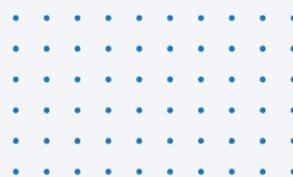




**FIN VAL**  
RESEARCH & CONSULTANCY

# HYDROGEN BREAKTHROUGH

Covered All Aspects



**18 August 2025**

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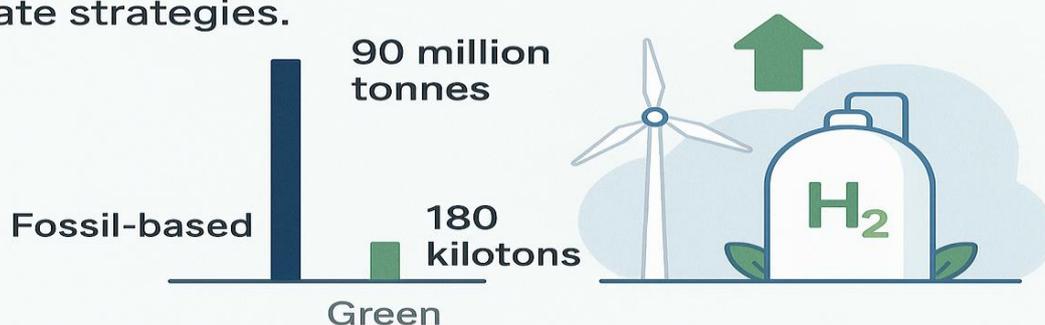
## Hydrogen Breakthrough

**World's first solar powered desert refinery fuels \$24 Billion industry**

### What is Green Hydrogen?

- ❑ Green hydrogen refers to hydrogen fuel produced with **no carbon emissions**, typically by splitting water into hydrogen and oxygen using renewable energy (electrolysis).
- ❑ Unlike “**grey**” hydrogen which uses natural gas without carbon capture and emits CO<sub>2</sub> or “**blue**” hydrogen which uses fossil fuels with carbon capture as CO<sub>2</sub> is captured, “**green**” hydrogen uses renewable power and releases no greenhouse gases.
- ❑ Green hydrogen is generated by using clean energy to split water or otherwise produce H<sub>2</sub> without carbon emissions. The predominant technology is water electrolysis. Several electrolysis technologies commercially available or in development:
  1. Alkaline Water Electrolysis (AWE)
  2. Proton Exchange Membrane (PEM) Electrolysis
  3. Solid Oxide Electrolysis (SOEC)
- ❑ **Recent Developments:** By mid-2024, 61 countries had published national hydrogen strategies. The European Union targets 10 million tonnes of green hydrogen production and 10 Mt of imports by 2030. In the U.S., the Department of Energy’s “Hydrogen Earth shot” **aims to cut green hydrogen costs to \$1 per kg by 2030—an 80% reduction.**

Currently, global hydrogen use is about 90 million tonnes annually, but over 99% of it is fossil-based. Green hydrogen production is still very limited, just 180 kilotons per year (<1% of total), but interest is surging, Governments and companies worldwide are investing heavily in green hydrogen as part of their climate strategies.



## Hydrogen and its properties

Attribute	Green Hydrogen	Grey Hydrogen	Blue Hydrogen
Source	Renewable energy via electrolysis	Natural gas via steam methane reforming (SMR)	Natural gas via SMR with carbon capture (CCS)
Carbon Emissions	Zero (if powered by 100% renewable energy)	High CO <sub>2</sub> emissions (not captured)	Low emissions (CO <sub>2</sub> is captured and stored)
Production Technology	Electrolysis	SMR or coal gasification	SMR + Carbon Capture and Storage (CCS)
Environmental Impact	Environmentally friendly	High carbon footprint	Lower impact, but fossil-dependent
Current Cost (2024)	\$3–6 per kg (falling fast)	\$1–2 per kg	\$1.5–3 per kg (including CCS costs)
Forecasted Cost (2050)	\$0.5–1.5 per kg (depending on region & scale)	\$1–1.5 per kg (stable with inflation)	\$1–2 per kg (subject to CCS and gas prices)
Energy Source	Renewable electricity	Fossil fuels (coal, oil, or gas)	Fossil fuels + CCS
Maturity & Availability	Emerging, scaling rapidly	Most widely used (>95% of global H <sub>2</sub> today)	Transitional, dependent on CCS infrastructure
Use Case Focus	Clean mobility, green steel, ammonia, energy storage	Fertilizer, refining, chemicals	Heavy industry, power decarbonization
Long-Term Viability	High (aligned with net-zero goals)	Low (unsustainable in net-zero scenarios)	Medium (viable as a transition fuel)

## Types of processes

1. **PV Electrolysis** - PV-Electrolysis couples solar photovoltaic (PV) panels with electrolyzer to convert sunlight directly into hydrogen. PV modules generate electricity, which powers the electrolysis of water into hydrogen and oxygen. This method is commercially mature, scalable, and can be deployed wherever solar resources are abundant.
2. **Thermochemical Cycles** - It uses high temperature heat—often from concentrated solar power (CSP) or nuclear reactors—to drive a sequence of chemical reactions that split water into hydrogen and oxygen without electricity. These cycles (e.g., sulphur-iodine, copper-chlorine) operate at 500–2,000°C,

enabling high theoretical efficiencies. The approach is still at pilot scale due to material challenges and the need for advanced high-temperature reactors.

- 3. Photocatalytic Water-Splitting** – It uses semiconductor catalysts that directly absorb sunlight to split water molecules into hydrogen and oxygen in a single step. Inspired by natural photosynthesis, this process requires minimal external infrastructure—just sunlight, water, and photocatalyst materials.

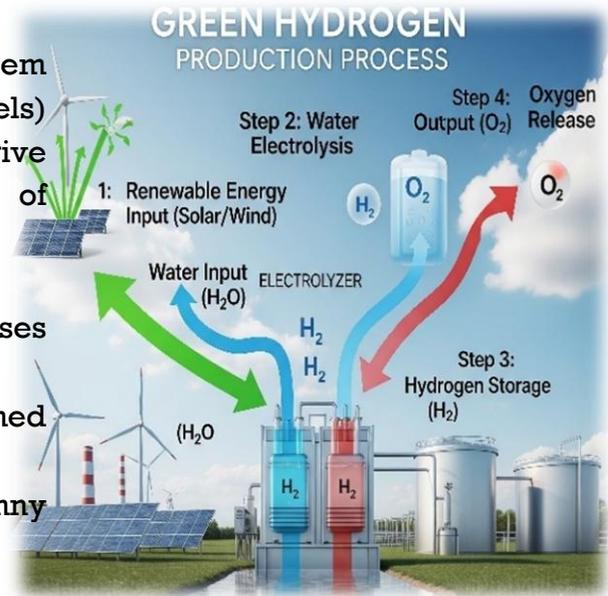
## Thermocatalytic Solar Reactor – Breakthrough Process

### What is Thermocatalytic Solar Reactor

It is a specialized solar-powered system designed to produce hydrogen (or other fuels) by using concentrated solar energy to drive thermochemical reactions with the aid of catalysts.

#### Key Advantages:

- Avoids electricity conversion losses (directly uses heat).
- High reaction rates due to combined heat and catalysis.
- Potential for high efficiency in sunny regions.



- ❑ A groundbreaking project H2Atacama has built the world’s first solar-powered desert hydrogen refinery in Atacama Desert, Chile, the driest region on Earth - which uses thermocatalytic solar reactors to extract moisture from the arid air and split it into hydrogen. This process eliminates the need for liquid water sourcing or grid electricity – essentially using the sun’s heat and a catalyst to produce hydrogen from atmospheric humidity.
- ❑ While these emerging methods are at early stages, they underscore that green hydrogen technology is rapidly evolving, potentially opening new pathways for efficient production in diverse environments.
- ❑ Chile’s desert refinery addresses this by sourcing water from air, and countries like Morocco and Portugal have stated that desalination investment is a small fraction of total project costs and worth the added water security

## Comparison of Various Processes

Feature	Thermocatalytic Solar Reactor	PV-Electrolysis	Thermochemical Cycles	Photocatalytic Water-Splitting
Solar-to-H <sub>2</sub> Efficiency	15–25%	12–18%	10–20%	1–5%

Electricity Requirement	Low (minor pumping/controls)	High (100% of input)	Moderate (balance-of-plant)	None (but low rates)
Capex Intensity	Moderate	High	Very high (multiple loops)	Low equipment, but nascent
Thermal Storage Integration	Easy	Difficult	Built-in (often)	N/A
By-Products	Solid carbon (value-add)	O <sub>2</sub> (vented)	O <sub>2</sub> /SO <sub>2</sub> /I <sub>2</sub> (handled)	O <sub>2</sub> (vented)
Scalability & Modularity	High	Moderate	Low	Low

## Global momentum

### Projects

- Governments and companies around the world have launched a **global race** to scale up green hydrogen. Over 1,000 large-scale projects have been announced as of early 2023. Collectively, these represent **\$320 billion** in planned direct investments in hydrogen production and infrastructure through 2030.
- Europe currently leads in project commitments, accounting for about 35% (>\$117 billion) of global hydrogen investments
- North America and Latin America follow, each with ~15% of announced investments.
- From today's ~0.18 million tonnes per year, *pipeline estimates suggest* the world could be producing over **14 million tonnes of green H<sub>2</sub> by 2030** (assuming projects under construction reach operation) This would be a **>70-fold increase** in roughly a decade – a growth trajectory reminiscent of the early renewable energy boom.

Project Name	Location	Capacity (GW)	Key Notes
NEOM	Saudi Arabia	4 GW	One of the world's largest green hydrogen projects
H2Atacama	Chile	Not specified	Located in Atacama Desert; large-scale production planned
Hyundai-Heimdal	Denmark	1 GW (electrolyzer)	Partnership to produce ammonia from green hydrogen

Asian Renewable Energy Hub	Western Australia	15 GW (initial), 26 GW (planned)	Wind and solar powered; exports to Asia
Hydrogen City	Texas, USA	60 GW (long-term goal)	By Green Hydrogen International; one of the most ambitious in the world
North Sea Wind Power Hub	North Sea (Offshore)	Not specified	Wind island concept to produce and convert hydrogen at sea
IPCEI Hydrogen Projects	Europe (DE, NL, FR, etc.)	Various (multiple sites)	Publicly funded projects to accelerate deployment across EU

## Indian Green Hydrogen Industry

### Mission Launch & Budget

The National Green Hydrogen Mission was approved in January 2023 with an initial outlay of ₹19,744 crore (~₹17,490 cr for SIGHT, ₹1,466 cr for pilot projects, ₹400 cr for R&D, and ₹388 cr for other components)

### Targets by 2030

- 1. Production:** At least 5 million metric tonnes of green hydrogen annually
- 2. Renewable Capacity:** Addition of ~125 GW
- 3. Investment:** Over ₹8 lakh crore (~\$100 billion)
- 4. Jobs:** Creation of over 600,000 employment opportunities
- 5. Emissions Abatement:** Reduction of ~50 MMT greenhouse gases per year

### ASPECT

### DETAILS

TARGET BY 2030	5 MMT green hydrogen, 125 GW renewables, ₹8 lakh crore investment, 600k jobs
CORE PROGRAMS	SIGHT (incentives for electrolyser & production); pilots & hubs funding
STATE FOCUS	Strong support from Odisha, Gujarat, etc., via subsidies and land incentives
EXECUTION	Electrolyser plants operationalizing; port projects; mobility pilots underway
GLOBAL STRATEGY	Ties for export, certification systems, and international collaboration

## Global Investment Opportunities and Future Outlook

### Market Potential Growth

- Not only is it a **fast-growing market**, but it is also bolstered by an unprecedented alignment of environmental necessity, government support, and industry commitment.
- **Market Growth Potential:** The global green hydrogen market could reach **\$1.4 trillion per year by 2050**, supplying upwards of 600 million tonnes of hydrogen annually if the world pursues net-zero emissions. This would make hydrogen comparable to the LNG (liquefied natural gas) trade or oil markets in scale.

The **Hydrogen Council** likewise envisions hydrogen meeting 18% of global energy demand by 2050 – a **\$2.5 trillion annual market** – in a scenario where the world hits climate targets.

Such growth translates to diverse investment opportunities across the value chain:

1. **Renewable Energy Development** - Green hydrogen drives investment in renewable projects bundled with electrolysis, forming integrated “power-to-x” hubs. Companies are targeting resource-rich areas to build wind-solar-hydrogen facilities and secure upstream energy assets.
2. **Electrolyser Manufacturing and Technology** - The Green Hydrogen manufacturing sector is poised for rapid growth, like PV boom. Rising demand for electrolyzer, fuel cells, and advanced tech like modular systems and AI optimization is attracting significant investment from venture capital and private equity.
3. **Infrastructure and Transport** - Developing hydrogen infrastructure—pipelines, storage, and export terminals—is capital-intensive and will likely involve public-private partnerships. Opportunities include financing ammonia terminals, liquid hydrogen facilities, retrofitting gas pipelines, and investing in bulk storage like salt caverns for grid balancing and seasonal supply.
4. **Downstream and Offtake** - Industries like steel (ArcelorMittal, Thyssenkrupp) and chemicals (Yara, CF Industries) are co-investing in green hydrogen to secure future feedstock. Transport firms like Toyota and Hyundai are advancing fuel cell vehicles, creating investment opportunities in hydrogen infrastructure such as electrolyzer, DRI plants, and refuelling stations, often with government support.
5. **Emerging Markets and Export Hubs** - Developing countries rich in renewables, like Namibia and South Africa, are attracting foreign capital for large-scale green hydrogen projects aimed at export. With proper investment, they could supply **70% of a \$1.4 trillion market by 2050**. Green hydrogen offers ESG-aligned investment potential through emissions cuts, sustainable development, and job creation.

# Venture Capital and Private Equity Interest in Green Hydrogen Projects

## Global Outlook

Venture Capital and Private Equity interest in green hydrogen has shifted from “science risk” to “scale-up risk.”

Capital is concentrated in:

1. Electrolyzer technologies (efficiency/cost/supply-chain plays)
2. Balance-of-plant, storage and compression
3. Downstream use-cases (e-fuels, ammonia, heavy mobility)

**Fund Trend:** Post-2021 climate-tech reset, green H<sub>2</sub> deals skew to larger, later rounds for companies with factory buildouts and purchase orders,

Signal examples as follows:

1. **H2Pro (Israel):** raised **\$450M** to scale E-TAC electrolyzer (2025), backed by strategic and financial investors, underscoring appetite for step-change efficiency plays.
2. **Sunfire (Germany):** closed **€215M** to expand solid-oxide/alkaline electrolyzer manufacturing (2024), a bellwether EU scale-up.
3. **Electric Hydrogen (US):** added **\$50M project debt** to its toolkit (2024), illustrating a blend of VC + project/asset finance as companies move into delivery.

## Representative (Recent) Signals & Why They Matter

Company	Focus	Round / Instrument	Why it's a Signal
H2Pro	High-efficiency E-TAC electrolyzer	\$450M growth (2025)	VC + strategics are backing step-change tech to factory scale.
Sunfire	SOEC + alkaline	€215M (2024)	EU is funding manufacturing scale, not just pilots
Electric Hydrogen	Large-scale alkaline systems	\$50M project debt (2024)	Blending VC equity with project finance as offtake firms up.
Newtrace (India)	Electrolysers	Series A (2024)	India IP + Make-in-India manufacturing is investable
SIGHT Tranche-1 (India)	Prod. & electrolyzer incentives	Awards notified (2024)	Policy-backed demand signals reduce early market risk.

## Indian Outlook

### VC Angle & Policy Catalysts

- **Policy Footing:** Under the **National Green Hydrogen Mission**, India awarded the first **SIGHT** tranches (electrolyzer and production), lowering early revenue risk and seeding domestic demand/manufacturing.
- **Domestic manufacturing plays.** **Newtrace (Bengaluru)** raised **Series A** to scale low-cost electrolyzer—an example of India-based IP plus local manufacturing as a VC theme
- **Scale ambitions.** National targets and private-sector roadmaps (e.g., multi-GW ambitions by leading Indian conglomerates) signal long-term market creation and a deep local supply chain opportunity for VC-backed components and software.



## Industry Players

- **Hydrogen technology and gas companies:** Industrial gas giants like **Linde**, **Air Liquide**, and **Air Products & Chemicals** are aggressively expanding into green hydrogen. Leveraging decades of hydrogen expertise, they’re building electrolysis and liquefaction plants globally. With projects like **NEOM**, their global reach and industrial clients position them as key players in scaling green hydrogen production and use.
- **Oil, gas, and utility companies:** Major energy players like **BP**, **Shell**, **TotalEnergies**, and **Aramco** are entering green hydrogen to meet net-zero goals, leveraging large-scale project expertise. Utilities such as **Engie**, **Equinor**, **ACWA Power**, and **Masdar** are integrating hydrogen into renewable strategies, enabling storage and clean fuel solutions, while driving global mega-project development.
- **Electrolyzer and fuel cell specialists:** A new wave of hydrogen tech firms is leading the green hydrogen revolution. Companies like **Plug Power**, **Nel ASA**, **ITM Power**, **Siemens Energy**, **Thyssenkrupp Nucera**, and **Cummins** build large-scale electrolyzer capacity globally. Their innovations and manufacturing scale-up are vital to making green hydrogen affordable and widespread.

## Global Leaders and Country Comparison



Country	Electrolyser Targets	Policy Support	Key Projects
European Union	40 GW by 2030	€5.4B subsidy package; Hydrogen Strategy	HyDeal Ambition (Spain), H2Med pipeline
China	100 GW by 2030 (targeted)	National hydrogen roadmap	Sinopec's 20,000 t/yr solar H <sub>2</sub> plant (Xinjiang)
Australia	15 GW planned by 2030	A\$2B Hydrogen Head start Program	Asian Renewable Energy Hub (WA), HESC
Chile	25 GW by 2030	Green Hydrogen Strategy, incentives	HIF Atacama refinery, Patagonia green fuels
United States	10 million tons/year by 2030	\$8B Hydrogen Hubs (IRA-funded)	Gulf Coast Hub, California H <sub>2</sub> Valley
Saudi Arabia	4 GW by 2026 (NEOM)	\$5B investment via NEOM, ACWA	NEOM Green Hydrogen Project (Air Products)

## Key Challenges in Scaling Up Green Hydrogen

While the promise of green hydrogen is immense, several challenges must be addressed to realize its full potential. Understanding these hurdles is crucial for stakeholders looking to invest in or develop projects in this sector:

1. **Cost Competitiveness:** Green hydrogen remains costlier than fossil-based hydrogen, ranging from \$3–8/kg versus \$1–2/kg. However, prices are falling and could reach \$1.2–1.8/kg by 2050 in renewables-rich regions. Cost drops depend on cheap clean power and electrolyzer scaling. Policy tools like subsidies and tax credits.
2. **Energy Efficiency and Infrastructure:** Green hydrogen's low efficiency (~30–40% round-trip) limits its use to hard-to-electrify sectors like steel, heavy transport, and aviation. Its infrastructure demands—due to low energy density and pipeline challenges—are significant. Governments and industry must coordinate to build hydrogen networks that align production hubs with end-use demand to ensure viability.
3. **Scaling Up Manufacturing and Supply Chain:** Electrolyzer production must double by 2030 to meet net-zero goals. Gigawatt-scale factories are

rising in Europe, China, and North America, but supply chain strains (e.g., platinum use), workforce shortages, and investment gaps persist. However, industrial giants and EPC firms are aiding scale-up, while standardization and global competition may reduce costs.

4. **Renewable Energy Availability:** Green Hydrogen depends on vast renewable energy capacity. Export-rich regions (like Chile, Australia) are investing heavily, while land-constrained nations may import hydrogen. Grid constraints, renewable intermittency, and infrastructure delays pose challenges. Hybrid energy setups and off-grid electrolyzer offer solutions, but scaling must not divert power from existing energy needs.
5. **Policy and Market Uncertainties:** The hydrogen industry faces regulatory uncertainty, varying definitions of “green” hydrogen, and evolving certification standards. Clear carbon accounting and policy support are essential for investment. Supply-demand coordination is critical, as infrastructure and markets are immature. Safety, public perception, and robust regulations will shape hydrogen’s widespread adoption and international trade potential.

## Our Expertise Can Add Value

### 1. **Strategic Market & Feasibility Studies**

Covers global-to-sectoral green hydrogen demand forecasts and competitive benchmarking of leading electrolyser makers and hydrogen producers.

### 2. **Project Valuation & Financial Modelling**

Includes early-stage valuation using DCF, real options, and comps, scenario modelling for cost and price variables, and bankability checks to meet lender/ECA requirements for project financing.

### 3. **Investment Advisory**

Involves identifying hydrogen investment targets, conducting technical/commercial/ESG due diligence, and structuring partnerships between renewable developers, industrial off takers, and infrastructure investors.

### 4. **Risk Mitigation & Structuring**

Involves mapping key project risks, using hedging strategies like PPAs and long-term offtakes, and structuring optimal financing through debt-equity and blended finance models.

## About Us

Founded in 2011, we are a boutique consulting firm focused on providing world class financial consulting, valuations and corporate finance services.

Managed and advised by Registered Valuers with more than 70 years of cumulative experience and more than 200 valuation assignments.

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**Address-** Plot number- 65, 2nd Floor, Sector 12A,  
Dwarka, New Delhi-110075

**Contact no.-** +91 98112 13275

**Email Add.-** [valuation@finvalresearch.in](mailto:valuation@finvalresearch.in)

**Website-** [www.finvalresearch.in](http://www.finvalresearch.in)