part of legislative jurisdiction. And, the high cost of both the hydrogen molecule and specialised infrastructure involves the developmental role. Therefore, the nature of Regulation ought to determine its requirement which is quite manifest in this case.

Two convictions have governed this Knowledge Paper. The first is that safety is not a chapter in the hydrogen story; it is the binding on which every page depends. Hydrogen will earn its place in India's energy system only through a record of incident-free operation, and every element of our programme - controlled pilots, independent assessment, expert scrutiny and testbed validation. The second is that no Regulator can do this alone. What has been built is the joint work of the Ministries of Petroleum and Natural Gas and of New and Renewable Energy, NITI Aayog, the Office of the Principal Scientific Adviser, our pilot entities, our academic partners, and our international counterparts.

The bridge that remains is legislative. The inclusion of hydrogen within the PNGRB Act, 2006 will convert readiness into authority. When that moment comes, this Board intends to be found prepared.

I commend the Hydrogen Cell for this paper, and I commend the paper to policymakers, industry, and researchers alike - as a record of what has been done, and a statement of intent for what must follow.

(Dr. Anil Kumar Jain)
15-7-2026

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Genesis & Mandate

> *Anticipatory regulation — the discipline of building the institutional, technical, and evidentiary architecture for a regulatory mandate before it is statutorily conferred. This paper records what India's downstream petroleum and natural gas regulator has built, since 2021, in service of that idea.*

Hydrogen sits at the centre of India's long-term energy transition. The National Green Hydrogen Mission, launched by the Government of India in January 2023 with an outlay of ₹19,744 crore, aims to make India a global hub for the production, use, and export of green hydrogen. The Mission's ambition is well-defined; its implementation, however, rests on a question the policy documents largely leave open, how will hydrogen actually move, at scale, from the points where it is produced to the points where it is consumed?

Pipelines are the answer. They are the lowest-cost mode of bulk gaseous-fuel transport over land, and in India a substantial network already exists. The Petroleum and Natural Gas Regulatory Board (PNGRB), constituted by an Act of Parliament in 2006, today oversees 25,428 km of operational natural gas transmission pipeline out of 34,233 km authorised, 3,00,612 inch-kilometres of City Gas Distribution pipeline serving 307 authorised geographical areas. It is the regulatory custodian of the infrastructure that will, in time, carry hydrogen.

The PNGRB Act, 2006, however, does not currently extend to hydrogen. Its remit covers petroleum, petroleum products, and natural gas, not hydrogen as a fuel in its own right, nor hydrogen blended with natural gas. The National Green Hydrogen Mission anticipates precisely this gap. Clause 6.4 of the Mission Document records that the Ministry of Petroleum and Natural Gas "will also enable development and facilitation of regulations through the Petroleum and Natural Gas Regulatory Board (PNGRB)."

Green hydrogen has three requirements that may not be available at the same place - **green power, water and consumer**. Natural Gas Pipeline can prove to be the solution by **blending hydrogen**. In a way, the blended supply can also provide **purchase support**, especially if natural gas prices remain low. This calls for development of a suitable regime that also includes safety aspects looking to the highly inflammable properties of hydrogen.

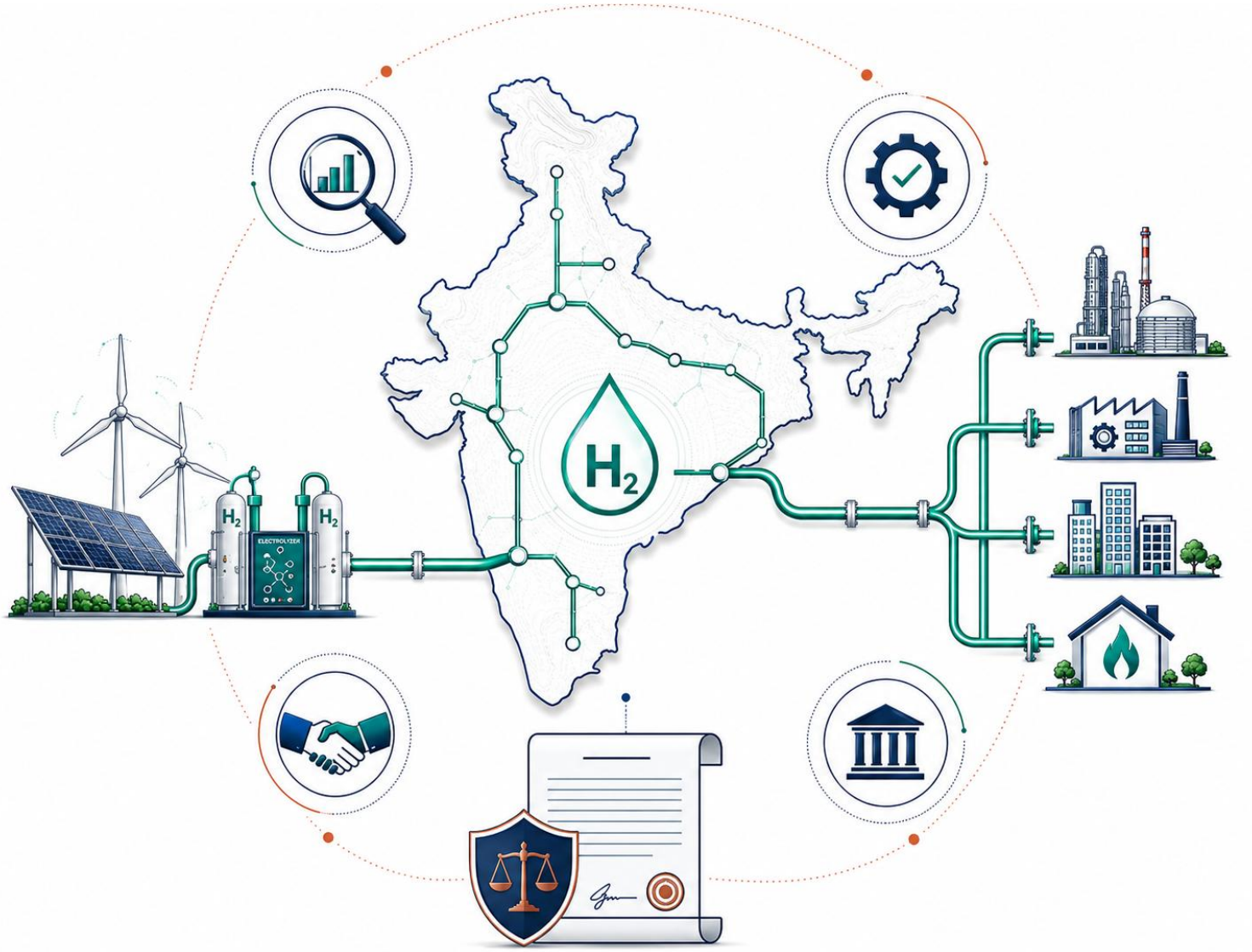
NGHM, Clause 6.4

MoPNG will facilitate uptake of Green Hydrogen in refineries and City Gas Distribution through both Public Sector Entities and private sector. MoPNG will also enable development and facilitation of regulations through the Petroleum and Natural Gas Regulatory Board (PNGRB). New refineries and CGD projects will be planned and designed to be compatible with maximum possible Green Hydrogen deployment.

Regulating hydrogen transport in India will therefore require two things in sequence: a legislative amendment to the PNGRB Act, 2006, and a regulator that is ready to act from the moment that amendment is notified. The lesson of past energy transitions is that regulation must precede the market, not follow it. Where regulatory direction has been absent, most starkly in the fragmented American hydrogen research efforts of the 1970s, which faded for want of consistent standards and sustained policy signalling, caused an initially well-funded effort to collapse investment, infrastructure, and public confidence have failed to take hold. The Hydrogen Cell was constituted within PNGRB to ensure that India does not repeat that pattern. Its remit is to build, in advance of statutory mandate, the evidence base, the technical standards, the institutional partnerships, and the regulatory depth that hydrogen will demand from day one.

The Cell's core objective is to establish PNGRB's preparedness to regulate the transportation of hydrogen through pipelines including its blending with natural gas, in a manner that protects consumers, ensures supply, brings energy security and promotes competitive markets, from the moment statutory authority is conferred.

What follows is the record, since inception, of what has been built in service of that objective.



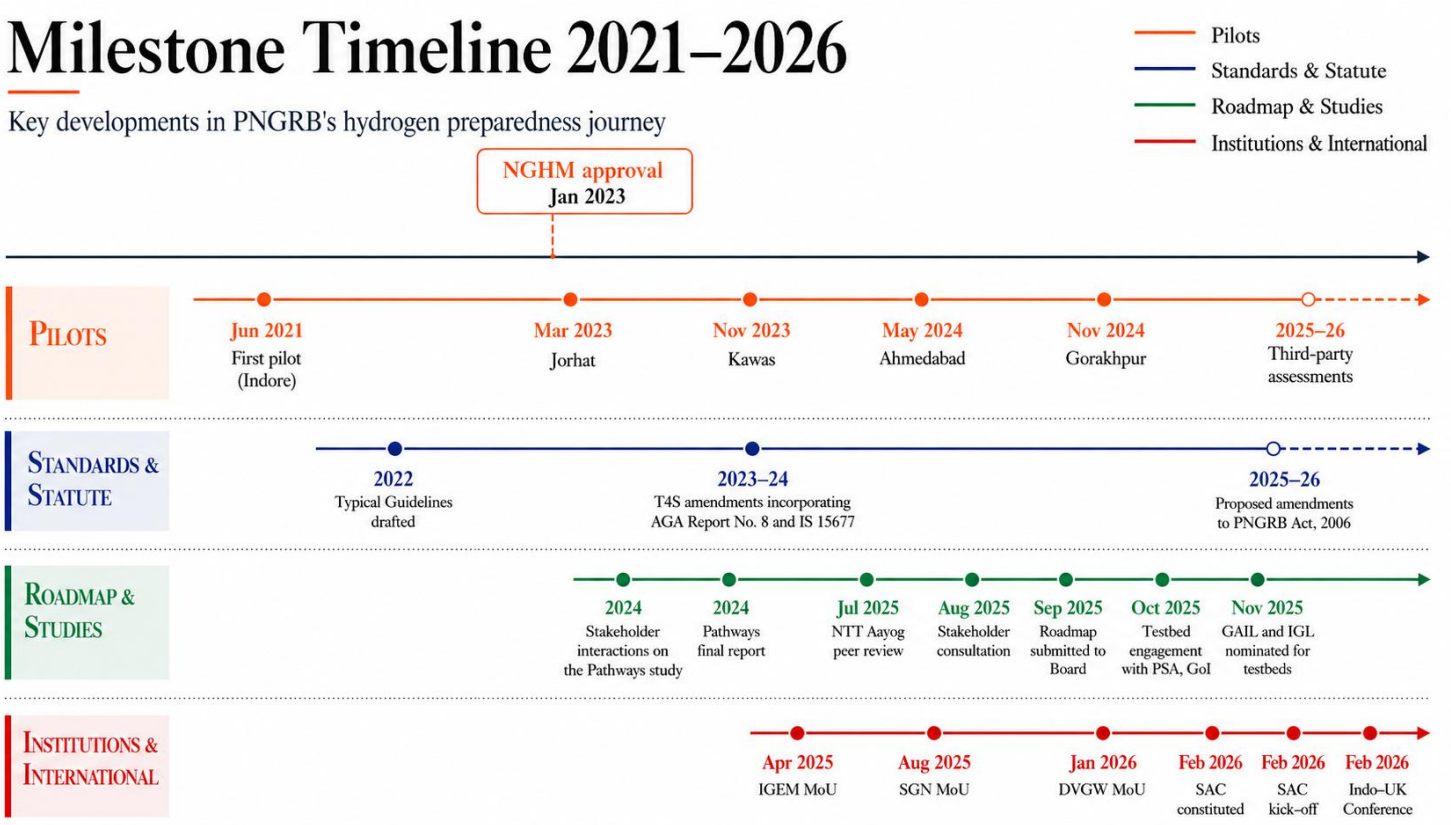
2

A Five-Year Build

> *Since June 2021, PNGRB's work on hydrogen has advanced along four parallel tracks — field pilots, technical guidelines and statutory groundwork, a phased national roadmap, and a network of domestic and international partnerships. The coherence of the sequence is its strongest claim to readiness.*

The first pilot in Indore in 2021 created the operational rationale for the Typical Guidelines drafted the following year. Those Guidelines created the framework within which four further pilots were authorised between 2022 and 2024. The pilots, together with the World Bank-ICF Pathways study, created the empirical foundation for the PNGRB Roadmap. The roadmap, in turn, prescribed the Scientific Advisory Committee, the National Hydrogen Testbed, and the structured international cooperations.

What began as a single approval has become a regulatory architecture. The timeline below records its construction.



3

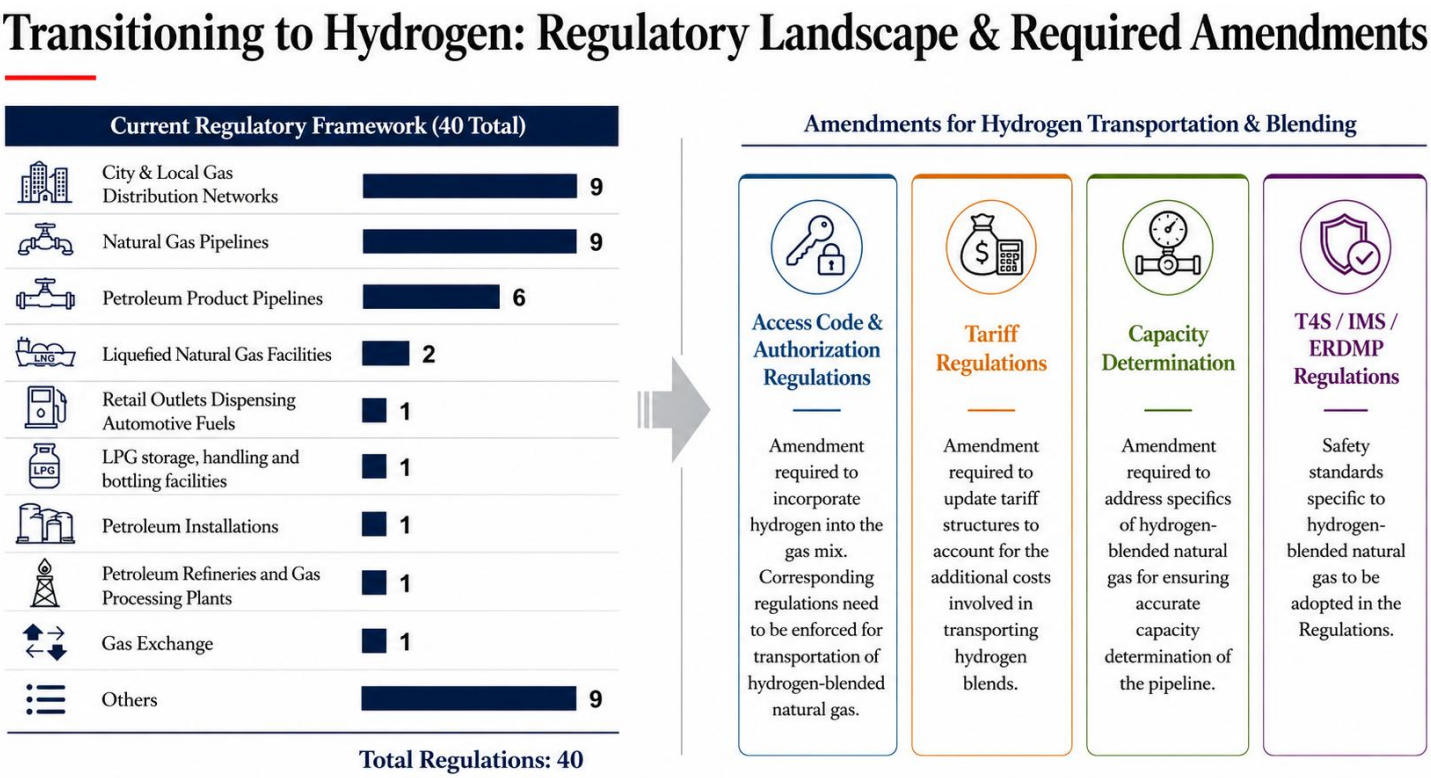
The Regulatory Groundwork

> *Hydrogen lies outside the current scope of the PNGRB Act, 2006. The regulatory machinery that would give effect to its inclusion has been under preparation since 2022.*

The Typical Guidelines for Hydrogen Blending with Natural Gas were drafted in 2022 by a PNGRB technical committee with industry representation. They establish a common technical and safety reference for hydrogen blending pilots.

Of twenty 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.

The proposed amendments to the PNGRB Act, 2006 lift the legislative ceiling on the rest of this work. PNGRB has formally proposed amendments to bring hydrogen - both as a fuel in its own right and as a blend with natural gas - within its statutory remit. Once notified, they would close the gap on which everything else depends. None of what follows - tariffs, access rules, capacity determination, dedicated hydrogen pipelines - can be regulated by an Act that does not name hydrogen.



The scale of regulatory adaptation required becomes visible when one surveys PNGRB's existing rulebook.

Forty notified regulations are currently in force. Four classes - Access Code & Authorization, Tariff, Capacity Determination, and T4S/IMS/ERDMP - will require substantive amendment to accommodate hydrogen blending. A further set will be required for dedicated 100% hydrogen pipelines once those become operational.

What this paper records is a regulator that has done what it can - Guidelines, T4S amendments, standards adoption, an Act amendment proposal - within the constraints of a statute that does not yet name the molecule it is preparing to regulate.

4

India's First Hydrogen Blending Pilots

> *Five PNGRB-approved pilots - across four states, and two pipeline materials - are generating the India-specific evidence base on which hydrogen regulation will rest.*

Borrowed evidence has limits. International blending trials demonstrate what is possible in German, British, or American networks; they do not establish what is safe and operable in Indian ones. India's natural gas pipeline grades, MDPE specifications, climatic envelope, odorization practice, and consumer end-use mix differ enough that PNGRB has chosen to build its regulatory evidence from Indian field data.

That decision has translated into a structured pilot programme. The first, at Indore, has run in two phases: an initial 2% injection (upstream of CGS) in 2021, followed by a 5% blend (MDPE) through from 2022; four more have since been authorised across Gujarat, Assam, and Uttar Pradesh. Together they span the operational range PNGRB will eventually have to regulate.

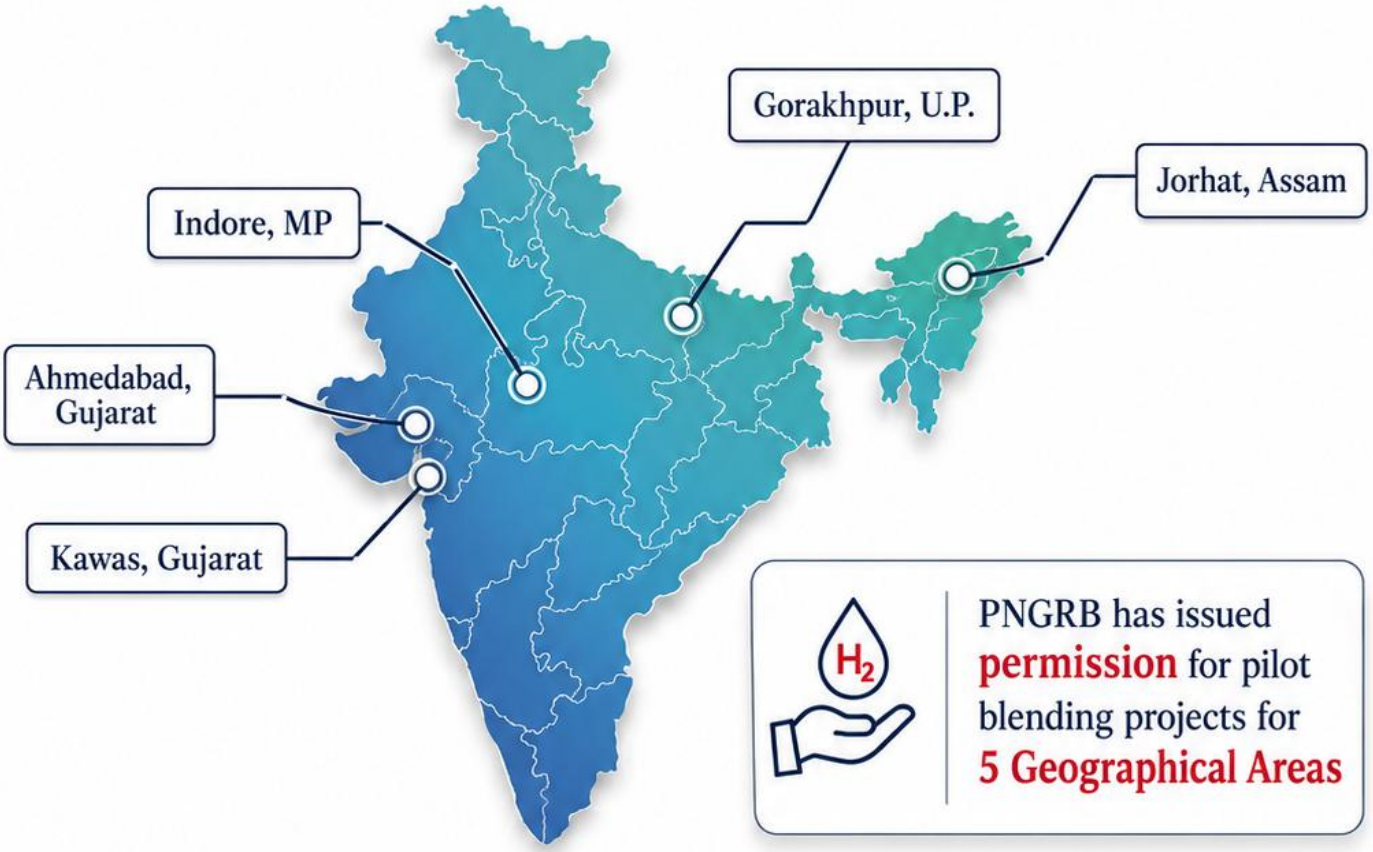
- **Pipeline materials.** Hydrogen has been injected into both MDPE pipelines — the predominant CGD material — and steel: at Indore in Phase 1 (CGS) and Gorakhpur (CGS).
- **Customer segments.** The five cover domestic PNG, commercial, industrial, and CNG customers.
- **Blend percentages.** Tested levels range from 2% to 8% by volume.

Each pilot ends with mandatory third-party assessment, the regulatory mechanism by which field data becomes evidence usable in regulation. Ahmedabad, Indore, and Kawas have completed their blending phases, with assessments now underway; Jorhat and Gorakhpur will complete blending by the end of 2026.

Parameters under assessment across all five pilots include MDPE and steel pipeline behaviour, stratification characteristics, leakage profiles, metering performance under blended flow, and end-use compatibility at the consumer interface.

INDIA'S FIRST HYDROGEN BLENDING PILOTS

Five pilot geographies approved for hydrogen blending in CGD networks



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PNGRB has issued **permission** for pilot blending projects for **5 Geographical Areas**

SOME KEY PARAMETERS UNDER ASSESSMENT

- MDPE & Steel Pipeline Behaviour
- Stratification Characteristics
- Leakage Profiles
- Metering Impacts
- Consumer-End Performance

The findings will feed two regulatory destinations: the Scientific Advisory Committee, which will validate the data and recommend technical thresholds; and the operational rulebook that will, in due course, govern the routine authorisation of hydrogen blending across India's CGD networks.

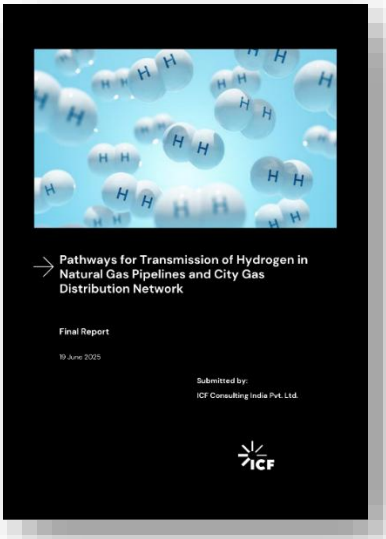
Location	Indore / MP (1st Pilot Study)	Indore / MP	NTPC Kawas / Gujarat	Jorhat / Assam	Ahmedabad / Gujarat	Gorakhpur / UP
Operator	GAIL(India) Ltd. (with Avantika Gas)	Avantika Gas Ltd.	Gujarat Gas Ltd.	Assam Gas Co.	Adani Total Gas Ltd.	Torrent Gas Ltd.
Pipeline	Steel (Upstream of CGS)	MDPE	MDPE	MDPE	MDPE	Steel (CGS)
Blend %	2% →	5%	5%	2%	5%	2%
Customers	Dom · Ind · Com · CNG	Dom · Ind · Com	Domestic (township)	Domestic (township)	Dom · Com	Dom · Ind · Com · CNG
Clearance	23.06.2021	23.10.2022	03.11.2023	31.03.2023	30.05.2024	29.11.2024
Status	Completed (No Adverse reports)	Assessment underway	Assessment underway	Assessment underway	Assessment underway	Blending; assess end-2026

5

From Pathways to Roadmap

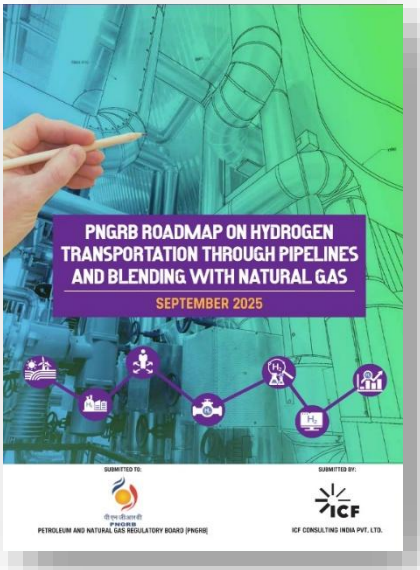
> *The Pathways study, completed in 2024, established what was technically feasible. The PNGRB Roadmap, published in September 2025, translated that feasibility into a phased programme to 2033, India's first published institutional plan for hydrogen transportation through pipelines.*

The Pathways study. Conducted by ICF Consulting India under PNGRB's mandate and in association with the World Bank, the study *Pathways for Transmission of Hydrogen in Natural Gas Pipelines and CGD Networks* was structured around five tasks: demand–supply mapping for low-carbon hydrogen, technical and commercial assessment of the existing pipeline sector, regulatory assessment against international practice, and a phased roadmap. Its final report, completed in 2024 and web-hosted on PNGRB's website since 19 June 2025, set the operating envelope. On a network-wide level, blending **up to 2%** is feasible with minimal adjustments; **up to 10%** is technically possible subject to case-specific pipeline and network assessment; **beyond 10%**, system-level changes are required, and dedicated pure-hydrogen pipelines may be the more cost-effective option. The study's twelve-month action set, addressed to PNGRB, **prioritised statutory amendment of the Act**, detailed technical assessments, and standards alignment.



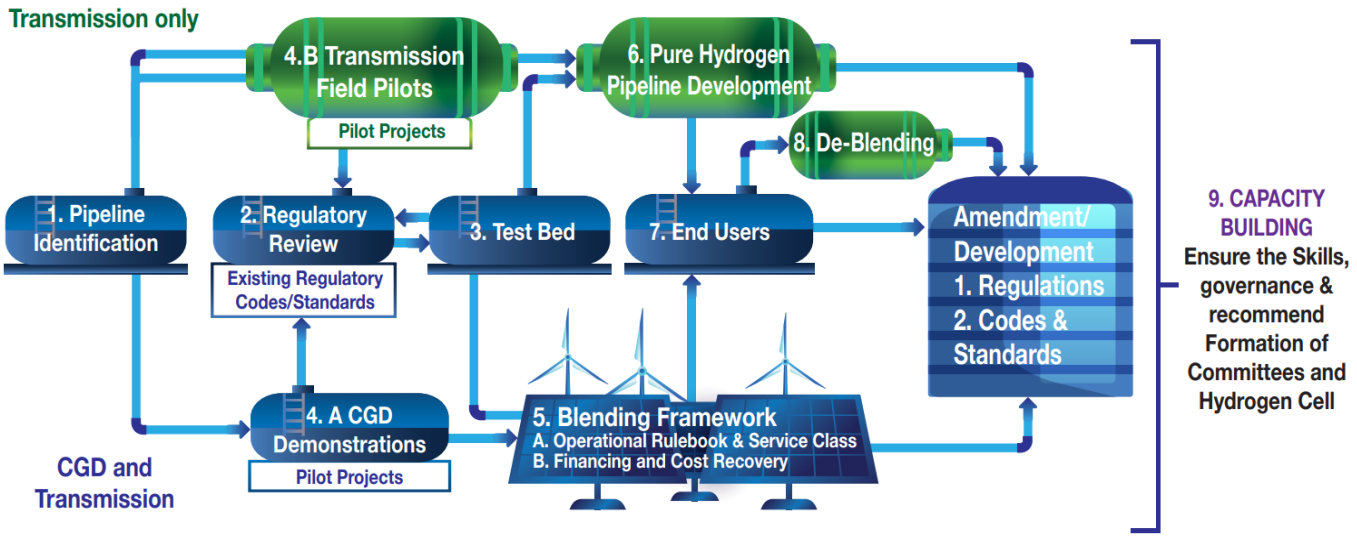
The roadmap. submitted to the PNGRB Board on 24 September 2025, web-hosted shortly thereafter, and circulated to over 130 stakeholders, including **Dr. V.K. Saraswat (Member, NITI Aayog), the Secretary, MoPNG, and the Secretary, MNRE,** the roadmap is structured as a phased, module-based pathway. The Pathways study's recommendations were translated into nine modules organised across two phases: **Phase I (2025–2028)** focused on capacity building and foundational readiness, pipeline identification, the National Hydrogen Testbed, foundational standards, and pilot demonstrations; **Phase II (2029–2033)** on scale-up and commercialisation, the blending framework, dedicated pure-hydrogen pipelines, end-user appliance compatibility, deblending technologies, and continued capacity building.

The institutional process behind the roadmap mattered as much as its content. The draft was reviewed at NITI Aayog on 9 July 2025 in a session chaired by Dr. V.K. Saraswat under the guidance of Dr. Anil Kumar Jain, Chairperson, PNGRB. A focused stakeholder consultation and the inaugural Hydrogen Pilot Project Forum was held on 1 August 2025 at the India Habitat Centre, New Delhi. Both shaped the final document.



PNGRB also engaged with the Office of the Principal Scientific Adviser to the Government of India on 28 October 2025. The meeting, chaired by **Prof. Ajay Kumar Sood, PSA to the GoI**, was convened to apprise the PSA of PNGRB's ongoing and proposed initiatives on hydrogen transportation through pipelines and blending with natural gas, including the World Bank-supported Pathways study, the PNGRB Roadmap, testbed creation, safety coordination mechanisms and the need for legislative amendments. The PSA appreciated the comprehensiveness of the roadmap and indicated that funding support under NGHM may be explored.

A central innovation of the roadmap is its **Readiness Assessment Module** - a nine-parameter scoring framework for evaluating which pipeline segments are technically suitable for initial blending. The framework converts "which pipelines can take hydrogen?" from a discretionary judgement into an evidence-based regulatory question.



The roadmap's two structural prescriptions - the National Hydrogen Testbed and the Scientific Advisory Committee - are taken up in the sections that follow.

6

The National Hydrogen Testbed

> *Field pilots establish what works at one site. A National Testbed establishes what works at scale — under controlled conditions, across the full range of components, materials, and operating regimes that regulation will eventually need to cover.*

The roadmap's most consequential prescription is institutional rather than regulatory. It calls for the establishment of a National Hydrogen Testbed, a permanent, instrumented infrastructure for full-scale testing of hydrogen transportation and blending in Indian conditions. Without such a facility, regulation would have to depend on extrapolation from limited pilot sites and on borrowed evidence from German, British, and American test programmes. With it, India can generate its own.

The architecture is bifurcated. Two nodal entities were designated on 19 November 2025:

- **GAIL (India) Limited** - nominated as the Central Nodal Agency for the **transmission (NGPL) hydrogen testbed**. GAIL has submitted a proposal to MNRE under the National Green Hydrogen Mission for a **Centre of Excellence at its Vijaipur facility** (Guna district, Madhya Pradesh), with **IIT Roorkee** as the academic partner for in-situ testing.
- **Indraprastha Gas Limited (IGL)** - nominated as the nodal entity for the **CGD/distribution hydrogen testbed**, covering low-pressure network applications including CNG and domestic PNG systems.

The split reflects a structural distinction in PNGRB's regulatory remit: transmission and distribution are technically and operationally different problems, and the Testbed mirrors that division. Both nodal facilities will operate under PNGRB oversight in coordination with MNRE/NGHM.

Six lines of work are envisaged across the Testbed system: full-scale test loops covering high-pressure transmission and low-pressure CGD/MDPE systems; material testing for hydrogen embrittlement, fatigue, elastomer compatibility, and weld performance; component assessment of valves, meters, compressors, and regulators under hydrogen service; operational safety testing for pressure cycling, leakage characteristics, and stratification behaviour; instrumented monitoring with SCADA-integrated real-time flow and integrity evaluation; and OEM certification - standards validation that allows Indian manufacturers to certify hydrogen-ready components.

The causal sequence is direct: **Testbed → National Standards → OEM Certifications → Safe Field Deployment**. Evidence generated in the loops becomes the technical basis for the regulations PNGRB will, once empowered, issue. PNGRB's study visits to DNV Spadeadam and SGN H100 Fife in the United Kingdom have provided design references for how comparable testbeds operate abroad, informing both the technical scope and the governance arrangements being developed for the Indian facilities.

National Hydrogen Test Bed

The scientific backbone for India-specific evidence generation

01

Full-Scale Test Loops

High-pressure transmission and low-pressure CGD/MDPE systems

02

Material Testing

H_2 embrittlement, fatigue, elastomer and weld compatibility

03

Component Assessment

Valves, meters and compressors under H_2 service

04

Operational Safety

Pressure cycling, leakage characteristics and stratification

05

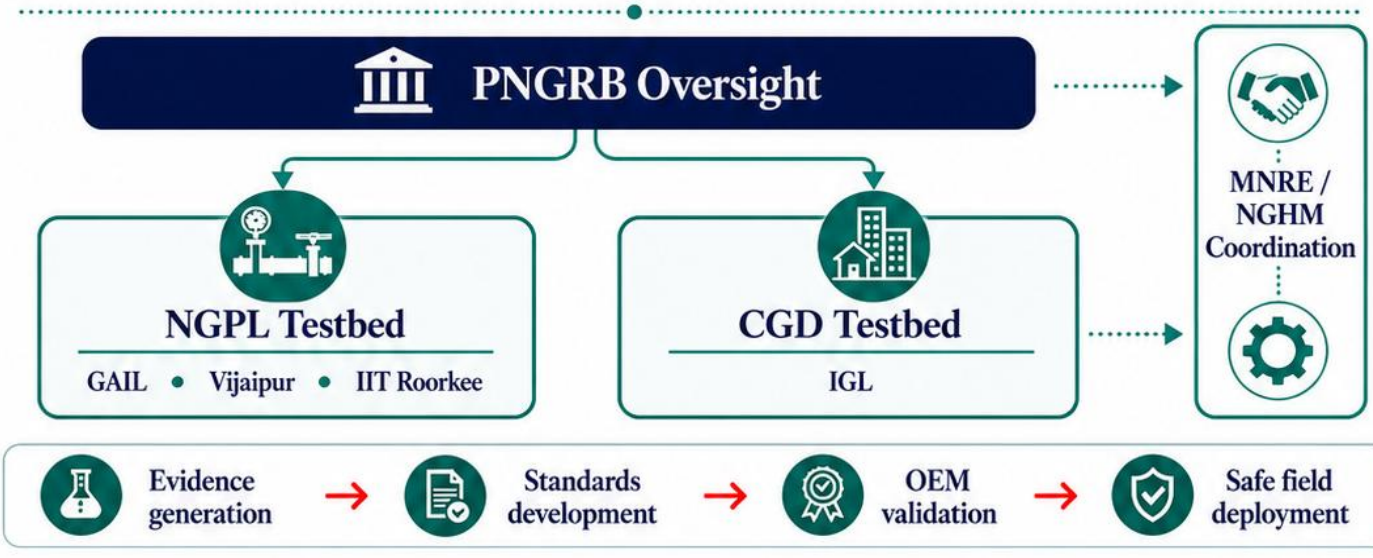
SCADA Monitoring

Real-time instrumented monitoring and flow evaluation

06

OEM Certification

Standards validation for manufacturer certifications



7

The Scientific Advisory Committee

> *Pilots generate data. The Testbed will generate more. But data does not translate itself into regulation. The Scientific Advisory Committee is the technical forum constituted to make that translation — under expert scrutiny, against international benchmarks, in Indian conditions.*

The Scientific Advisory Committee on Hydrogen Initiatives was constituted by PNGRB Order **PNGRB/Coordination/1-H2Roadmap/(1)/2025 (E-6041)** dated **12 February 2026** and met for the first time on **24 February 2026** at the PNGRB office, New Delhi. It is chaired by **Sh. Mukesh Mohan**, Executive Director, IOCL, and convened by **Sh. Muktikam Phukan**, Director (Coordination) and Officer-in-Charge of the Hydrogen Cell, with the Hydrogen Cell functioning as Secretariat. Its membership is drawn from across the relevant ecosystem — gas transmission and distribution entities, refineries, IITs and other academic institutions, MNRE, pipeline manufacturing entities and EPC Consultants as well as standards making bodies.

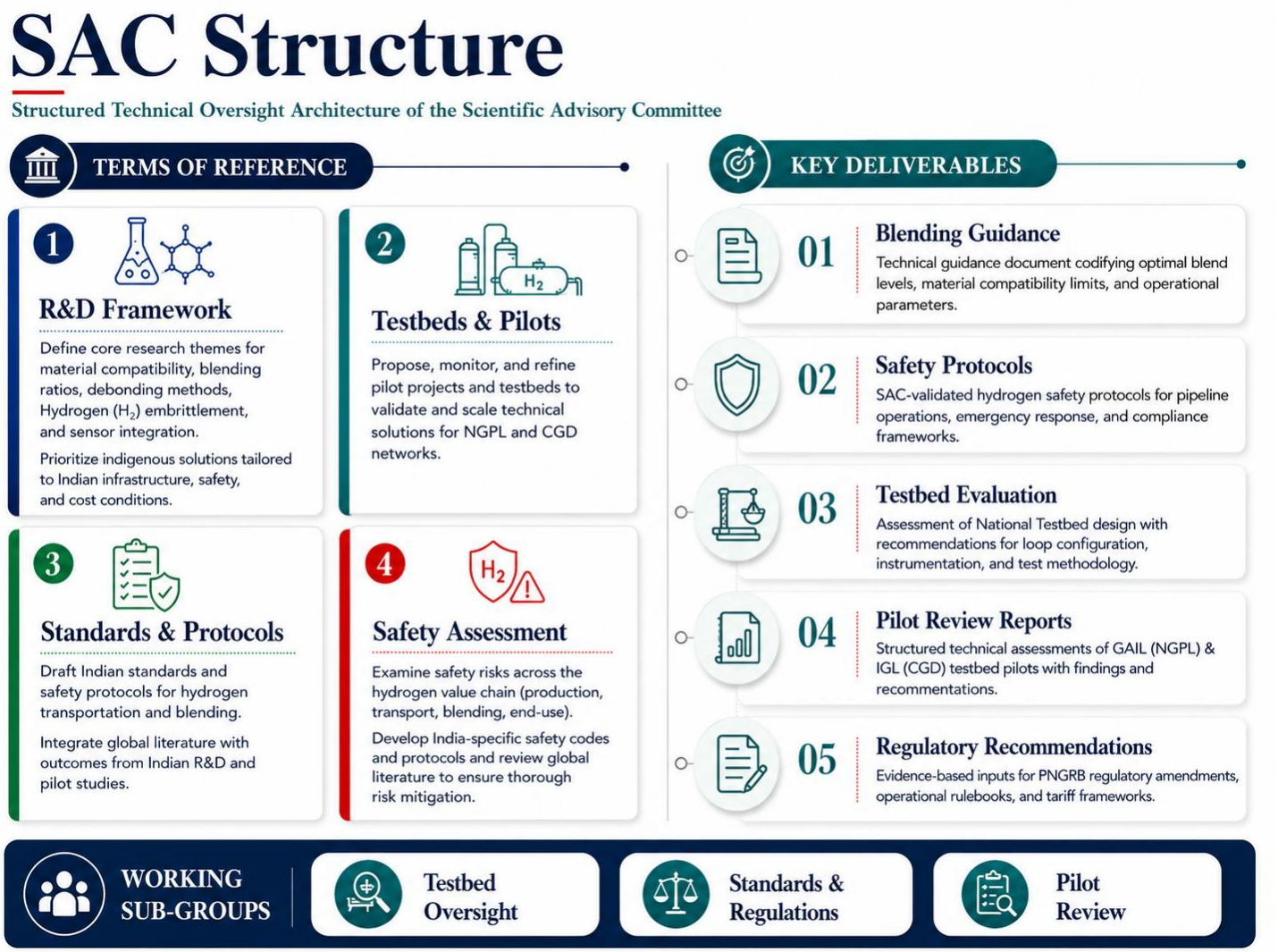
The SAC is constituted as the apex advisory body, providing evidence-based inputs to PNGRB**.** Its remit, as recorded in the constituting order, is to deliver India-specific guidance on hydrogen transportation through pipelines, hydrogen–natural gas blending, and associated safety protocols.

The deliverables are correspondingly concrete: **India-specific blending guidance**, **validated safety protocols**, **assessment of the National Testbed design**, **structured technical review reports on the GAIL and IGL testbeds and the five field pilots**, and **evidence-based regulatory recommendations** for PNGRB amendments, operational rulebooks, and tariff frameworks.

The SAC fits a pattern visible across every country building a hydrogen economy at scale: regulators reach for expert advisory bodies to do what they cannot do alone. Germany's National Hydrogen Council, established in June 2020, sits at the centre of that country's hydrogen strategy with twenty-five experts drawn from industry, science, and civil society. The United Kingdom's Hydrogen Delivery Council - originally the Hydrogen Advisory Council, constituted in July 2020 - is the joint government–industry forum

that informs UK hydrogen policy. The European Union runs the Clean Hydrogen Partnership; the United States its Hydrogen and Fuel Cell Technical Advisory Committee under the Department of Energy. The logic is consistent across jurisdictions: regulating an emerging energy technology demands depth in materials science, pipeline engineering, safety analysis, and end-use compatibility that no single regulator can hold in-house, and expert bodies provide that depth without diluting regulatory authority.

The SAC reflects this pattern but is more sharply specified. Where Germany's and the UK's councils advise on the full hydrogen economy, the SAC's remit is targeted to a specific regulatory perimeter - transportation through pipelines, blending with natural gas, and the associated safety architecture - which is precisely the perimeter PNGRB will be asked to regulate. Its outputs are operational, not deliberative: technical guidance documents, validated safety protocols, structured pilot review reports, and concrete regulatory recommendations. The intent is that when PNGRB eventually issues hydrogen regulations, those regulations will already have been stress-tested against expert scrutiny - Indian conditions verified, international benchmarks applied, multi-stakeholder consensus reached.



The SAC is, in effect, the validation layer between the evidence base PNGRB has been building since 2021 and the regulations it will eventually need to issue. Its work over the coming year will determine the quality of those regulations.

8

International Cooperation

> *PNGRB has signed three Memoranda of Understanding with leading European technical institutions since April 2025. Each one shortens the time between an Indian regulatory question and a defensible answer.*

The argument for international cooperation in hydrogen regulation is straightforward. Standards, test methodologies, simulation tools, and safety frameworks that have taken Germany and the United Kingdom two decades to develop can be adopted and adapted in a fraction of that time - provided the institutional pathway exists. Three Memoranda have been signed since April 2025 to build that pathway.

PNGRB × IGEM (United Kingdom) — April 2025. The Institution of Gas Engineers and Managers (IGEM) is the United Kingdom's principal technical body for gas engineering and standards. Its hydrogen series, IGEM/TD/1, TD/3, TD/13, and SR/25, covers high-pressure hydrogen pipelines, the repurposing of natural gas pipelines for hydrogen service, pressure-regulating installations for hydrogen and blended mixtures, and hydrogen safety. The MoU gives PNGRB structured access to these standards and to IGEM's training and certification programmes, with the explicit objective of strengthening India's hydrogen standards and certification ecosystem.

PNGRB × SGN (United Kingdom) — August 2025. SGN, one of the United Kingdom's principal gas distribution network operators, runs the H100 Fife project, the world's first 100% hydrogen domestic distribution pilot, supplying around 1,000 homes in Scotland. The MoU, signed during the Secretary, PNGRB's UK study visit, is focused on knowledge exchange in blending pilots, integrity management, and pathways for hydrogen adoption in CGD networks. Joint research and pilot projects fall within scope.

PNGRB × DVGW (Germany) — January 2026. The MoU with the Deutscher Verein des Gas- und Wasserfaches (DVGW) - Germany's technical and scientific association for gas and water - was exchanged on 12 January 2026 at Mahatma Mandir, Gandhinagar, in the presence of the **Hon'ble Prime Minister of India and the Federal Chancellor of Germany**. DVGW's *Regelwerk*, including **G 260** (gas quality), **G 407/G 408** (conversion of steel

and plastic pipelines for hydrogen), **G 409** (hydrogen suitability of steel components), **G 463** (new steel hydrogen pipelines), and **G 464** (fracture mechanical assessment) is among the most comprehensive hydrogen technical rule sets in the world. The MoU provides PNGRB with access to these rules and test principles (with translation support), the **Hydrogen Readiness Testing Scheme (HRTS)** for materials and components, hydrogen-ready certification methodology, and network simulation tools for blends up to twenty percent and beyond. The operationalisation kick-off was held on 9 February 2026.

A fair question follows from all of this: if Europe's hydrogen standards are this mature, why can they not simply be adopted wholesale? The answer is that a technical standard is not a free-standing document; it is the codified evidence of the network it was written for. DVGW's rules assume German gas qualities as defined in G 260, German pipeline steels and vintages, and German operating temperatures; IGEM's assume the material stock and pressure regimes of the British grid. Indian conditions differ at almost every one of those parameters, a gas basket that blends domestic production with regasified LNG of varying composition, pipeline steel grades and MDPE specifications procured to Indian standards, a climatic envelope that ranges from sub-zero winters to soil temperatures European polymer standards never contemplated, distinct odorisation practice, and a consumer appliance base never certified against European norms. A blending threshold that is safe on a German network is a hypothesis, not a conclusion, on an Indian one. There is also a legal dimension: to be enforceable, standards must be adopted into India's own regulatory framework through T4S notification, in coordination with BIS and PESO, rather than referenced from a foreign rulebook. What the MoUs therefore provide is not a shortcut around Indian evidence but a head start toward it: European test methodologies, certification schemes, and simulation tools, adapted and validated against Indian field data from the pilots and, in time, the National Testbeds. The inheritance is curated, not copied - built without compromising Indian regulatory authority, and structured to feed Indian standards, Indian testbeds, and Indian regulations.

Study visits. Alongside the formal MoUs, PNGRB has undertaken structured study visits to **DNV Spadeadam** - the United Kingdom's principal hazardous-trials facility, operated by the Norwegian risk-management firm DNV - and to **SGN H100 Fife**. These visits have provided design references for the National Hydrogen Testbed and have informed the governance arrangements being put in place around it.

What the three MoUs and the associated study visits give PNGRB is, in effect, a curated technical inheritance, built without compromising Indian regulatory authority, and structured to feed Indian standards, Indian testbeds, and Indian regulations.

9

Domestic Engagement & Capacity Building

> *Hydrogen regulation cannot be built in isolation. PNGRB has been deliberately constructing the domestic ecosystem — industry partners, academic institutions, and the cross-ministerial coordination on which coherent national action depends.*

Three lines of engagement have advanced in parallel with the international cooperation set out on the previous page.

Industry. The five blending pilots are the most visible engagement, each one a structured collaboration with a CGD authorised entity (GAIL/Avantika Gas, Adani Total Gas, Gujarat Gas Ltd., Assam Gas Company, Torrent Gas). Beyond the pilots, the two testbed designations of November 2025 brought **GAIL** and **Indraprastha Gas Limited** into structured technical partnership with PNGRB. Industry workshops have broadened the conversation: most recently, the **IOCL Panipat workshop on hydrogen transportation through pipelines** (4 November 2025), and the **inaugural Hydrogen Pilot Project Forum** held alongside the stakeholder consultation at the India Habitat Centre on 1 August 2025.

Academia and research. The Testbed at GAIL Vijaipur is being developed with **IIT Roorkee** as academic partner for in-situ testing. Engagement with the **Gujarat Energy Research and Management Institute (GERMI-Gujarat)** is active. **IOCL R&D Faridabad** has been a technical interlocutor on multiple workstreams. The roadmap envisages widening this network, its capacity-building module is explicitly dedicated to skills, governance, and the institutional infrastructure needed for sustained engagement.

Cross-ministerial coordination. Hydrogen regulation requires coherent action across a constellation of central institutions. PNGRB's structured engagement covers:

- **MoPNG** as the parent ministry, with PNGRB designated for hydrogen regulation under NGHM Clause 6.4;
- **MNRE**, the nodal ministry for the National Green Hydrogen Mission, with PNGRB's Director (Coordination) serving on the **National Hydrogen Safety Panel** constituted under NGHM, and PNGRB's systematic adoption of MNRE-recommended hydrogen standards as set out earlier;
- **NITI Aayog**, which reviewed the draft Roadmap on 9 July 2025 in a session chaired by Dr. V.K. Saraswat;
- **BIS and PESO**, the principal Indian standards and explosives-safety bodies, with coordination flagged in the Roadmap's Regulatory Review module.

The apex engagement in this constellation came on 28 October 2025, when a PNGRB delegation led by the Chairperson was received by **Prof. Ajay Kumar Sood, Principal Scientific Adviser to the Government of India**. The Pathways study and the Roadmap were formally presented, and the Chairperson laid before the

PSA the regulatory questions that hydrogen blending will pose in practice: tariff methodology, since natural gas tariffs are determined on an energy basis and hydrogen's lower energy density could translate into higher effective tariffs post-blending; the treatment of pipeline authorisations issued for specific end-use segments once blended gas is supplied; and the absence of a dedicated R&D funding mechanism for testbed creation, PNGRB not being a scientific body per se.

Two requests were placed before the PSA: recognition of PNGRB as an essential stakeholder in national scientific and technical coordination on hydrogen safety and infrastructure, and support under the National Green Hydrogen Mission for regulatory studies and the National Hydrogen Testbed. The PSA appreciated the comprehensiveness of the Roadmap and concurred that funding support under NGHM may be explored, noting existing Mission allocations for sectors such as fertiliser, shipping, and mobility.

The final Roadmap document, on publication in September 2025, was circulated to **over 130 stakeholders**: government, industry, academia, etc., to ensure the regulatory direction was visible to every actor whose work it would touch.

The picture that emerges is of a regulator that has chosen, deliberately, to do its work in the open and in partnership rather than in isolation, and to build, in advance of statutory mandate, the relationships on which future regulation will depend.

10

Safety is Non-Negotiable

> *The single largest determinant of whether India's hydrogen pipeline architecture succeeds is whether it remains safe. Public trust, once lost, is exceptionally difficult to rebuild — and the entire economic case for hydrogen rests on a record of incident-free operation.*

The Hindenburg disaster of 6 May 1937, when a hydrogen airship erupted in flames, captured on newsreel and radio recordings heard by millions within a day, ended commercial hydrogen aviation overnight. It took three decades, until the Apollo programme, for hydrogen to recover public confidence as a fuel. The root

cause of the disaster, later analyses have argued the airship's incendiary skin coating, rather than the hydrogen itself, was the primary culprit - the attribution remains debated, but hydrogen bore the blame regardless. The lesson is institutional: an emerging energy technology cannot afford a single visible incident in its formative years, and the safety regime that prevents such incidents is therefore not a cost on the system, it is the precondition for the system existing at all.

For PNGRB, safety has therefore been treated as a design principle rather than a downstream compliance requirement. The hydrogen programme has been built around controlled pilots, mandatory third-party assessment, SAC scrutiny, testbed-based validation, standards alignment, and coordination with national safety mechanisms. Each layer is intended to ensure that technical feasibility is converted into regulatory confidence only after evidence has been generated and independently reviewed. The principal technical and operational risks being considered for hydrogen transportation and hydrogen-natural gas blending may be summarised as follows:

Concern	Engineering response
Hydrogen embrittlement	Material selection, fracture-mechanics assessment under ASME B31.12, pressure management
Leak detection	Hydrogen-specific sensor arrays; SCADA-integrated monitoring; lower-explosive-limit alarms at critical points
Odorisation	Conventional mercaptan-based odorants interfere with fuel cells; novel odorants or alternative detection strategies required for hydrogen networks
Blending-ratio control	Precision injection systems, flow metering, and real-time compositional monitoring
Pipeline integrity	In-line inspection tool compatibility; modified cathodic protection protocols for hydrogen service
Emergency response	Protocols recognising hydrogen's wider flammability range (4–75%), rapid dispersion behaviour, and distinct ignition characteristics

PNGRB's existing safety regulatory architecture, the **Technical Standards and Specifications (T4S)**, **Integrity Management System (IMS)**, and **Emergency Response and Disaster Management Plan (ERDMP)** regulations, provide the structural foundation. These are precisely the regulations identified earlier as requiring amendment to accommodate hydrogen blending; the underlying safety logic is already present and well-established for natural gas, and the amendments will extend it to hydrogen.

Institutionally, three layers govern safety in PNGRB's hydrogen programme. The **Scientific Advisory Committee's** dedicated Safety Assessment terms of reference cover hydrogen risks across the value chain - production, transport, blending, end-use - with explicit emphasis on high-pressure blending and residential use. The **National Hydrogen Safety Panel** under NGHM, on which PNGRB serves as a member, provides the inter-ministerial coordination mechanism. The **upcoming Testbeds & mandatory third-party assessment** of every blending pilot is the operational safeguard that converts pilot-stage learning into validated, externally verified safety evidence.

Safety is not a constraint on ambition — it is the foundation on which ambition can be built.

11

Key Takeaways

> *If the work of the past five years has a single organising principle, it is anticipation — the deliberate construction of a regulatory architecture in advance of statute authorising its use.*

Six observations summarise what has been built, and what its construction implies.

1. Anticipation, not reaction. Since June 2021, PNGRB has progressed hydrogen-relevant work in advance of statutory mandate: five pilots authorised, Typical Guidelines drafted, eight MNRE-recommended standards adopted, three international MoUs signed, a National Hydrogen Testbed designated, a Scientific Advisory Committee constituted, and a Roadmap to 2033 notified. This is the institutional record of a regulator choosing not to wait.

2. Evidence-based prescription, not borrowed prescription. Every regulatory recommendation that PNGRB will issue rests on a defensible empirical foundation, Indian field data from five pilots, technical inheritance through three structured European cooperations, and reviewed analytical work in the Pathways study and the roadmap.

3. Institutional architecture, not just rules. The Scientific Advisory Committee, the National Hydrogen Testbed, the international partnerships, the National Hydrogen Safety Panel - these are the institutions that will sustain hydrogen regulation across the multiple regulatory cycles a thirty-year energy transition will demand. Rules age; institutions endure.

4. A phased horizon, sequenced to capability. The roadmap's two-phase structure - capacity building and foundational readiness (2025–2028), followed by scale-up and commercialisation (2029–2033) - sequences hydrogen regulation to what can be demonstrably done, not to what would be politically convenient.

5. The bottleneck is statutory, not technical. Nearly every component of the architecture described in this paper — from the regulations that would replace the Typical Guidelines, to the adoption of ASME B31.12, to PNGRB's ability to issue dedicated hydrogen-pipeline tariffs and access rules - is contingent on a single legislative action: the inclusion of hydrogen within the scope of the PNGRB Act, 2006.

6. Safety underwrites everything. The economic case for hydrogen, the investor confidence behind ₹19,744 crore of NGHM commitments, and the public acceptance on which residential blending will eventually depend, all rest on a safety record that has yet to be built. PNGRB's safety architecture is the load-bearing wall of the entire structure.

12

Enabler · Facilitator · Regulator

> *A regulator's role is conventionally understood as the issuance and enforcement of rules. In emerging energy sectors, that understanding is insufficient. PNGRB sees its role in India's hydrogen pipeline future as a triad — enabler, facilitator, and regulator — and the work described in this paper is the institutional expression of that view.*

As Enabler. PNGRB has prepared technical reference frameworks, advanced standards alignment, commissioned analytical work, supported the development of the roadmap, and proposed statutory amendments that would give the hydrogen architecture formal legal footing.

As Facilitator. PNGRB has coordinated pilots, testbed development, the Scientific Advisory Committee, domestic stakeholder consultations, cross-ministerial engagement and international technical cooperation with institutions such as IGEM, SGN and DVGW. This connective role is indispensable because hydrogen transportation cannot be built by one institution alone.

As Regulator. PNGRB is preparing the evidence base, safety logic, institutional mechanisms and draft regulatory pathways that can support enforceable regulations once hydrogen is expressly brought within the PNGRB Act, 2006. The paper therefore records not the completion of regulation, but the creation of regulatory readiness.

The three roles are not sequential. They are simultaneous. The work since 2021 has been the work of all three at once - enabling, facilitating, and preparing to regulate. This is what an anticipatory regulator looks like in practice.

Hydrogen will move at the pace of trust. Trust will be earned through evidence, partnership, and uncompromising attention to safety. PNGRB's task — across all three of its roles — is to keep that pace honest.

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