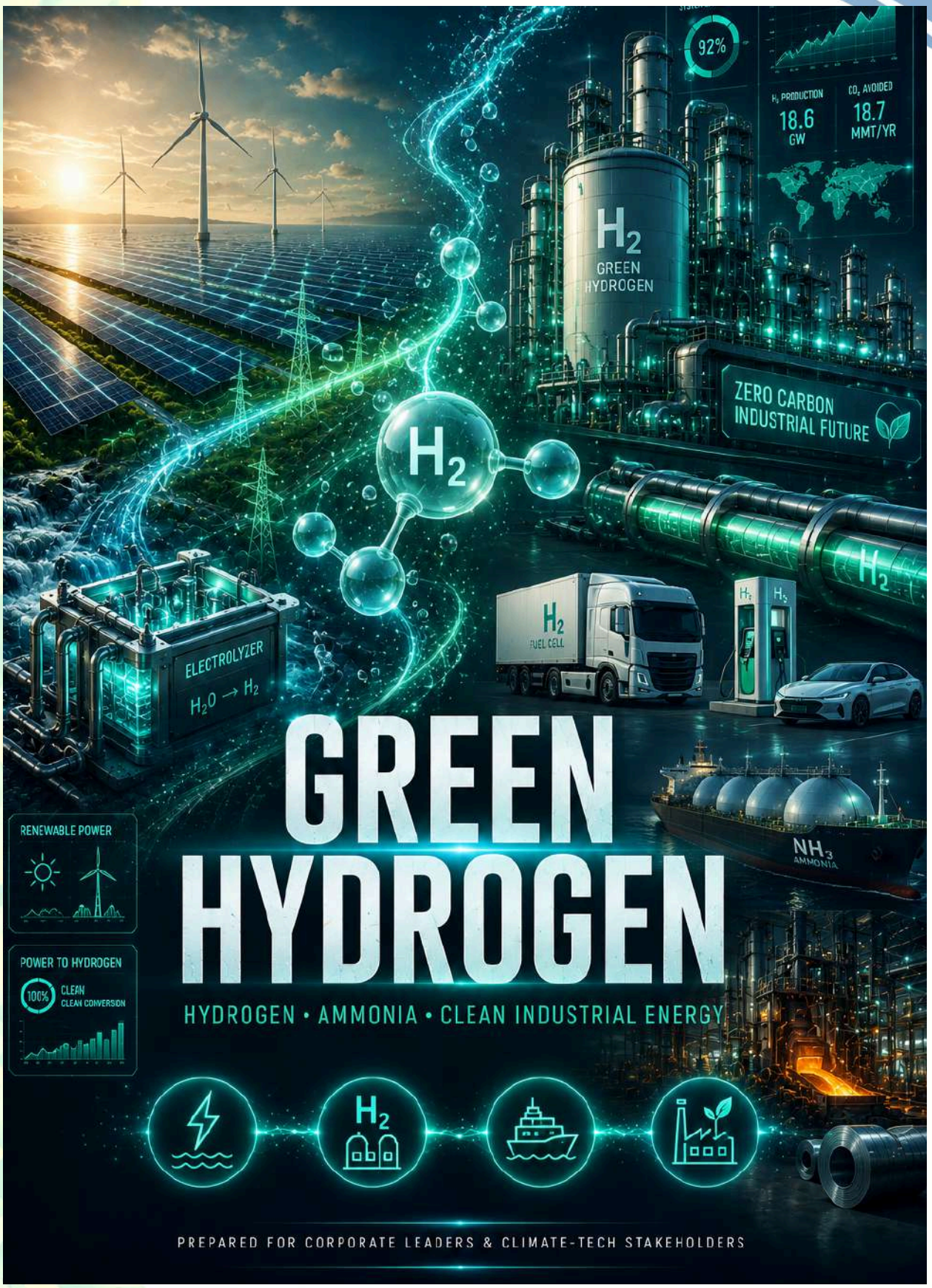
92%
H_2 PRODUCTION
18.6
GW
CO_2 AVOIDED
18.7
MMT/YR
H_2
GREEN
HYDROGEN
ZERO CARBON
INDUSTRIAL FUTURE
H_2
ELECTROLYZER
$H_2O \rightarrow H_2$
H_2
FUEL CELL
H_2
RENEWABLE POWER
POWER TO HYDROGEN
100%
CLEAN
CLEAN CONVERSION
GREEN
HYDROGEN
NH_3
AMMONIA
HYDROGEN • AMMONIA • CLEAN INDUSTRIAL ENERGY
H_2
PREPARED FOR CORPORATE LEADERS & CLIMATE-TECH STAKEHOLDERS

Energy Storage

Green Hydrogen

This section discusses business opportunities along the entire green hydrogen ecosystem & value chain.

Opportunity Snapshot: Green Hydrogen

Zero-carbon hydrogen produced using renewable energy as a clean fuel for industry and energy.

Market Signal

- India's National Green Hydrogen Mission targets nearly **5 MTPA by 2030**
- Strong demand from **refining, fertilizers, and export markets** (EU, Japan)
- **Annual Market size by 2030:** 13,000 - 15,000 ₹ Cr

What Makes or Breaks It?

- Access to low-cost renewable energy (key cost driver)
- Electrolyzer efficiency and scale (technology selection critical)
- Secured long-term offtake (industrial + export contracts)

Why It Matters NOW?

- Decarbonisation of **hard-to-abate sectors (steel, chemicals, shipping)**
- Export opportunity as global markets **seek low-carbon fuels**
- **Falling renewable costs** improving green hydrogen economics over time

Well Aligned Opportunity for

- **Large energy companies** (oil & gas, power utilities)
- **Industrial players** (steel, fertilizers, chemicals)
- **Export-focused developers and infrastructure players**

Key Challenges

- **High production cost:** 2–3x grey hydrogen currently
- **Infrastructure gaps** (storage, transport, pipelines)
- **Limited demand visibility** without long-term contracts

Business Model

- Integrated projects: renewables + electrolyzers + hydrogen production
- Partnerships with industrial users for captive demand
- Export-oriented projects (green ammonia, shipping fuels)

Introduction and Business Case

Green hydrogen — typically produced via electrolysis of water using renewable power — is a versatile decarbonisation fuel. It can substitute coal in steelmaking, provide feedstock for ammonia/methanol and power long-haul transport where batteries fall short.

For India, green hydrogen reduces crude and LNG imports, positions the country as a global export hub and helps industries meet Net Zero and National Green Hydrogen Mission targets. It's thus both an industrial and a geopolitical necessity.

Market Potential for Green Hydrogen in India

Market potential estimates provided are the sum total of potential of all opportunities along the entire green hydrogen value chain.

Year	Market Size (₹ Cr)	Capacity Outlook	Drivers
2025	Nascent	Pilot projects, ~100-150	Early industrial demos, blending in refineries/fertilisers.
2030	13,000-15,000	0.5 MT annual demand	National Green Hydrogen Mission target; steel, fertiliser adoption.
2040	85,000-110,000	5-10 MT demand	Deep penetration in steel, ammonia, methanol, heavy transport, exports.

Market Segments and Applications

Segment	Applications	Business Model	Key Drivers
Electrolyzer manufacturing	Green hydrogen production	Equipment sales + long-term service	Falling electrolyzer costs & scale-up
Utility-scale green H_2 production	Industrial hydrogen replacement	Own–operate plants with offtake contracts	Industrial decarbonization mandates
Integrated renewables + hydrogen	Green H_2 & derivatives	Co-located renewable-hydrogen projects	Low-cost renewable power availability
Green ammonia	Fertilizers, shipping	Hydrogen-to-ammoni	Global ammonia

production	fuel	a conversion & export	demand decarbonization
Hydrogen for mobility	Fuel-cell vehicles, buses, trucks	Hydrogen supply + refueling infrastructure	Zero-emission transport policies
Fuel cells production	Primary use will be in vehicles and mobility sector	Fuel cell production and sale	Growth in electrification of heavy vehicles
Hydrogen for refining & chemicals	Refineries, methanol, chemicals	Long-term industrial supply contracts	Scope-1 emission reduction
Export-oriented hydrogen hubs	Cross-border H_2/ammonia trade	Mega-project development & export contracts	Regional energy cost arbitrage
Hydrogen storage & logistics	Storage, compression, liquefaction	Infrastructure ownership & services	Scale-up of hydrogen volumes
EPC & system integration	End-to-end hydrogen plants	Turnkey EPC + O&M	Industrial project bankability
Hydrogen trading & certification	Guarantees of origin, certificates	Platform & market orchestration	Policy-driven traceability requirements

Typical Project Capacities & Investments Required in India

Project Type	Typical Capacity	Indicative CapEx (₹ Cr)	Notes
Electrolyzer Production	5 MW / year — pilot / R&D line 50 MW / year — small commercial line 200 MW / year — medium scale	₹32 – 50 Cr ₹320 – 500 Cr ₹1,280 – 2,000 Cr	Small pilot lines carry higher per-unit cost (setup, test rigs, prototyping equipment, low automation). Useful for PEM/stack R&D and qualification runs.
Fuel Cell Production	500 kW / year — pilot / lab / low-volume R&D 20,000 kW / year (20 MW/yr) — medium	₹0.55 – 2.7 Cr ₹21.8 – 109.2 Cr	Very small lab/pilot line. High unit testing cost, manual assembly, low throughput. Useful for prototyping, qualification, local R&D (stack presses, MEA

	scale 100,000 kW / year (100 MW/yr) — large / mass-production line	 ₹109.2 – 546.0	handling, small test benches). (Low capital because volumes and tooling are small).
Green Hydrogen Production facility along with RE power plants	10 MW (pilot/demo) 50 MW (early commercial) 100 MW (standard industrial project) 500 MW (large integrated plant)	₹250 – 450 Cr ₹1,200 – 2,000 Cr ₹2,500 – 4,500 Cr ₹12,000 – 20,000 Cr	Pilot-scale industrial demo projects (ports, refineries, research facilities). Includes electrolyser, power electronics, compression, small storage. Higher per-MW cost due to limited economies of scale. Example: small pilot projects across India.
Production of prominent BoS for a Green Hydrogen facility	200–500 MW electrolyser-equivalent electrical systems	₹300 – 800 Cr	Power electronics (rectifiers, transformers, converters, switchgear). Largest BoP cost driver. Electrical systems alone can represent 30–50% of project CAPEX; large manufacturing potential in India leveraging existing power equipment ecosystem.
Green Ammonia Production	100 TPD (~35,000 TPA) – pilot / early commercial 00 TPD (~100,000 TPA) – small commercial 1,000 TPD (~350,000 TPA) – standard industrial/export plant	₹1,500 – 2,500 Cr ₹4,500 – 7,000 Cr ₹12,000 – 20,000 Cr	Early industrial decarbonisation projects (fertilizer blending, pilot export). Higher per-tonne cost due to smaller scale and limited optimization.
Production of Storage Tanks for Green Hydrogen	5,000–15,000 cylinders/year OR 500–1,000 tonnes storage equivalent/year	₹80 – 200 Cr	Conventional steel fabrication lines. Lowest technical barrier. Suitable for industrial buffer storage (20–200 bar). Existing oil & gas fabrication ecosystem in India can adapt quickly. Type I Steel Pressure Vessels (Low–Medium pressure)

Transport Vehicles for Green Hydrogen	50–150 trailers/year	₹120 – 300 Cr	Most common near-term transport solution. Uses steel or composite cylinders mounted on trailers. Leverages existing industrial gas logistics ecosystem. Lower technical risk vs cryogenic systems.
Production of Hydrogen Dispensing Units	50–150 units/year	₹40 – 120 Cr	Basic hydrogen dispensers (350 bar industrial/fleet) Entry-level manufacturing. Includes metering, nozzle, control electronics. Similar to CNG dispensing manufacturing but with higher safety requirements.

Underlying Technologies & Processes

Stage	Technologies/Tools
Production	Alkaline, PEM, AEM, SOEC electrolyzers
Power Supply	Solar, wind, hydro, battery energy storage
Water Supply	Reverse osmosis, demineralization units
Storage & Handling	Compressors, storage tanks, cryogenic/liquid systems
Conversion	Ammonia synthesis, fuel cell production, synthetic fuel plants
Monitoring/Control	SCADA, smart grid systems, AI/ML optimization

Processes / Conversion Technologies

Process/Use	Description
Fuel Cells (PEM, SOFC)	For transport and backup power
Green Ammonia Synthesis	NH_3 for fertilizer or export
Synthetic Fuels	E-methanol, e-kerosene, SAF for aviation
DRI Steel	H_2 used instead of coal
Blending with Natural Gas	For industrial heating or cooking

Key Challenges

Challenge Area	Key Issues	Business Impact	India Specific	Strategic Implications
High Production Cost & Economic Viability	Expensive electrolyzers, renewable power costs, low economies of scale	Green hydrogen currently costlier than grey hydrogen; weak short-term profitability	India targeting cost reduction through National Green Hydrogen Mission and scale deployment	Need ultra-low-cost renewable power, hybrid RE sourcing, and long-term PPAs
Capital Intensity & Financing Risk	Large upfront investment for electrolysis plants, renewable integration, storage infrastructure	Long payback periods and uncertain returns deter investors	Early-stage market with limited operational track record	Strategic partnerships, government incentives, and blended finance essential
Infrastructure & Supply Chain Gaps	Lack of hydrogen pipelines, storage systems, transportation solutions	Logistics challenges increase cost and limit market scalability	Opportunity in ammonia conversion and port-based export hubs	Infrastructure development critical for scaling production and exports
Demand Uncertainty & Offtaker Readiness	Limited current demand; industrial sectors evaluating transition economics	Revenue risk without long-term offtake agreements	Potential demand from refineries, fertilizers, steel; export markets emerging	Secure anchor customers; co-location with industrial clusters reduces risk
Technology Maturity, Water Availability & Operational Complexity	Rapid tech evolution (ALK, PEM, SOEC); water purification needs; intermittency of renewables	Technology risk and operational inefficiencies affect reliability and ROI	Water scarcity in some regions; renewable intermittency impacts utilization	Focus on R&D, integrated energy management, and site selection near water + RE resources

Prominent Players in the Indian Market

Company / Entity	Project Details
Reliance Industries (RIL)	Announced 100 GW renewable + green hydrogen projects in Gujarat; building electrolyzer Giga factory at Jamnagar.
Adani New Industries Ltd. (ANIL)	Targeting 1 million tonnes per annum of green H_2 by 2030.
NTPC Ltd.	Operating pilot GH_2 buses in Delhi; developing green hydrogen hubs at Ladakh and Gujarat.
ReNew Power (ReNew Energy Global)	JV with Indian Oil & L&T for green H_2/ammonia projects; targeting export-oriented hubs.
Greenko Group	Building integrated RE + PSP + GH_2/ammonia projects; focus on export markets (Japan, Korea, EU).
JSW Energy	Announced green H_2 and ammonia projects linked with RE assets; exploring steel sector integration.
Indian Oil Corporation (IOCL)	Developing green hydrogen production at refineries (Panipat, Mathura); part of JV with ReNew and L&T.
Hydrogen Gentech, GreenH Electrolysis	Technology-based manufacturer and supplier of Green Hydrogen systems, manufacturing electrolysers in India using PEM technology
Ohmium & Newtrace - electrolyzer makers	Cost-effective green hydrogen electrolyzers, PEM manufacturers and suppliers
SFC Energy, Sainergy	Hydrogen and direct methanol fuel cells, fuel cell components
Tata Motors, Ashok Leyland, Hyundai Motors	Hydrogen fuel cell truck, developing hydrogen-powered buses and trucks, Hydrogen fuel cell passenger vehicles and SUVs.

Innovation Perspectives

Innovation	Business Opportunity	For Senior Management
Hydrogen as contracted infrastructure	Hydrogen IPP platforms	Bankable, utility-like cash flows
Electrolyzer cost-down & scale	Gigafactory electrolyzer platforms	Technology leadership becomes cost moat

Co-located renewables + hydrogen	Renewable-hydrogen mega hubs	Lowest LCOH globally
Hydrogen derivatives (ammonia, methanol)	Export-oriented green fuels	Faster market creation than pure H_2
Industrial cluster decarbonization	Industrial hydrogen parks	Risk diversification
Hydrogen storage & flexibility	Hydrogen storage utilities	Unlocks system-level benefits
Certification & guarantees of origin	Hydrogen credit exchanges	Enables global trade
EPC + performance guarantees	Hydrogen EPC platforms	De-risks first-of-a-kind plants
Hydrogen-to-power backup	Firm clean-power solutions	Complements batteries
Hydrogen trading & aggregation	Hydrogen trading desks	Capital-light, high leverage

Concentric & Satellite Opportunities

- Electrolyser & BOP manufacturing clusters: Concentric local production of stacks, rectifiers, cooling skids and power electronics adapted to Indian grid conditions.
- Port-based H_2/NH_3 export ecosystems: Shared desalination, storage and bunkering infrastructure enabling scale and global market access.
- Industrial retrofits & process integration services: Brownfield swaps (SMR to electrolysis) and DRI pilot integration with heat/oxygen valorisation.
- H_2 logistics & safety services: Satellite businesses in tube-trailer fleets, composite tanks, leak detection and training/certification.
- CO_2 capture pairing for e-fuels: CCUS-enabled CO_2 supply for e-methanol/e-kerosene, creating cross-sector hubs around refineries and cement clusters.
- Green finance & risk wraps: Price floors, offtake insurance and carbon-linked
- Refueling Station Dispensers: Supplying fast-fill nozzles, cooling systems and other infrastructure for FCEV/HDV infrastructure.
- Balance of Plant Components: Gas separators, dryers, and power conditioning skids for system integration.

Key Takeaway for Senior Management

Takeaway	Details
Green hydrogen is an industrial platform opportunity, not just a fuel project	• The real value lies in decarbonizing hard-to-abate sectors such as steel, ammonia, refining, and shipping • ***Examples**:* green steel pilots, ammonia export hubs, refinery hydrogen substitution • **Suggested innovation focus:** integrated hydrogen ecosystems linking production, storage, and end-use • **Competitive advantage:** firms positioned as industrial decarbonization partners secure long-term anchor demand
Electricity cost is the dominant economic driver	• Hydrogen competitiveness depends primarily on renewable power pricing and utilization • ***Recommendations**:* co-located solar/wind farms, hybrid renewable portfolios, dedicated grid connections • **Competitive advantage:** lowest LCOH (levelized cost of hydrogen) wins scale markets
Electrolyzer flexibility is a hedge against rapid technology change	• Alkaline, PEM, and SOEC technologies evolve quickly. Fixed plants risk obsolescence • ***Examples**:* modular electrolyzer stacks, upgrade-ready balance-of-plant design • **Innovation focus:** technology-agnostic architecture and rapid retrofit capability
Hydrogen derivatives amplify value creation	• Ammonia, methanol, and synthetic fuels extend market reach • ***Examples**:* green ammonia export terminals, e-fuel aviation supply chains • **Competitive advantage:** diversified revenue beyond raw hydrogen sales
Digital optimization will separate leaders from commodity producers	• Hydrogen plants are complex electrochemical systems requiring real-time optimization • ***Examples**:* predictive electrolyzer maintenance, AI dispatch, energy balancing • **Innovation focus:** intelligent plant control and performance analytics

Next Steps for Corporate Leaders

Green hydrogen is moving from pilot demonstrations into early commercial deployment as corporates and governments pursue fuel substitution, industrial decarbonization, and future export opportunities. Electrolyzer technologies (PEM, Alkaline, SOEC) are maturing, renewable PPAs are expanding, and industrial clusters are forming around refineries, fertilizers, steel, mobility, and ports. However, viability remains linked to renewable energy cost, electrolyzer scale-up, offtake certainty, and enabling policy frameworks.

This could be an attractive climate tech opportunity for industries and firms in specific sectors and industries keen on catering to this growing market.

Connect with Team EAI to know more about this opportunity and take your corporate's initial steps. Send a note to consult@eai.in or talk to Muthukrishnan - 9952910083